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HEIGHT-VELOCITY TEST
AH-1G HELICOPTER AT HEAVY GROSS WEIGHT

LOW ELEVATION

FINAL REPORT

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JUNE 1974

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The United States Army Aviation Systems Test Activity conducted engineering flight tests to determine the operational height-velocity envelopes of the AH-1G helicopter at 9000 and 9500 pounds gross weight. This report constitutes the low elevation part of the evaluation conducted at Edwards Air Force Base, California, from 14 November 1973 through 5 February 1974. Operational height-velocity envelopes were defined from test data, are valid for 9000 and 9500 pounds at →

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20. Abstract

density altitudes up to 1000 feet, and represent combinations of airspeed and height above ground level where a straight-ahead landing may be accomplished following an engine failure. Autorotational landings at gross weights over 9250 pounds will probably result in rotor overspeed and the height above ground level at which the flare is executed becomes more critical as gross weight is increased to 9500 pounds. The operator's manual lacks clarity in describing pilot techniques to be used during the height-velocity maneuver and needs improvement in other areas. The height-velocity diagram developed during this evaluation, a discussion of the height-velocity diagram, a more thorough discussion of pilot techniques, the correct airspeed calibration chart, and the hog configuration descent performance chart should be incorporated in the operator's manual. A radio altimeter should be installed as standard equipment on the AH-1G helicopter.

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INTRODUCTION

BACKGROUND

1. The operator's manual for the AH-1G helicopter (ref 1, app A) currently contains an operational height-velocity (H-V) diagram. This diagram is an extrapolation to 9500 pounds gross weight based on tests performed by the United States Army Aviation Systems Test Activity (USAASTA) at 8300 pounds gross weight (ref 2). A heavy gross weight autorotational evaluation (ref 3) was conducted by USAASTA to determine if any adverse autorotational entry or landing characteristics exist for the AH-1G helicopter up to 10,000 pounds gross weight. The latter report recommended H-V testing up to the maximum gross weights anticipated for future AH-1G operations. The United States Army Aviation Systems Command (AVSCOM) requested that USAASTA conduct tests to determine the actual operational H-V envelope of the AH-1G helicopter for gross weights of 9000 and 9500 pounds (refs 4 and 5).

TEST OBJECTIVE

2. The objective of this evaluation was to expand operational AH-1G H-V envelopes up to 9500 pounds gross weight.

DESCRIPTION

3. The AH-1G is an attack helicopter manufactured by Bell Helicopter Company (BHC) and incorporates an integral chin gun turret, skid-type landing gear, and stub wings with four external stores stations. Tandem seating is provided for a two-man crew. The rotor system is two-bladed and semirigid with a flex-beam hub, and the antitorque system incorporates a tractor tail rotor. The maximum gross weight of the AH-1G helicopter is 9500 pounds. More detailed AH-1G information and aircraft limits are presented in the operator's manual (ref 1, app A). Aircraft photographs are presented in appendix B.

TEST SCOPE

4. Fourteen flights for H-V envelope determination were conducted in 18.6 flight hours, of which 8.3 hours were productive, in AH-1G helicopter S/N 71-20985 at Edwards Air Force Base, California, from 14 November 1973 through 5 February 1974. This report constitutes the low elevation portion of the evaluation, performed at a field elevation of 2280 feet (density altitude 1000 ±300 feet). Testing was scheduled to be continued at a field elevation of approximately 7000 feet, but was deferred because of higher priority project workload. Tests were conducted with four M159C rocket pods as wing stores (hog

configuration). The rocket pods were loaded with dummy rockets to achieve aim gross weights of 8600, 9000, 9250, and 9500 pounds with a mid center of gravity (cg). Ballast was added between landings as necessary to maintain aim gross weight within 50 pounds. Engine and rotor system rigging were standard, with the average entry rotor speed being 324 rpm.

5. The operator's manual established the basic limitations observed during this evaluation. The safety-of-flight release (ref 6, app A) permitted a maximum gross weight at takeoff of 9800 pounds and at touchdown of 9500 pounds, with a maximum touchdown rate of descent of 4 feet per second (ft/sec).

TEST METHODOLOGY

6. Conventional H-V test techniques (ref 7, app A) were employed in order to ensure maximum safety-of-flight conditions and minimum test time. Tests were conducted under stable atmospheric conditions with a wind velocity of 5 knots or less, to preclude uncontrolled perturbations from influencing test results. All touchdown autorotations were made on an asphalt-surfaced runway.

7. A series of preliminary assessments to familiarize the test team with the helicopter's handling qualities and performance and a review of earlier tests (refs 2 and 3, app A) were made to initially define test variables. Build-up flights in clean and hog configurations included throttle chops, H-V entries, steady-state autorotations at various airspeeds, evaluation of flare, autorotational touchdowns, power recoveries, and go-arounds. Also, operational H-V curve predictions were extrapolated from data obtained during USAASTA Project No. 69-13 (ref 2) and used as guides for establishing test entry conditions of airspeed and altitude.

8. In determining the H-V envelopes, the collective control was held fixed for 1.5 to 2 seconds after rapidly retarding the throttle to the engine-idle position to simulate a sudden engine failure (throttle chop). The cyclic control delay time was at least 1.5 seconds. Because the pilot recognition cues were so readily discernible in the yaw axis, no delay time was employed with the directional controls.

9. A detailed listing of test instrumentation and special equipment is shown in appendix C. Test techniques and data analysis methods are presented in appendix D. Qualitative pilot comments were used to aid in the analysis of data and to assist in the overall assessment of the H-V characteristics of the AH-1G helicopter. Test data are presented in appendix E.

RESULTS AND DISCUSSION

GENERAL

10. Engineering flight tests were conducted to define the AH-1G H-V envelopes at 9000 and 9500 pounds gross weight applicable for the operational aviator. Operational H-V envelopes were defined from test data and are valid for 9000 pounds and 9500 pounds at a density of 1000 feet. The H-V envelopes developed provide the operational pilot with the combinations of airspeed and height above ground level (AGL) where a straight-ahead landing may be accomplished in the event of an engine failure. Should engine failure occur during flight within the CAUTION area of the H-V diagram, aircraft damage will probably occur. Autorotational landings at gross weights over 9250 pounds will probably result in rotor overspeed and the height AGL at which a flare is executed becomes more critical as gross weight is increased to 9500 pounds. The operator's manual lacks clarity in pilot techniques to be used during the H-V maneuver and needs improvment in other areas. The H-V diagram developed during this evaluation, a discussion of the H-V diagram, a more thorough discussion of pilot techniques, the correct airspeed calibration chart, and the hog configuration descent performance chart should be incorporated in the operator's manual. A radio altimeter should be installed as standard equipment on the AH-1G helicopter for use in the accurate determination of flare heights.

ENTRY TECHNIQUE

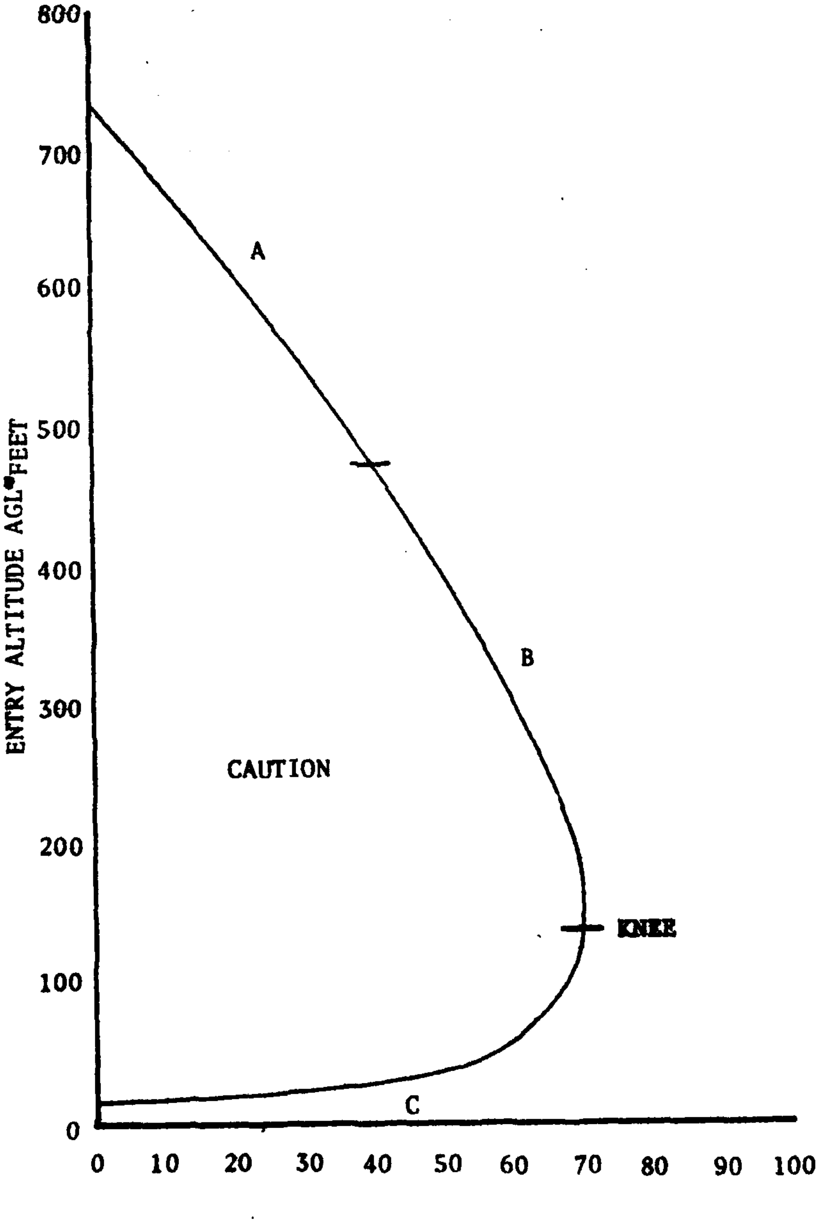
11. The entry technique described in the operator's manual is valid for engine failure occurring at flight conditions near the H-V curve but requires additional explanation. Figure A is presented to assist in describing the effects of pilot technique. Typical time histories of H-V entry and landing for 9500 pounds gross weight are presented in figures 1 through 5, appendix E.

12. Autorotational entry from a high hover is shown in time history format in figure 1, appendix E, and is representative of the entries made in area A of figure A. The technique from zero to 40 knots indicated airspeed (KIAS) was characterized by a requirement for a rapid forward longitudinal control input and early establishment of the nose-down accelerating attitude. A 25-degree nose-down pitch attitude will produce a rapid airspeed increase to 65 KIAS (the airspeed for minimum rate of descent; fig. C, para 33) with an associated rate of descent of up to 4000 feet per minute (ft/min). Steeper nose-down attitudes to gain airspeed reduced altitude lost during the entry but produced higher rates of descent and would be disconcerting to the aviator (ref 2, app A). Shallower pitch attitudes delayed reaching the target airspeed and increased the altitude lost in the maneuver (table 1).

FIGURE A

AH-1G OPERATIONAL HEIGHT VELOCITY ENVELOPE

9500 LBS 1000 FT Hd



INDICATED ENTRY AIRSPEED~KNOTS

Table 1. Pitch Attitude Effects on Rate of Descent and Altitude Loss.[1]

Maximum Nose-Down Attitude (deg)	Maximum Rate of Descent (ft/min)	Altitude Loss Required to Attain 65 KIAS (ft)
19	3750	430
31	4800	370

[1] Entry conditions: High hover entry; gross weight, 9500 pounds; entry rotor speed, 324 rpm; density altitude, 1000 feet. Nose-down pitch rates and maximum dive airspeeds were essentially the same.

13. Figures 2 and 3, appendix E, reflect the technique variation required in area B of figure A. At an entry airspeed of 40 KIAS, a nose-down attitude of 20 degrees was adequate to rapidly attain the target airspeed of 65 KIAS without excessive rate-of-descent increase or loss of altitude. As the entry airspeed was increased above 40 KIAS, the longitudinal control input and the nose-down pitch attitude required to obtain the target airspeed were reduced to the point where no intentional lowering of aircraft pitch attitude was required at the knee.

14. The technique required in area C of figure A is variable, as shown in figures 4 through 6, appendix E. The pilot actions in the event of engine failure in this regime are well described in the operator's manual.

15. Figure 1, appendix E, shows how vertical speed is affected by stabilizing airspeed at 65 KIAS while maintaining rotor speed within limits. By holding 65 KIAS, the rate of descent was rapidly reduced from the 4200-ft/min rate of descent developed during the entry to approximately 2000 ft/min, from which a normal flare for landing could be made. Table 2 shows that higher airspeeds produced higher rates of descent and increased altitude loss. In addition, the flare for landing was complicated at higher airspeeds by the requirement to dissipate the additional airspeed. Stabilizing airspeed at 65 KIAS during the descent produced the best combination of altitude loss to gain flare airspeed and reduction in rate of descent prior to the flare.

Table 2. Airspeed Effects on Rate of Descent and Altitude Loss.[1]

Indicated Airspeed (kt)	Maximum Rate of Descent (ft/min)	Altitude Loss Required to Attain Maximum Airspeed (ft)
71	3800	325
78	4300	435

[1] Entry conditions: High 20-KIAS entry; gross weight, 9500 pounds; entry rotor speed, 324 rpm; density altitude, 1000 feet. Nose-down pitch rates and attitudes were essentially the same.

FLARE FOR LANDING

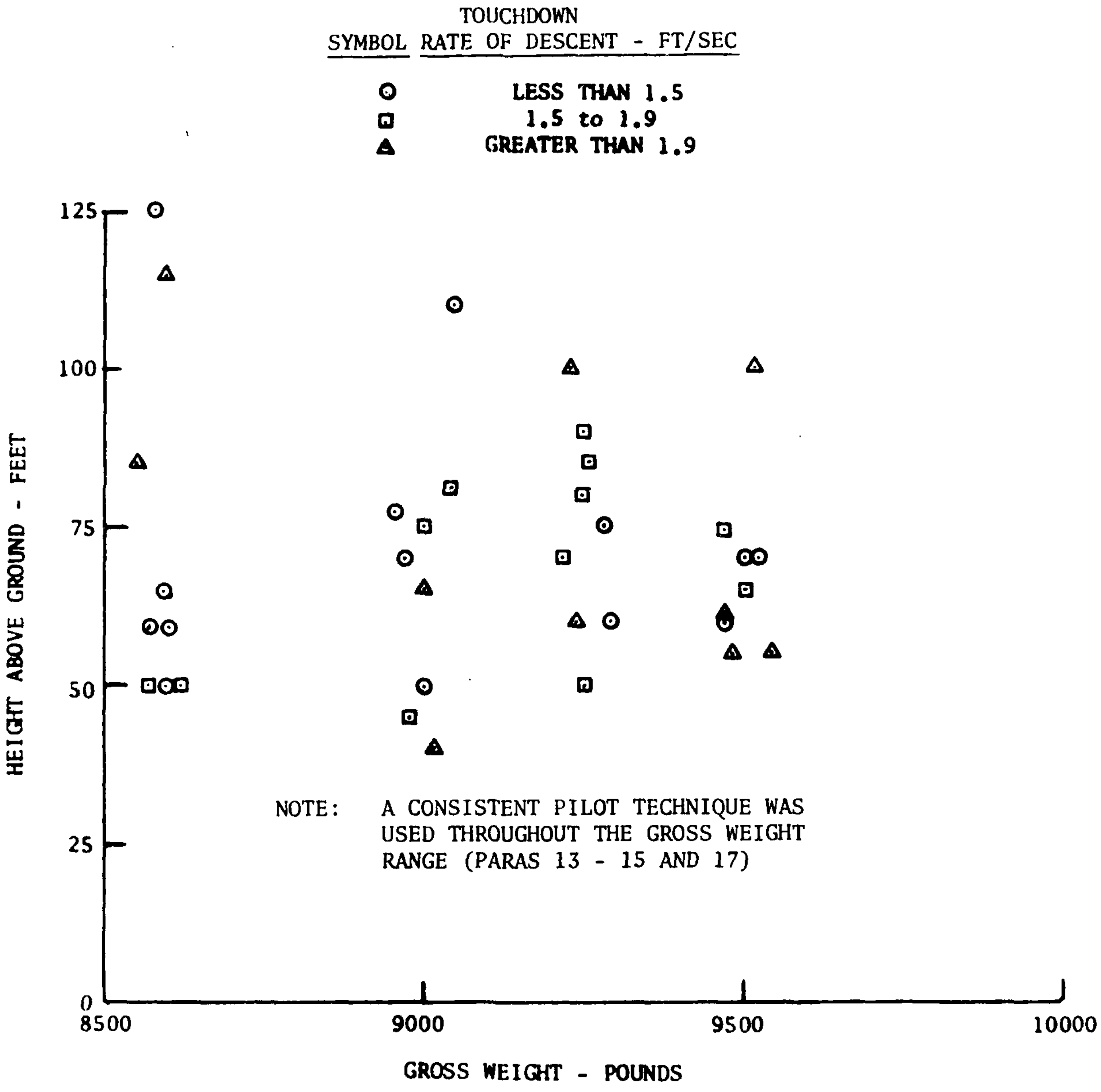
16. During this evaluation, 95 autorotational landings were made at gross weights from 8600 to 9500 pounds. The radio altimeter installed as special instrumentation provided an opportunity for a limited evaluation of flare height ranges in which successful landings could be accomplished. The effects of gross weight on a safe range of flare heights are graphically summarized in figure B.

17. Flares were executed at 8600 pounds gross weight over a height range of 50 to 125 feet AGL, while at 9500 pounds gross weight, the range was 60 to approximately 80 feet (fig. B). At 9500 pounds, the best overall results were achieved with a flare height of 70 feet, an average flare attitude of 18 degrees, nose up, and a pitch rate of 7 degrees per second (deg/sec). Higher flare heights frequently resulted in relatively high sink rates and high touchdown airspeeds. When an attempt was made to reduce touchdown airspeed from the high flare, low rotor speed resulted and greater precision in collective control application was required (para 19). Flares executed below 60 feet required higher pitch rates (10 to 12 deg/sec) and nose-up pitch attitudes (20 to 25 degrees) to arrest the descent rate, resulting in restricted field of view and more difficult rotor speed control. The height AGL at which the autorotational flare was initiated became increasingly critical as gross weight was increased to 9500 pounds.

18. As gross weight increased and flare height became increasingly critical, greater reliance was placed on the radio altimeter installed for this test. Accurate estimation of height AGL is a difficult task. This task is complicated in forced landings by the dynamics of the maneuver (rate of closure, aircraft attitudes); urgency of the situation; the physical properties of the touchdown area (open or wooded, grassy or bare); the wide variation of external references; pressure altimeter variations; and the proficiency of the pilot. The radio altimeter provided very accurate cockpit

(figure B)

AUTOROTATIONAL FLARE HEIGHT RANGE



NOTE: A CONSISTENT PILOT TECHNIQUE WAS USED THROUGHOUT THE GROSS WEIGHT RANGE (PARAS 13 - 15 AND 17) indications during this evaluation and was unaffected by the above-mentioned factors. A radio altimeter should be installed as standard equipment on the AH-1G helicopter to enhance the capability of the pilot in conducting safe autorotational landings.

19. As gross weight was increased from 8600 pounds to 9500 pounds, the collective control input required to keep rotor speed within the allowable autorotational rotor speed range during the flare was increased. This characteristic was most apparent at the higher gross weights and produced a signficant increase in pilot workload to maintain proper rotor speed during the flare. At 9500 pounds gross weight, the main rotor was more sensitive to changes in longitudinal and collective control position, and frequent reference to the rotor tachometer was required to maintain rotor speed within the operating range. The pilot's attention must be directed outside the cockpit during the flare for landing; therefore, it is expected that forced landings at gross weights over 9250 pounds will probably result in rotor overspeed.

TOUCHDOWN

20. The test directive (refs 4 and 5, app A) stated that the touchdown airspeeds above the knee of the H-V curve were to be 20 KIAS or less. This touchdown airspeed limit was possible for gross weights from 8600 pounds up to 9250 pounds. Touchdown airspeeds at 9500 pounds gross weight averaged 23 KIAS, with the minimum repeatable airspeed being 20 KIAS. Lower touchdown airspeeds were possible at 9500 pounds gross weight; however, the pilot technique involved was not applicable to current operational training procedures. Touchdown airspeeds below the knee of the H-V curve were higher because of the limited deceleration capability, due to the tail rotor proximity to the ground.

21. Touchdown rates of descent were generally between 1.0 and 2.5 ft/sec for all gross weights tested. No trends in rate of descent were identified with gross weight changes.

22. Standard heavy-duty, two-piece skid shoes (FSN's 1630-462-8862 and 1630-462-8865) were used during the first part of this evaluation. A set of strap-on training skid shoes (photo 3, app B) were obtained from the United States Army Aviation School at Fort Rucker, Alabama, and were used during part of the 9000-pound test and for all the 9500-pound autorotations. Landings were performed on an asphalt runway and a comparison at 9000 pounds gross weight was made of the slide distances for the two types of skid shoes. The standard shoes at 9000 pounds consistently produced slide distances of 50 feet from 15 knots ground speed. Distances with the training shoes installed varied from 50 to 80 feet at the same conditions. The average slide distance for the training skid shoes was approximately 70 feet.

23. The AH-1G helicopter with the training skid shoes installed tended to turn to the right during ground slide after autorotational landing when the following conditions existed:

a. Low rotor speed at touchdown.

b. Engine running at idle (72 percent gas producer speed (N_1)).

24. Several practice autorotational landings were conducted after the training skid shoes were installed. During these practice landings at 9000 pounds, and during subsequent build-up autorotational landings at 9500 pounds, the turning tendency was noted when rotor speed decayed below 240 rpm prior to touchdown. At 9000 pounds gross weight, no turning tendency developed with the standard heavy-duty skid shoes installed; however, no comparison was made at 9500 pounds gross weight. The most significant turn was 110 degrees, right, when touchdown rotor speed was 210 rpm. On each occasion where a turn developed, full left pedal produced insufficient thrust from the antitorque tail rotor to arrest the right turn. The turning slides were not caused by cross winds, since the right turns developed during light winds (less than 4 knots) from both sides of the aircraft. Personnel using aircraft with the training skid shoes installed should be advised that turning slides may result if the touchdown rotor speed decays below 240 rpm.

OPERATIONAL HEIGHT-VELOCITY ENVELOPES

25. The operational H-V diagram depicts combinations of airspeed and height AGL where an operational pilot may accomplish a successful straight-ahead landing to a suitable landing area in the event of an engine failure in level or hovering flight. Delay in recognition of the failure, improper technique, or maneuvering to reach a suitable landing area reduce the probability of a safe touchdown. Flight conducted within the CAUTION area of the H-V envelope exposes the aircraft to a high probability of damage, despite the best efforts of the pilot. The operational H-V envelopes determined during this test are presented in figures 7 through 10, appendix E.

26. The operational H-V envelopes were based on the following criteria (test variables, para 7):

a. Collective and cyclic control delay times of 1.5 to 2.0 seconds.

b. Minimum transient entry rotor speed of 250 rpm.

c. Maximum nose-down pitch attitude of 25 degrees.

d. Minimum flare airspeed of 65 KIAS for autorotations entered above the knee of the envelope.

e. Maximum rate of descent at touchdown of 2.5 ft/sec.

f. Maximum touchdown true airspeed of 20 knots up to 9250 pounds gross weight, and 23 knots at 9500 pounds gross weight.

g. Technique described in the operator's manual.

27. The 9000 and 9500-pound operational H-V envelopes for a density altitude of 1000 feet are presented in figures 7 and 8, appendix E, and compared with the 8300-pound sea-level H-V curve from earlier testing (ref 2, app A) in figure 9. Test results at and below the knee of the curve showed no change in shape or position of the curve with increased gross weight. The gross weight effect above the knee is essentially a splaying of the curve to higher required heights AGL with increased gross weight. The knee area is more blunt with high gross weight. The curves presented for 9000 and 9500 pounds gross weight are applicable for the operational Army aviator and should be included in the operator's manual.

OPERATOR'S MANUAL CHANGES

Height-Velocity Curve

28. Figure 10, appendix E, presents a comparison of the current extrapolated 9500-pound H-V curve in the operator's manual (fig. 7-4) and the test results. The presentation in the manual is slightly optimistic at the high hover, indicating an operational capability at 1000 feet density altitude of approximately 700 feet at 9500 pounds. Test data show that the high hover point is 730 feet at 9500 pounds gross weight and 1000 feet density altitude. The knee area presented in the operator's manual indicates that the CAUTION area extends to 75 KIAS. Test data show that adequate airspeed is available at 70 KIAS to perform a successful autorotation at 9500 pounds (fig. 8, app E). Operational H-V curves for 8300, 9000, and 9500 pounds are presented in figure 9 and should be included in chapter 7 of the operator's manual to replace the extrapolated curve (fig. 7-4).

29. The discussion in the operator's manual of the H-V diagram (para 7-14) states that the emergency procedures described in chapter 4 are applicable within the CAUTION area when, in fact, these procedures are applicable to flight in the unshaded area near the curve. The CAUTION area should be avoided when permitted by the tactical mission, due to the high probability of damage should engine failure occur. If flight is required within the CAUTION area of the H-V curve, aircraft gross weight, pilot reaction time, pilot skill, surface wind, availability of a landing area straight ahead, and flight conditions of airspeed and altitude at time of failure become determining factors for a successful autorotational landing. The following NOTE should be added in the "Emergency" chapter (para 4-12) of the operator's manual:

NOTE

> The H-V diagram depicts combinations of airspeed and height above ground level where a successful straight-ahead landing to a suitable landing area may be made from level or hovering flight in the event of an engine failure. Delay in recognition of the failure, improper technique, or excessive maneuvering to reach a suitable landing area reduces the probability of a safe touchdown. Flight conducted within the CAUTION area of the H-V envelope exposes the aircraft to a high probability of damage, despite the best efforts of the pilot.

30. The H-V envelope is mentioned briefly in the "Emergency" chapter of the operator's manual (para 4-12.2) without reference to the figure or chapter where the diagram may be found. The H-V diagram is found in the "Operating Limitations" chapter (fig. 7-4). The discussion of emergency procedures for engine failure (chap. 4) should be visualized by the reader to be meaningful. Figure A of this report (discussed in paras 11 through 15) is a presentation of the H-V diagram with the various areas marked to follow the discussions in the operator's manual. Figure A should be included in chapter 4 of the operator's manual to assist the operator in understanding the use of the diagram and to help in visualizing techniques required.

Height-Velocity Technique

31. The technique to be used in the event of engine failure is discussed in very general terms in paragraph 4-12 of the operator's manual. The earlier H-V test report (ref 2, app A) recommended a more thorough discussion of technique. Results of testing at 9000 and 9500 pounds gross weight support the earlier recommendations in this report (paras 11 through 15). The following description of technique, together with figure A of this report, should be included in paragraph 4-12 in the operator's manual.

> **Engine Failure - zero airspeed/high hover to 40 KIAS and 475 feet (area A)**
>
> Forward cyclic should be applied in conjunction with lowering of collective to establish a nose-down pitch attitude of 25 degrees, in order to reach and stabilize on a descent airspeed of 70 KIAS (65 KIAS in the hog configuration).

Engine Failure - 40 KIAS and 475 feet to 70 KIAS and 125 feet (area B)

Forward cyclic should be applied as nececessary in conjunction with lowering of collective to establish a nose-down pitch attitude of 20 degrees at 40 KIAS, varying to no forward cyclic at 70 KIAS, in order to reach and stabilize on a descent airspeed of 70 KIAS (65 KIAS in the hog configuration).

NOTE

> Additional airspeed above the aim dive speed increases rate of descent and should only be used as necessary to extend glide distance (fig. 4-4).

Engine Failure - Low hover to 70 KIAS and 125 feet (area C)

From conditions of low airspeed and low height, the deceleration capability is limited, and caution should be used to avoid striking the ground with the tail rotor. Initial collective reduction will vary from no reduction at zero airspeed and 15 feet, to full down at 70 KIAS and 125 feet. Intermediate altitudes and airspeeds will require a partial reduction of collective in order to reach the termination prior to excessive rotor speed decay. Touchdown should be made in a slightly nose-high attitude to reduce the ground run as much as possible.

Airspeed Calibration Chart

32. An airspeed calibration was conducted in conjunction with this evaluation and is presented in figure 1, appendix C. The calibration obtained corresponds with data reported during Phase D testing of the AH-1G helicopter (ref 8, app A). The operator's manual airspeed calibration chart (fig. 14-1) corresponds directly with the special instrumentation boom airspeed system calibration used during the Phase D testing. The airspeed calibration chart presented in the operator's manual is not applicable to the production AH-1G helicopter. The operator's manual airspeed calibration chart must be revised to present the airspeed calibration shown in figure 1, appendix C, of this report.

Autorotational Descent Chart

33. Autorotational descent performance is primarily a function of airspeed, rotor speed, and aircraft configuration. The Phase D report (ref 8, app A) presents data for both clean and hog configurations and shows a substantial change in the airspeed for minimum rate of descent and for maximum glide distance (figs. 110 and 111, ref 8). A comparison of the two configurations based on Phase D data is presented in operator's manual format in figure C. The operator's manual presents charts

for glide ratio and rate of descent versus airspeed in the clean configuration only (fig. 4-4). The operator's manual should be revised to add the hog configuration curves (fig. C) to figure 4-4 and paragraph 4-10 should be modified to indicate 90 KIAS as maximum glide distance airspeed and 65 KIAS as minimum rate-of-descent airspeed in the hog configuration.

SPECIFICATION COMPLIANCE

34. Aircraft characteristics, as appropriate, were checked for compliance with specific requirements of military specification MIL-H-8501A (ref 9, app A). Within the scope of this test, the AH-1G helicopter met the requirements of paragraphs 3.5.4.3 and 3.4.4 of MIL-H-8501A.

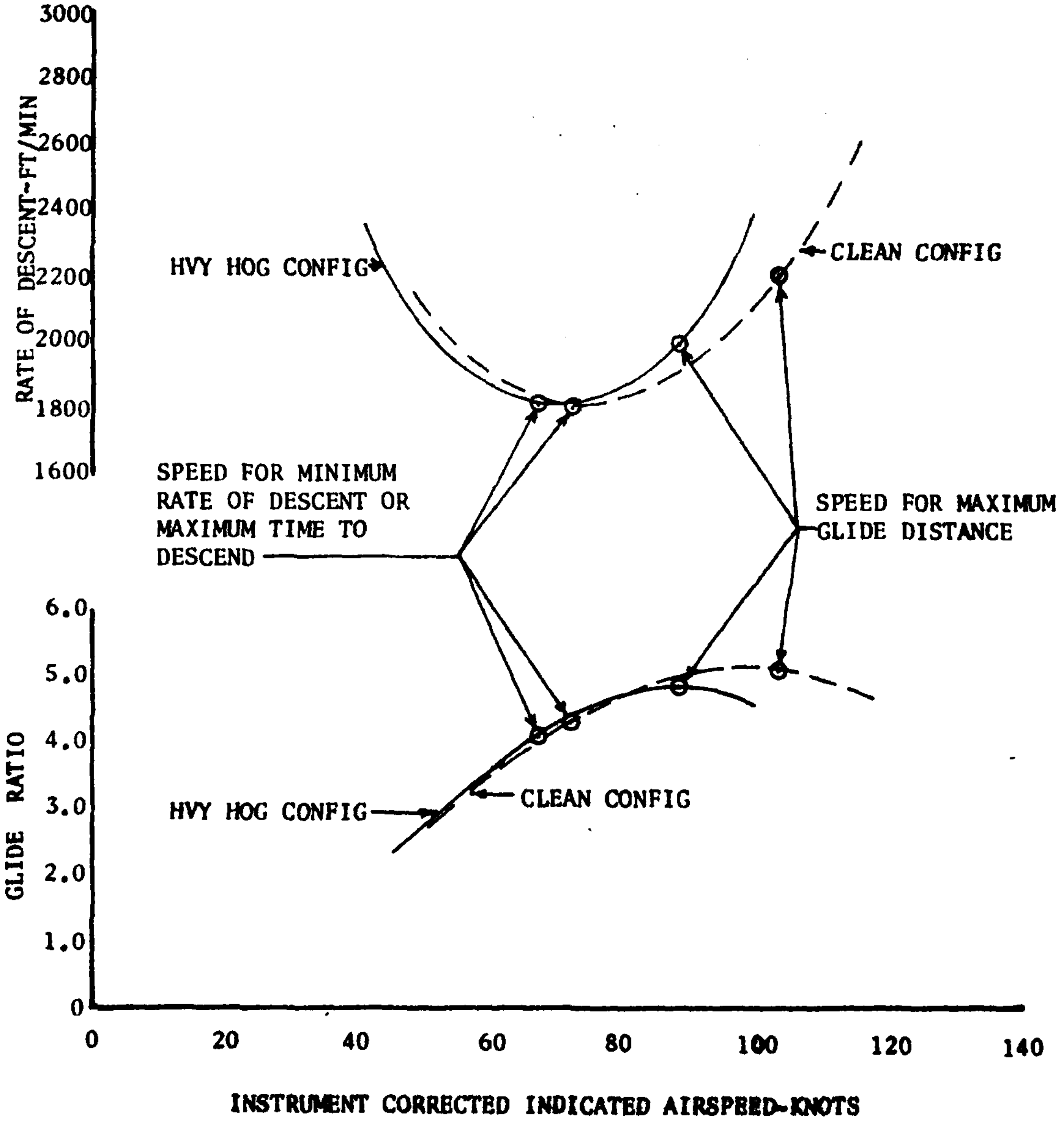
35. One touchdown autorotation at 35 knots touchdown airspeed was made at 9000 pounds gross weight with standard heavy-duty type skid shoes installed. The slide distance was 330 feet, which exceeded the 200-foot specification requirement. Although not intentionally tested, it appears that the AH-1G helicopter will not meet the requirement of paragraph 3.5.4.4 of MIL-H-8501A.

36. Test data and qualitative pilot comments indicate that approximately 20 knots true airspeed (KTAS) is the minimum repeatably safe touchdown airspeed at 9500 pounds gross weight. The capability to repeatedly accomplish safe power-off autorotational landings at touchdown airspeeds of 15 knots or less at 9500 pounds gross weight, in compliance with paragraph 3.5.7 of MIL-H-8501A, is impossible.

FIGURE C

AUTOROTATIONAL DESCENT PERFORMANCE
AH-1G
AVG. ROTOR SPEED - 324 RPM

NOTE - DATA ARE TAKEN FROM FIG'S 110 AND
111 PROJECT NO. 66-06 PHASE D
PART 2 PERFORMANCE



CONCLUSIONS

GENERAL

37. The following conclusions were reached upon completion of testing:

a. The height AGL at which the autorotational landing flare is initiated becomes more restrictive as gross weight is increased to 9500 pounds (paras 16 and 17).

b. Autorotational landings at gross weights over 9250 pounds will probably result in rotor overspeed during flare for landing (para 19).

c. The AH-1G helicopter with training skid shoes installed tended to turn right during autorotational landing slide (paras 23 and 24).

d. The operatior's manual needs improvement in clarifying the techniques to be used during autorotational landings (paras 28 through 33).

e. The explanation of the H-V diagram in the operator's manual needs improvement (para 29).

SPECIFICATION COMPLIANCE

38. Within the scope of this test, the AH-1G helicopter at 9500 pounds maximum allowable gross weight will not meet the following requirements of MIL-H-8501A:

a. Paragraph 3.5.4.4 - From a 35-knot autorotational touchdown, bring the helicopter to a stop within 200 feet (para 35).

b. Paragraph 3.5.7 - To make repeatedly safe power-off autorotational landings at speeds of 15 knots or less (para 36).

RECOMMENDATIONS

39. A radio altimeter should be installed as standard equipment on the AH-1G helicopter (para 18).

40. The findings of this report, as listed below, should be incorporated in the operator's manual.

a. Revise the H-V diagram in figure 7-4, chapter 7 (para 28).

b. Add a note to paragraph 4-12 of the "Emergency" chapter (para 29).

c. Include the H-V diagram in paragraph 4-12 of the "Emergency" chapter (para 30).

d. Expand the description of H-V techniques in paragraph 4-12 of the "Emergency" chapter (para 31).

e. Correct the airspeed calibration chart in figure 14-1, chapter 14 (para 32).

f. Revise the autorotational descent performance chart in figure 4-4 to include the hog configuration (para 33).

APPENDIX A. REFERENCES

1. Technical Manual, TM 55-1520-221-10, *Operator's Manual, Army Model AH-1G Helicopter*, 19 June 1971, with Changes 1 through 10.

2. Final Report, USAASTA, Project No. 69-13, *Height-Velocity Test, AH-1G Helicopter*, February 1971.

3. Final Report, USAASTA, Project No. 74-10, *Engineering Flight Test, AH-1G Helicopter, Heavyweight Autorotational Evaluation*, May 1974.

4. Message, AVSCOM, AMSAV-EFT, 10-17, 232200Z October 1973, subject: AH-1G Heavyweight Height-Velocity Tests.

5. Message, AVSCOM, AMSAV-EFT, 11-10, 062137Z November 1973, subject: AH-1G Heavyweight Height-Velocity Tests.

6. Message, AVSCOM, AMSAV-EFT, 11-17, 092200Z November 1973, subject: Safety-of-Flight Release for Project Number 74-19.

7. Engineering Design Handbook, Army Materiel Command, AMCP-706-204, *Helicopter Performance Testing*, August 1974.

8. Final Report, USAASTA, Project No. 66-06, *Engineering Flight Test of the AH-1G Helicopter (HueyCobra), Phase D, Part II, Performance*, April 1970.

9. Military Specification, MIL-H-8501A, *Helicopter Flying and Ground Handling Qualities; General Requirements For*, September 1961, with Amendment 1, 3 April 1962.

APPENDIX B. PHOTOGRAPHS

Photo 1. Front View, AH-1G Helicopter.

Photo 2. Side View, AH-1G Helicopter.

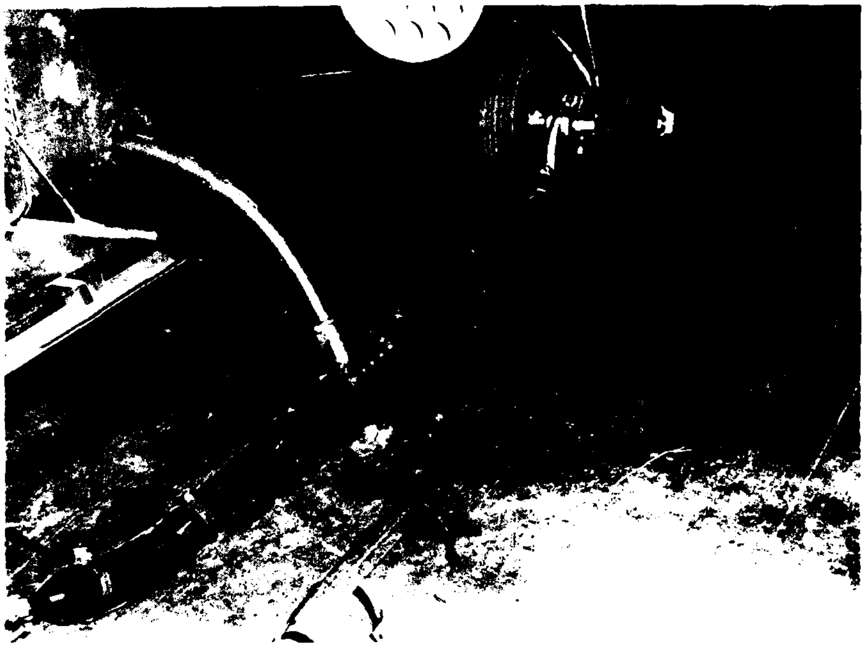


Photo 3. Training Skid Shoes, AH-1G Helicopter.

APPENDIX C. INSTRUMENTATION AND SPECIAL EQUIPMENT

INSTRUMENTATION

1. The test instrumentation was installed, calibrated, and maintained by the Data Systems Office of USAASTA. A test boom with a swiveling pitot-static head was installed at the nose of the aircraft and was connected to sensitive airspeed indicators and altimeters on both cockpit instrument panels and recorded on magnetic tape. A radio altimeter and a touchdown time sequencer (wand), described in the Special Equipment section, were added to the aircraft and the data were recorded on magnetic tape. Data were obtained from calibrated instrumentation and displayed or recorded on the following aircraft sources.

Pilot Panel

Airspeed (boom)
Airspeed (ship's system)
Altitude (boom)
Altitude (ship's system)
Rate of climb
Main rotor speed (sensitive)
Angle of sideslip
Center-of-gravity normal acceleration
Engine torque (ship's system)
Radio altimeter

Engineer Panel

Airspeed (boom)
Altitude (boom)
Main rotor speed
Outside air temperature (sensitive)
Fuel used (counter)
Directional control position
Remote time code
Exhaust gas temperature
Gas producer speed (N_1)
Engine torque (ship's system)

Magnetic Tape	Accuracy Estimate
Airspeed (boom)	±0.5 knot
Altitude (boom)	±25 feet

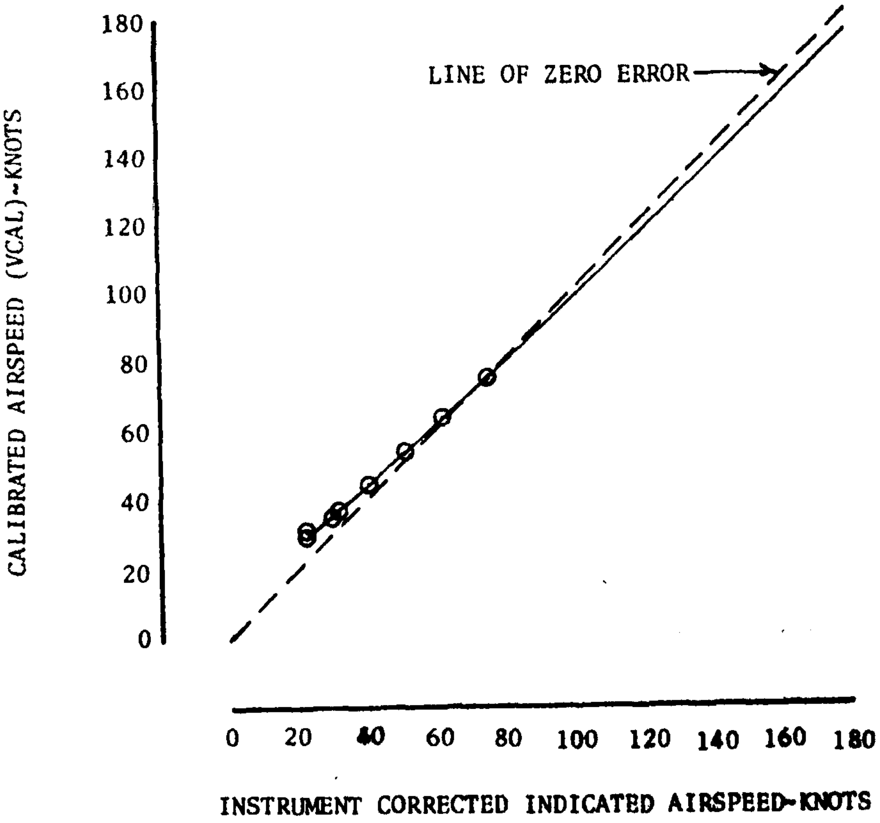
Radio altimeter:	
Altitude	Zero to 500 feet ±1% of reading 500 to 2500 feet ±4% of reading
Rate of descent	±1 ft/sec
Control position:	
Longitudinal	±0.1 inch
Lateral	±0.1 inch
Directional	±0.1 inch
Collective	±0.1 inch
Throttle	±0.5% of reading
Control position after SCAS:	
Longitudinal	±0.1 inch
Lateral	±0.1 inch
Directional	±0.1 inch
Control force:	
Longitudinal	±0.25 pound
Lateral	±0.25 pound
Directional	±0.25 pound
Attitude:	
Pitch	±0.5 deg
Roll	±0.5 deg
Yaw	±0.5 deg
Rate:	
Pitch	±0.5 deg/sec
Roll	±0.5 deg/sec
Yaw	±0.5 deg/sec
Angular acceleration:	
Pitch	±0.5 deg/sec^2
Roll	±0.5 deg/sec^2
Yaw	±0.5 deg/sec^2
Angle of attack	±0.5 deg
Angle of sideslip	±0.5 deg
Center-of-gravity normal acceleration	±0.1g
Outside air temperature	±0.25°C
Main rotor speed	±0.5 rev/min
Engine delta torque	±0.25 lb/in.^{2}
Touchdown events (2)	
Time code	
Pilot event	
Engineer event	

2. Figure 1 graphically depicts the equation used for determining calibrated airspeed.

FIGURE 1
AIRSPEED CALIBRATION
SHIP'S STANDARD SYSTEM
AH-1G S/N 71-20985

AVG GROSS WEIGHT -LB	AVG C.G. LOCATION -IN	AVG DENSITY ALTITUDE -FT	AVG OAT -°C	AVG ROTOR SPEED -RPM	FLIGHT CONDITION	TEST METHOD
9300	196.5	4200	8.0	324	LEVEL	TRAILING BOMB

NOTE: CURVE OBTAINED FROM USAASTA REPORT NUMBER 66-06 PHASE D, PART 1 AND IS ESSENTIALLY THE SAME FOR ALL FLIGHT CONDITIONS.



SPECIAL EQUIPMENT

Digital Recording Observation Instrument

3. The digital recording observation instrument (ROI) is an optical tracking device manufactured by Keuffel and Esser Company, Morristown, New Jersey. The ROI is designed to continuously gather elevation and azimuth data, both of which are electronically sensed and printed on paper tape as an object is tracked. Two ROI's were used to track the aircraft from entry through touchdown. The data derived from the ROI recordings were as follows:

Vertical height
Vertical rate of descent
Horizontal distance
Horizontal speed

Weather Station

4. A portable weather station, consisting of an anemometer and sensitive temperature gauge, was used to record the following data:

Wind speed
Wind direction
Ambient temperature

Digital Doppler Traffic Radar (Speedgun)

5. The speedgun is a hand-held battery-operated radar device with a digital readout manufactured by CMI, Inc, Chanute, Kansas. The speedgun was used to record the aircraft ground speed in knots at touchdown.

Movie and Video Cameras

6. A 16mm movie camera and a video tape camera were used simultaneously throughout the test. Flights were recorded on film and video tape to provide the test team with a means of reviewing technique. The video tape was especially useful because it could be replayed immediately after flying. Specific parameters were not recorded with this equipment.

Touchdown Time Sequencer (Wand)

7. The touchdown wand was designed, fabricated, and installed in the test aircraft by USAASTA personnel to provide accurate vertical rate-of-descent data at touchdown. The wand was designed to extend below skid level and event the time of wand contact and time of skid contact; both event switches were attached to the wand. The elapsed time between events and the known distance below the skids to which the wand extended were used to calculate rate of descent at touchdown.

Radio Altimeter

8. The AA-200 series helicopter radio altimeter (photos 1 through 4) is manufactured by Sperry Flight Systems, Phoenix, Arizona. It was designed to give an accurate pilot and copilot readout of the aircraft's altitude AGL. The instrument was incremented from zero to 2500 feet, of which zero to 1000 feet were recorded on magnetic tape on board the aircraft. Also, a vertical speed channel with no pilot readout capability was incorporated. The channel was calibrated for +10 to -90 ft/sec rates of descent and was recorded on magnetic tape on board the aircraft.

Fairchild Flight Analyzer

9. The Fairchild flight analyzer (FFA) is a visual tracking device manufactured by Fairchild Data Devices Corporation, Yonkers, New York. The FFA takes a sequence of strip exposures on a photographic plate as the camera is slewed to track a moving target. Each exposure includes a view of a precision timer. Horizontal and vertical displacement of the aircraft as a function of time may be determined by applying the appropriate scale factors to the photographic measurements. A sample FFA photograph is presented as photo 5. Data derived from the analyzer were as follows:

Vertical height
Vertical rate of descent
Horizontal distance
Horizontal speed

Photo 1. Radio Altimeter Installation - Antenna.

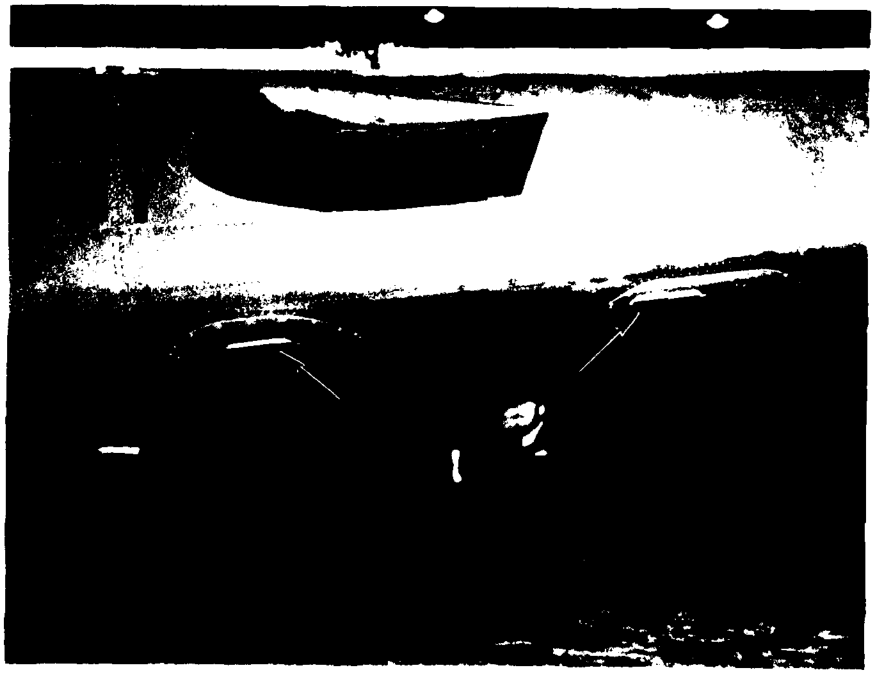


Photo 2. Radio Altimeter Installation - Antenna.

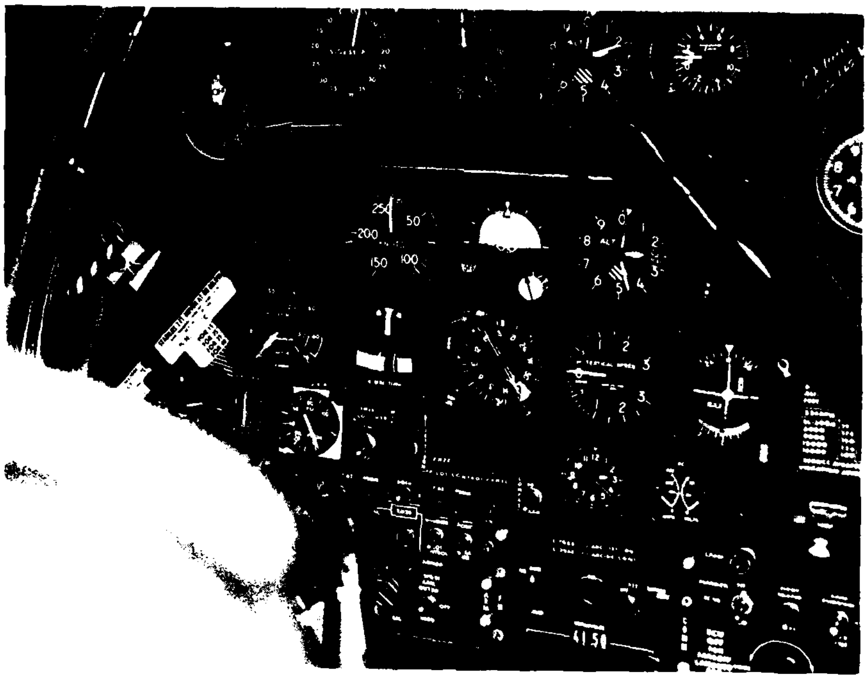


Photo 3. Radio Altimeter Installation - Pilot Station.

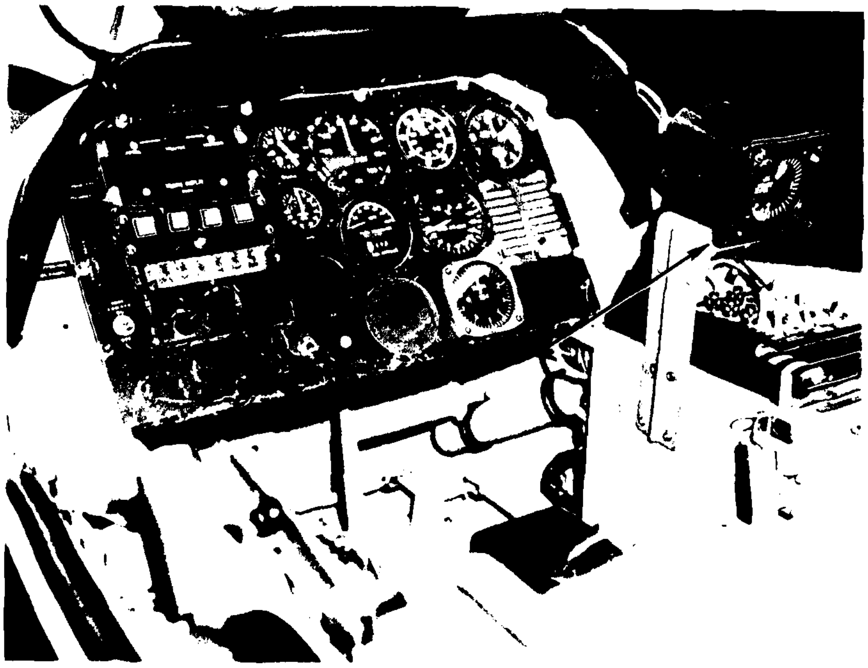


Photo 4. Radio Altimeter Installation - Copilot Station.

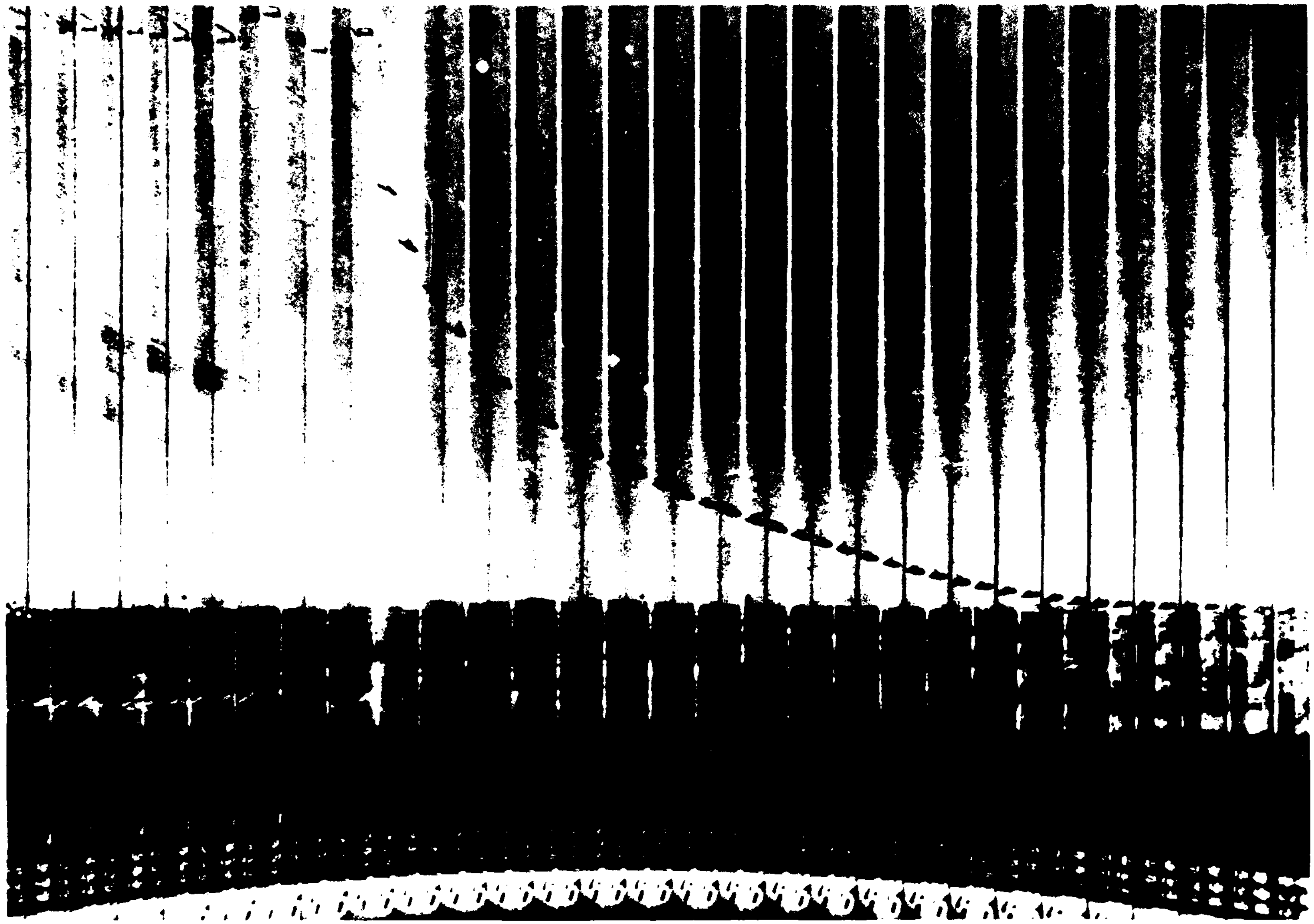


Photo 5. Fairchild Flight Analyzer Data Plate.

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

TEST TECHNIQUES

1. Height-velocity curve predictions were made for 9000 and 9500 pounds gross weight for the AH-1G helicopter at 2300 feet density altitude, using data from earlier AH-1G H-V testing (ref 2, app A). These predictions were used as guides for establishing test entry conditions of airspeed and altitude.

2. The following criteria and techniques were based on the earlier AH-1G H-V test results (ref 2, app A) and further developed during this H-V determination.

a. Collective and cyclic control delay times of 1.5 to 2.0 seconds.

b. Minimum transient entry rotor speed of 250 rpm.

c. Maximum nose-down pitch attitude of 25 degrees.

d. Accelerate in order to stabilize airspeed at 65 KIAS.

e. Minimum flare airspeed of 65 KIAS and a flare altitude of 70 feet AGL for entry points above the knee of the curve.

f. Maximum touchdown rate of descent of 2.5 ft/sec.

g. Aim maximum touchdown airspeed of 20 KTAS.

h. Pilot technique as described in the operator's manual.

3. Sudden engine failure was simulated by rolling the twist grip throttle to the engine-idle position. Cyclic and collective controls were held fixed for 1.5 to 2.0 seconds. Pilot recognition cues were readily discernible in the yaw axis; therefore, no delay was employed with the directional control.

4. A consistent pilot technique was used for defining each point on the H-V curve. Table 1 presents the levels of deviation from the target conditions.

Table 1. Consistency Level.

Parameter	Deviation from Mean Value
Delay time	±0.3 seconds
Pitch attitude	±4 degrees
Pitch rate	±1 degree per second
Stabilized airspeed	±5 KIAS
Flare airspeed	±4 KIAS
Flare altitude	±10 feet
Airspeed at touchdown	±4 KTAS
Touchdown rate of descent	±1 foot per second

DATA ANALYSIS METHODS

5. The test aircraft was weighed after the installation of test instrumentation. The fuel load for each test flight was determined prior to engine start and following engine shutdown by using a calibrated external sight gauge to determine fuel volume and by measuring specific gravity. Fuel used in flight was recorded by a sensitive fuel-used system and cross-checked with readings taken from the sight gauge following the flight. Aircraft gross weight and cg were controlled by ballast installed at various locations in the aircraft. Dummy rockets were added to the rocket pods between data points as necessary to compensate for fuel consumption and to maintain aircraft gross weight within 50 pounds of the test gross weight.

6. Data for each autorotation were recorded on airborne magnetic tape, space positioning equipment, and from cockpit instruments. The system included a real time telemetry and readout of selected parameters, using a mobile instrumentation and data acquisition van and an EMR 6135 computer. Selected parameters were monitored by the project engineer. Time histories of additional data were obtained from the following equipment:

a. Radio altimeter: Height AGL and vertical rate of descent.

b. Recording observation instrument: Azimuth and elevation of the aircraft were printed continuously on paper tape during each data run. The following equations were used to reduce these data to a workable form. Figure 1 illustrates the geometric relationship of the aircraft to the ROI.

Horizontal displacement:

$$X = X_2 - \left[\frac{X_3}{\text{TAN}\ \gamma - \text{TAN}\ \alpha}\right] \text{TAN}\ \alpha \qquad (1)$$

Elevation:

$$Z = \frac{X_3}{\text{TAN}\ \gamma - \text{TAN}\ \alpha} \frac{\text{TAN}\ \beta}{\text{COS}\ \alpha} \qquad (2)$$

Where:

X = Horizontal displacement of aircraft from base reference

Z = Elevation of aircraft from runway

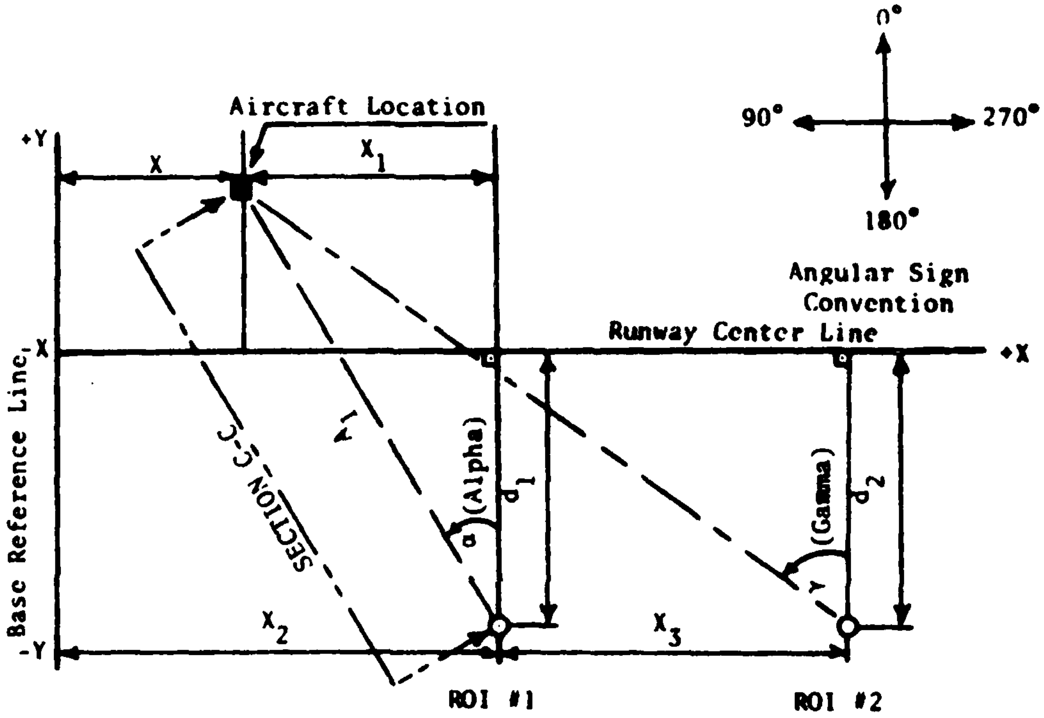
Y = Aircraft displacement from center line

d_1 and d_2 = Distance ROI offset from runway center line

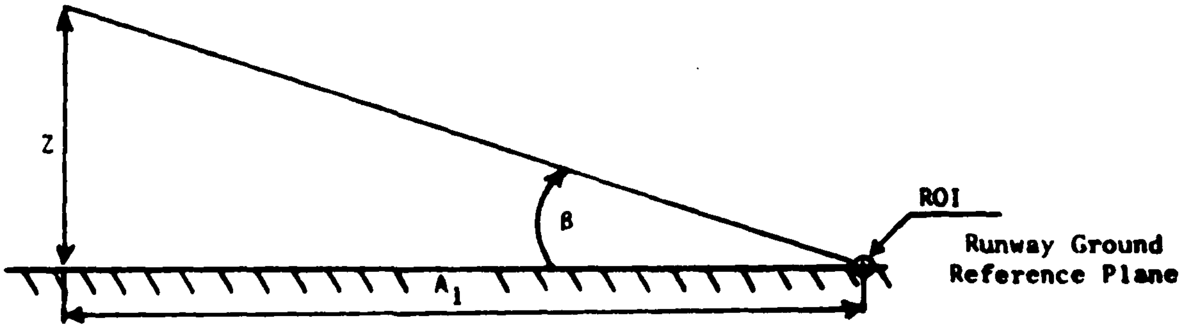
α and γ = Horizontal displacement angles

β = Vertical displacement angle (ROI No. 1)

(figure 1)



SECTION C-C



Base reference line: **An imaginary line located a convenient distance from the intended touchdown point.**

Rate of descent and horizontal velocity were obtained by taking the first time derivatives of the resulting displacements.

c. Fairchild flight analyzer: Raw data consisted of a photographic record of each flight point. The following equations were used to reduce these data to a workable form.

Horizontal displacement:

$$X = \frac{THD}{PTW} \cdot \frac{OD}{TOD} \cdot X_{pic} \tag{3}$$

Vertical displacement:

$$Z = \frac{THD}{PTW} \cdot \frac{OD}{TOD} \cdot Z_{pic} \tag{4}$$

Where: X = Horizontal distance (feet) from a selected reference axis

Z = Vertical distance (feet) from a selected reference axis (runway)

(Note: Aircraft assumed to be above runway center line)

X_{pic} = Horizontal distance (inches) on the photographic record from a selected reference axis

Z_{pic} = Vertical distance (inches) on the photographic record from a selected reference axis (runway)

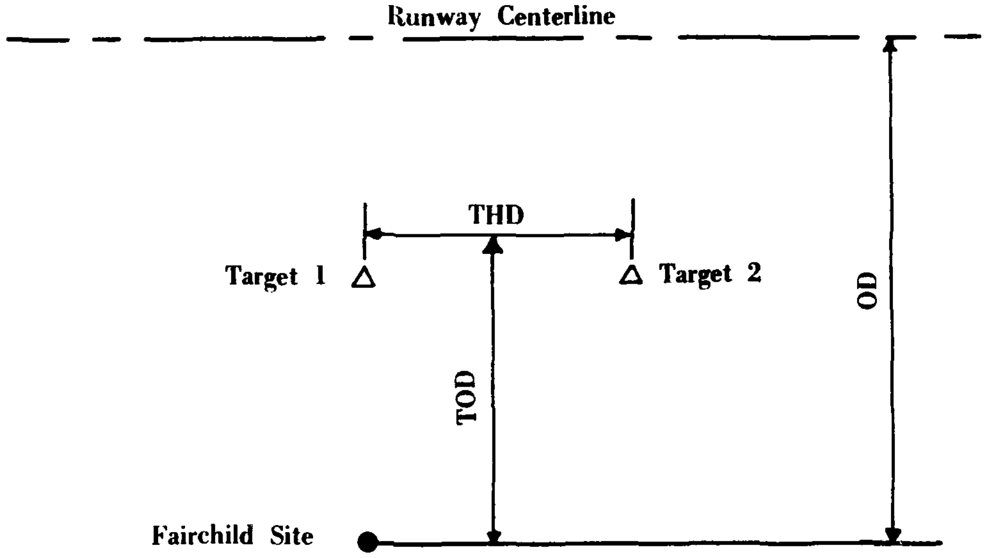
OD = Perpendicular offset distance from FFA to runway center line (feet)

TOD = Perpendicular distance from FFA to a line connecting the targets (feet)

THD - Distance between targets (feet)

PTW = Distance between targets on the photographic record (inches)

(diagram)



Rate of descent and horizontal velocity were obtained by taking the first time derivatives of the resulting displacements.

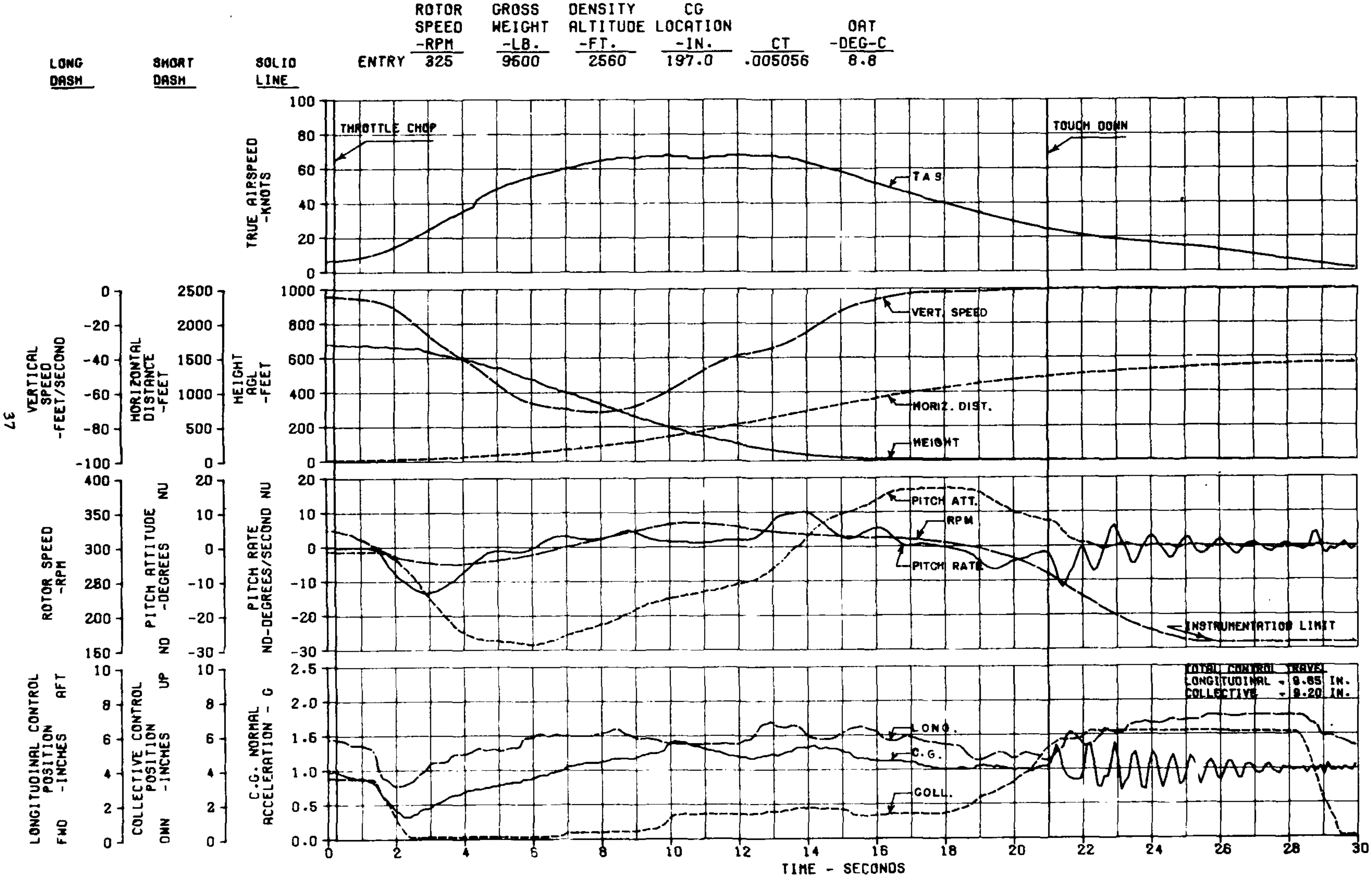
7. The time histories obtained for each point flown were then analyzed for compliance with the operational criteria (para 2, app D). These quantitative data, combined with the pilot's comments, were then used to fair the operational H-V curve.

APPENDIX E. TEST DATA

INDEX

Figure	Figure Number
Time History of Autorotational Landing	1 through 6
AH-1G Height-Velocity Determination (9000 Pounds Gross Weight)	7
AH-1G Height-Velocity Determination (9500 Pounds Gross Weight)	8
AH-1G Recommended Operational Height-Velocity Envelope	9
AH-1G Operational Height-Velocity Comparison	10

FIGURE 1
TIME HISTORY OF AUTOROTATIONAL LANDING
AH-1G USA S/N 71-20985



	ROTOR SPEED -RPM	GROSS WEIGHT -LB.	DENSITY ALTITUDE -FT.	CG LOCATION -IN.	CT	OAT -DEG-C
ENTRY	325	9600	2560	197.0	.005056	8.8

FIGURE 2
TIME HISTORY OF AUTOROTATIONAL LANDING
AH-1G USA S/N 71-20985

	ROTOR SPEED -RPM	GROSS WEIGHT -LB.	DENSITY ALTITUDE -FT.	CG LOCATION -IN.	CT	OAT -DEG-C
ENTRY	324	9480	2080	196.8	.005005	7.1

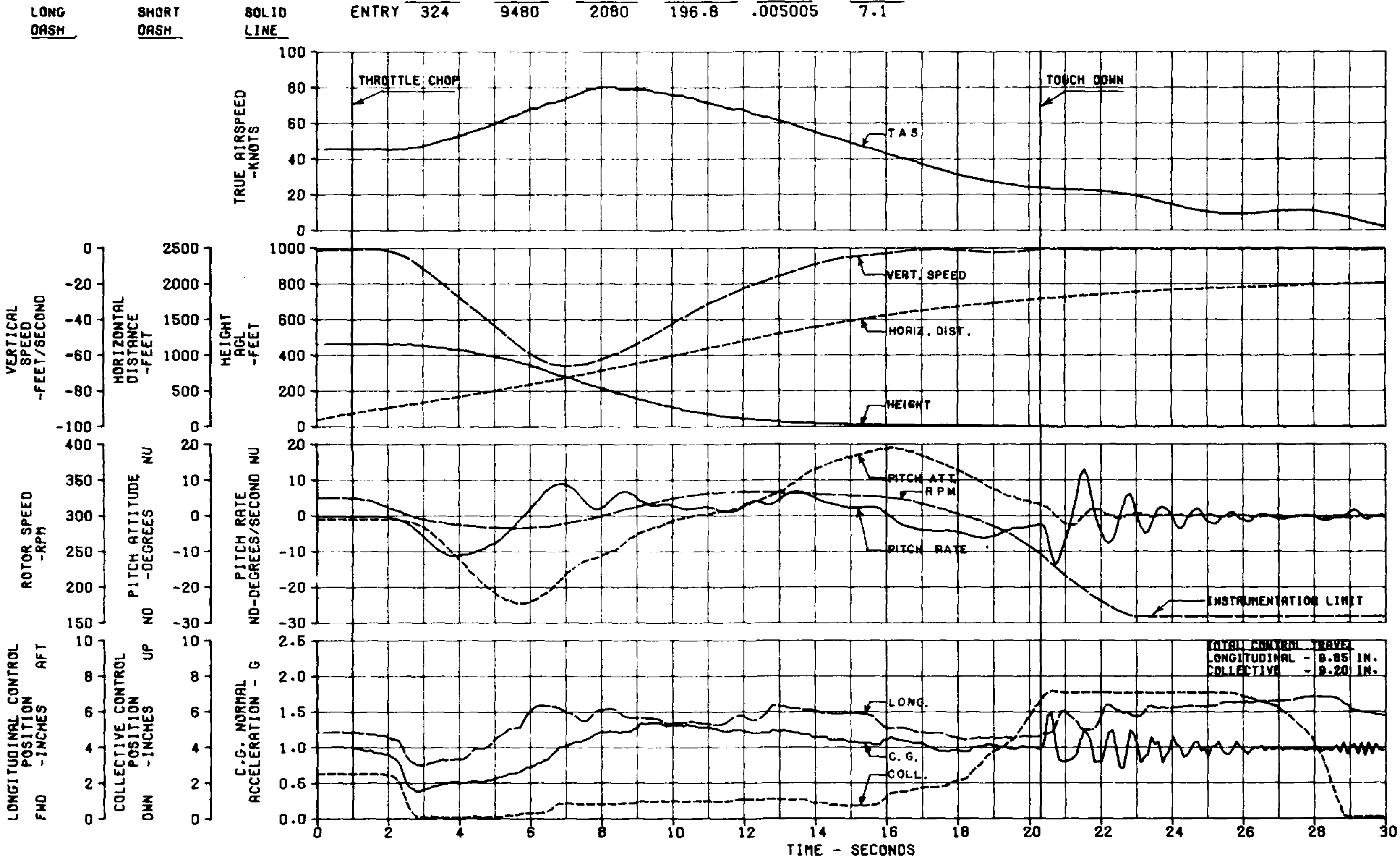


FIGURE 3
TIME HISTORY OF AUTOROTATIONAL LANDING
AH-1G USA S/N 71-20985

	ROTOR SPEED -RPM	GROSS WEIGHT -LB.	DENSITY ALTITUDE -FT.	CG LOCATION -IN.	CT	OAT -DEG-C
ENTRY	325	9540	1080	196.7	.004860	1.5

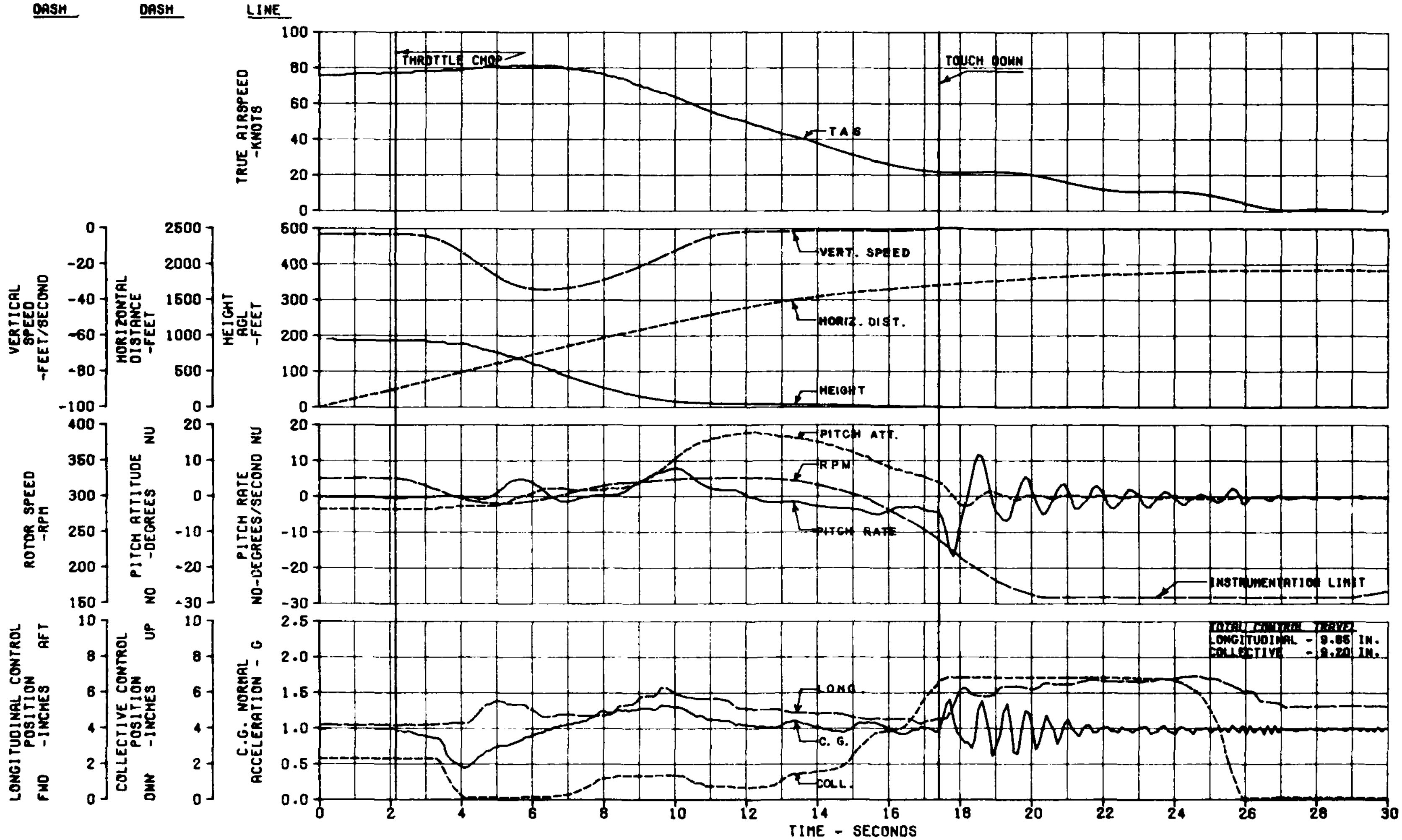


FIGURE 4
TIME HISTORY OF AUTOROTATIONAL LANDING
AH-1G USA S/N 71-20985

	ROTOR SPEED -RPM	GROSS WEIGHT -LB.	DENSITY ALTITUDE -FT.	CG LOCATION -IN.	CT	OAT -DEG-C
ENTRY	330	9430	1060	196.6	.004657	2.8

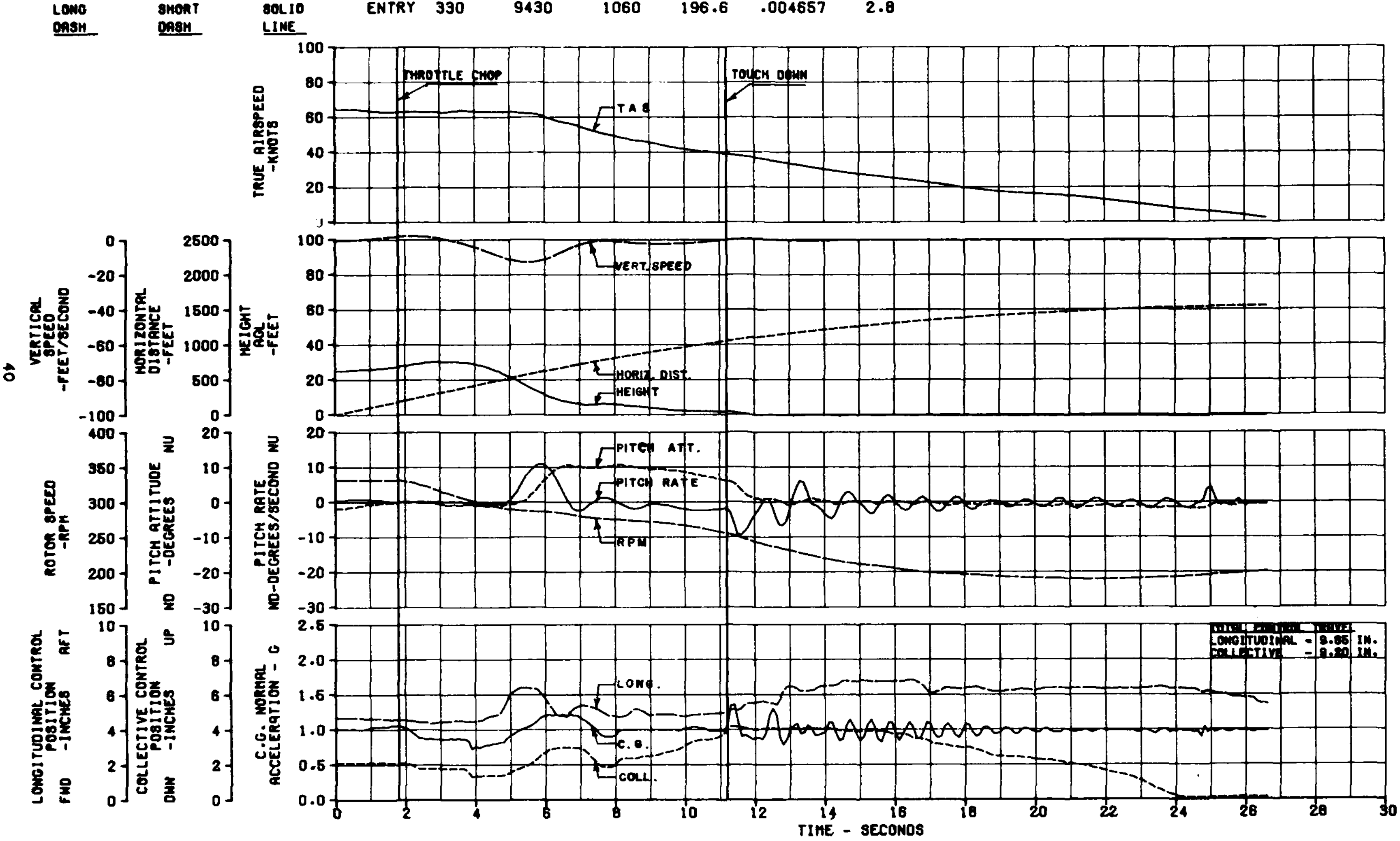


FIGURE 5
TIME HISTORY OF AUTOROTATIONAL LANDING
AH-1G USA S/N 71-20985

	ROTOR SPEED -RPM	GROSS WEIGHT -LB.	DENSITY ALTITUDE -FT.	CG LOCATION -IN.	CT	OAT -DEG-C
ENTRY	330	9450	1010	196.7	.004660	2.4

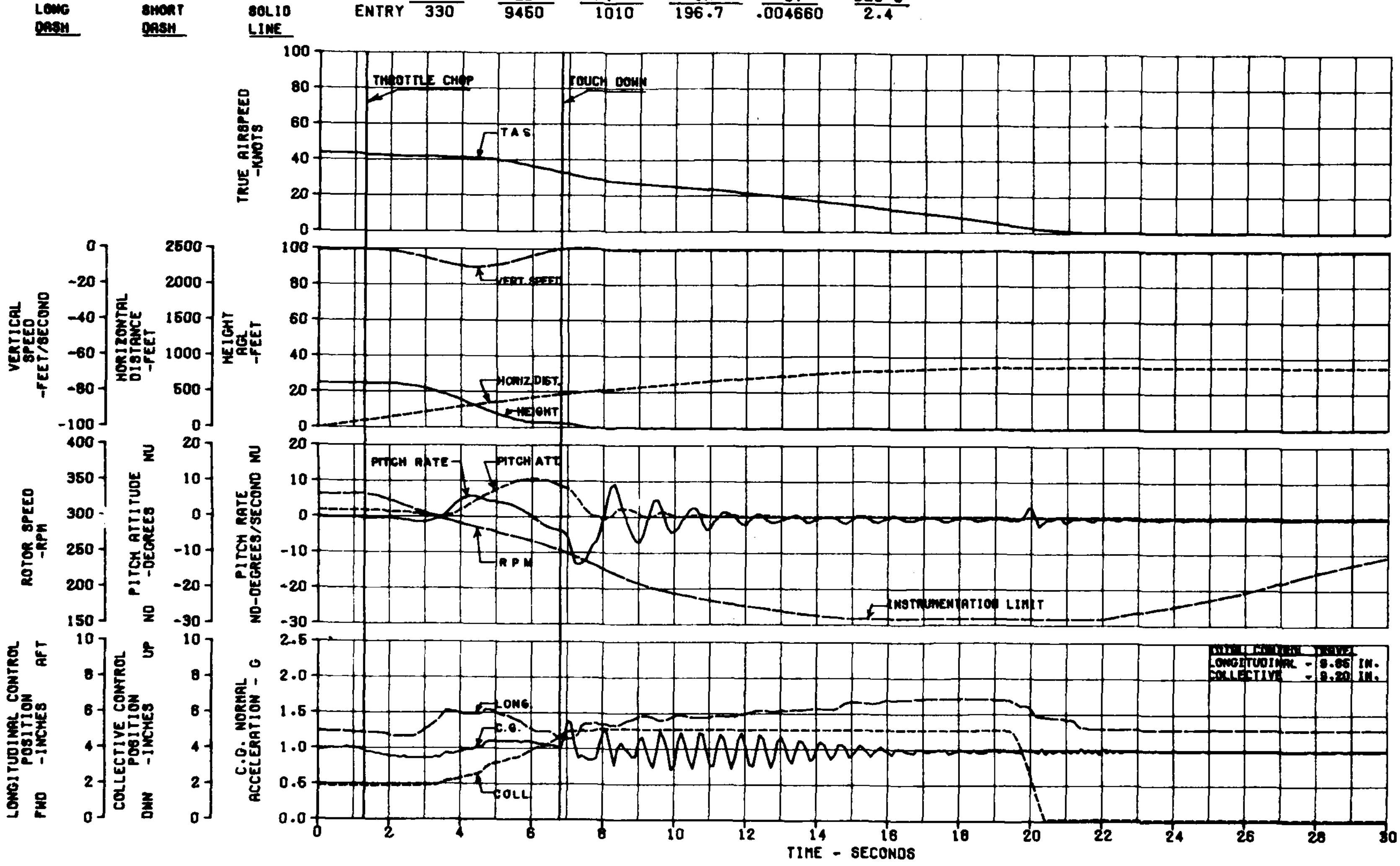


FIGURE 6
TIME HISTORY OF AUTOROTATIONAL LANDING
AH-1G USA S/N 71-20985

	ROTOR SPEED -RPM	GROSS WEIGHT -LB.	DENSITY ALTITUDE -FT.	CG LOCATION -IN.	CT	OAT -DEG-C	FLIGHT CONDITION
ENTRY	324	9050	800	196.4	.004600	1.9	LOW HOVER

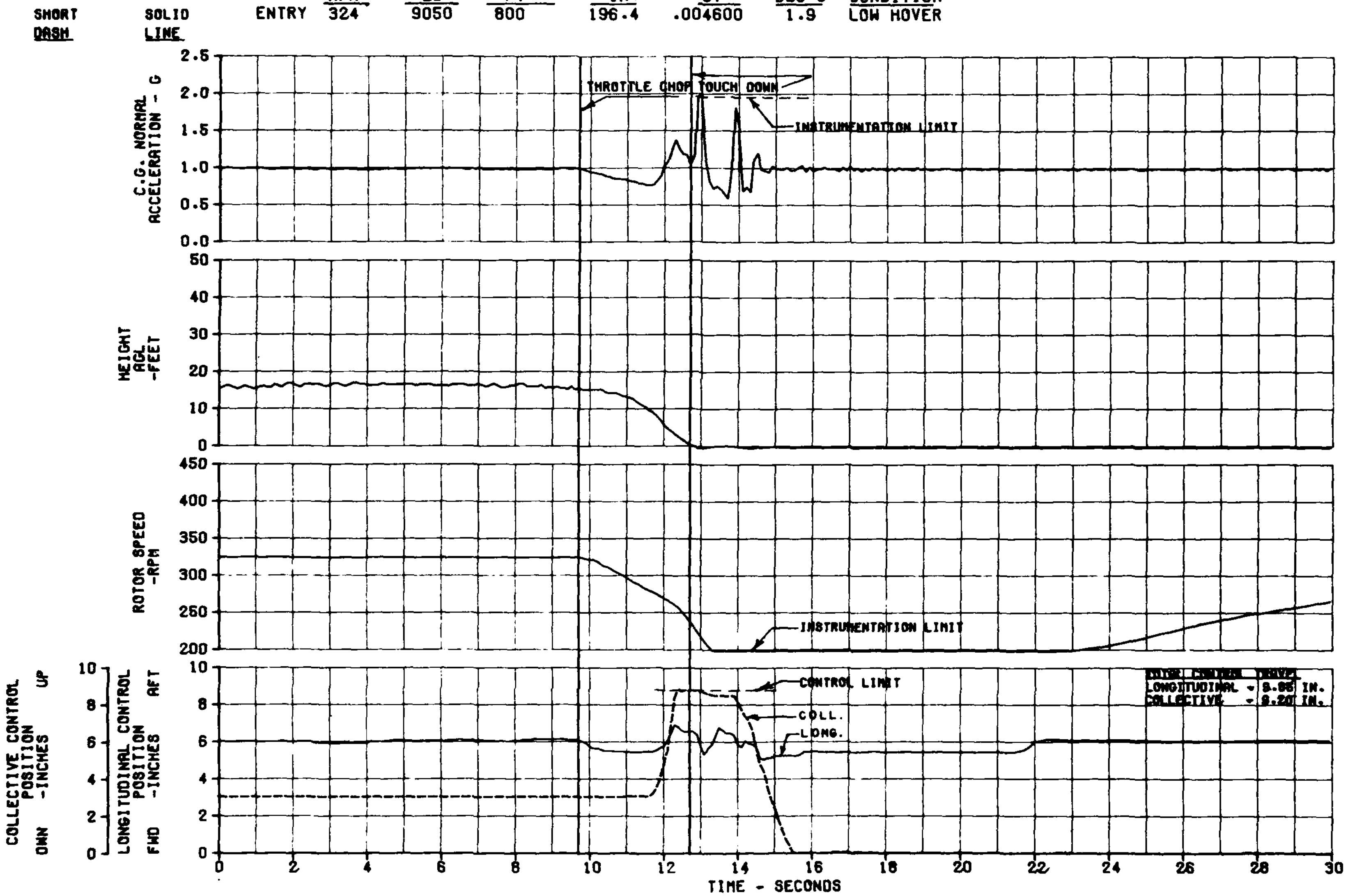


FIGURE 7

AH-1G HEIGHT VELOCITY DETERMINATION

SYMBOL	AVG G.W. ~LB	CONFIG	AVG Hd ~FT	AVG OAT ~°C	AVG C.G. ~IN	AVG ENTRY ROTOR SPEED~RPM
⊙	8600	HVY HOG	710	-0.5	196.8	324
⊡	9000	HVY HOG	1000	3.5	196.6	324
▲	9250	HVY HOG	600	1.5	196.8	324

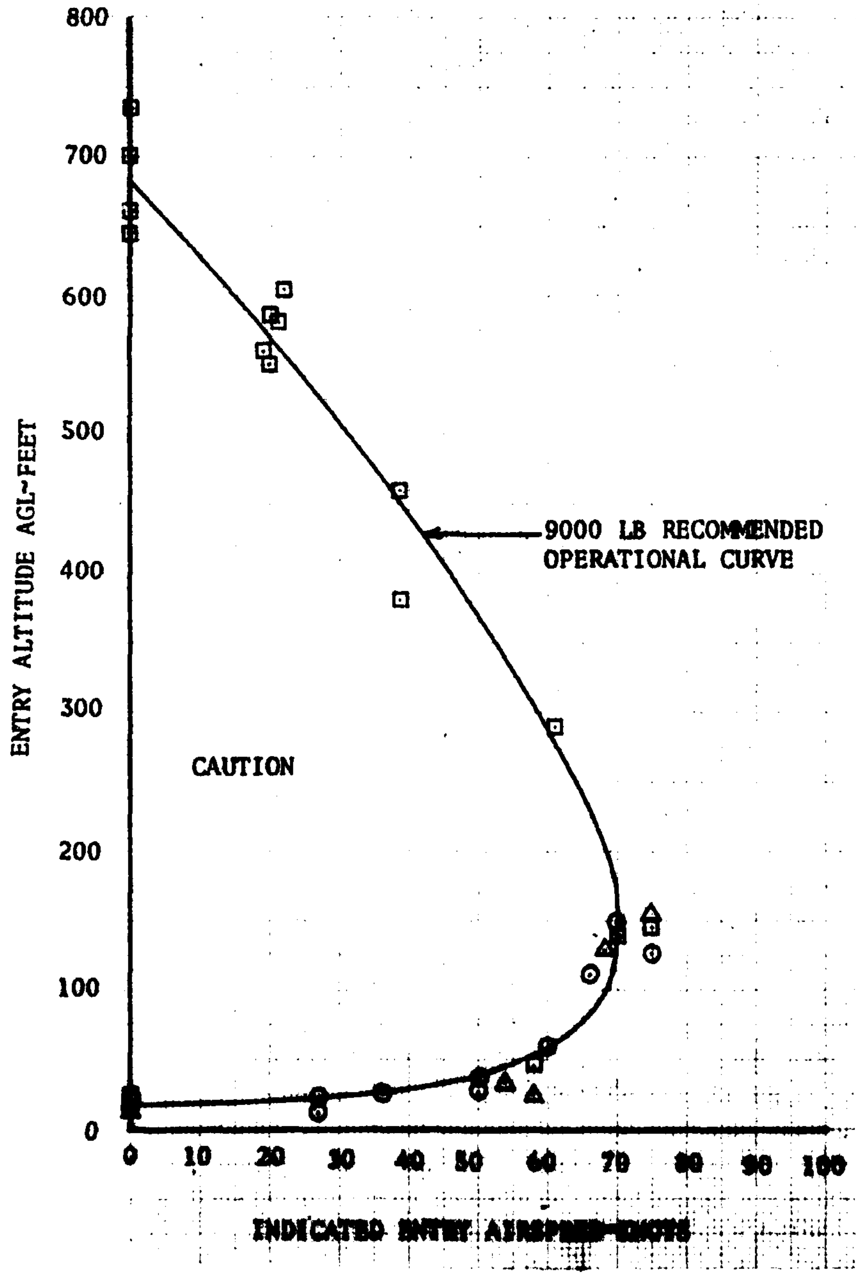


FIGURE 8

AH-1G HEIGHT VELOCITY DETERMINATION

SYMBOL	AVG G.W. ~LB	CONFIG	AVG Hd ~FT	AVG OAT ~°C	AVG C.G. ~IN	AVG ENTRY ROTOR SPEED~RPM
⊙	8600	HVY HOG	710	-0.5	196.8	324
△	9250	HVY HOG	600	1.5	196.8	324
⊡	9500	HVY HOG	1000	2.6	196.8	324

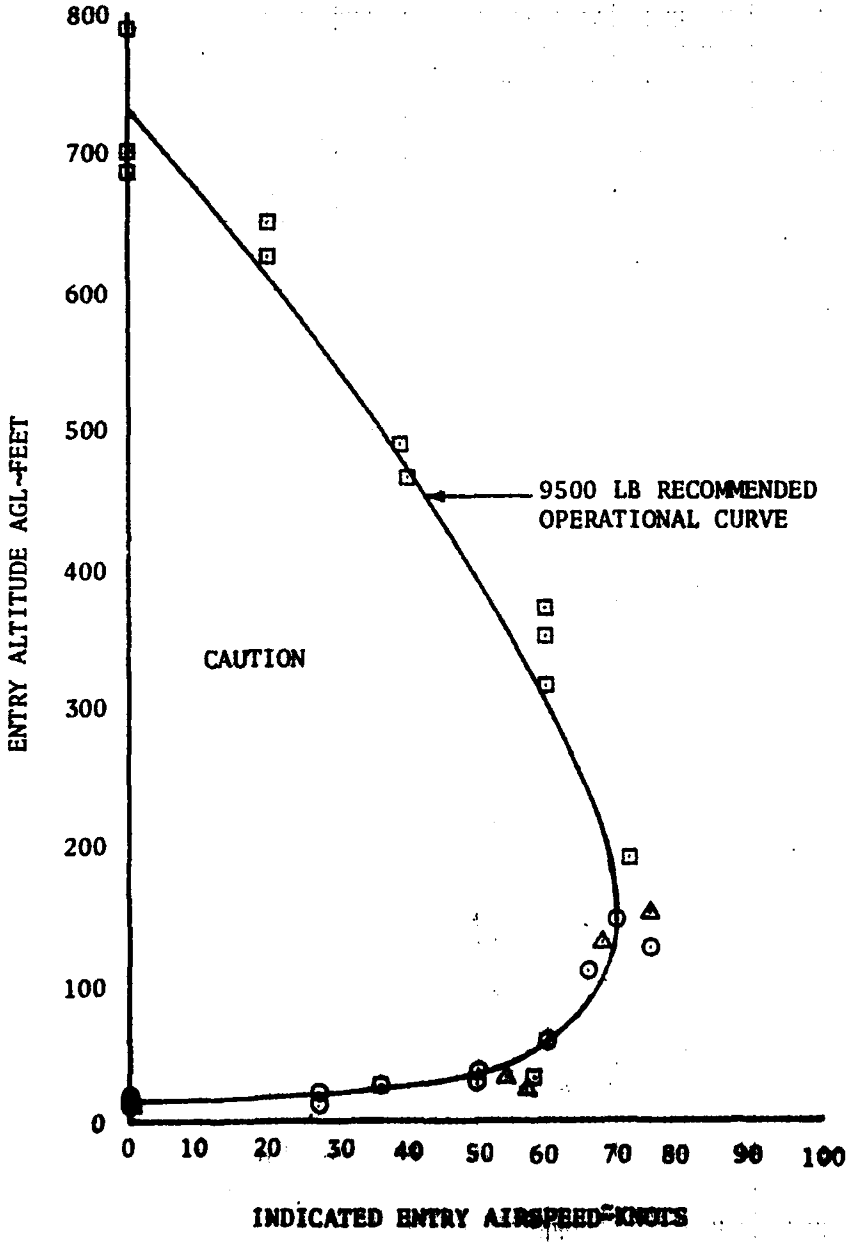


FIGURE 9

AH-1G RECOMMENDED OPERATIONAL HEIGHT
VELOCITY ENVELOPE

NOTE: 1. 8300 lb CURVE OBTAINED FROM FIGURE 15,
USAASTA REPORT NO. 69-13.
2. 9000 lb CURVE OBTAINED FROM FIGURE 7.
3. 9500 lb CURVE OBTAINED FROM FIGURE 8.

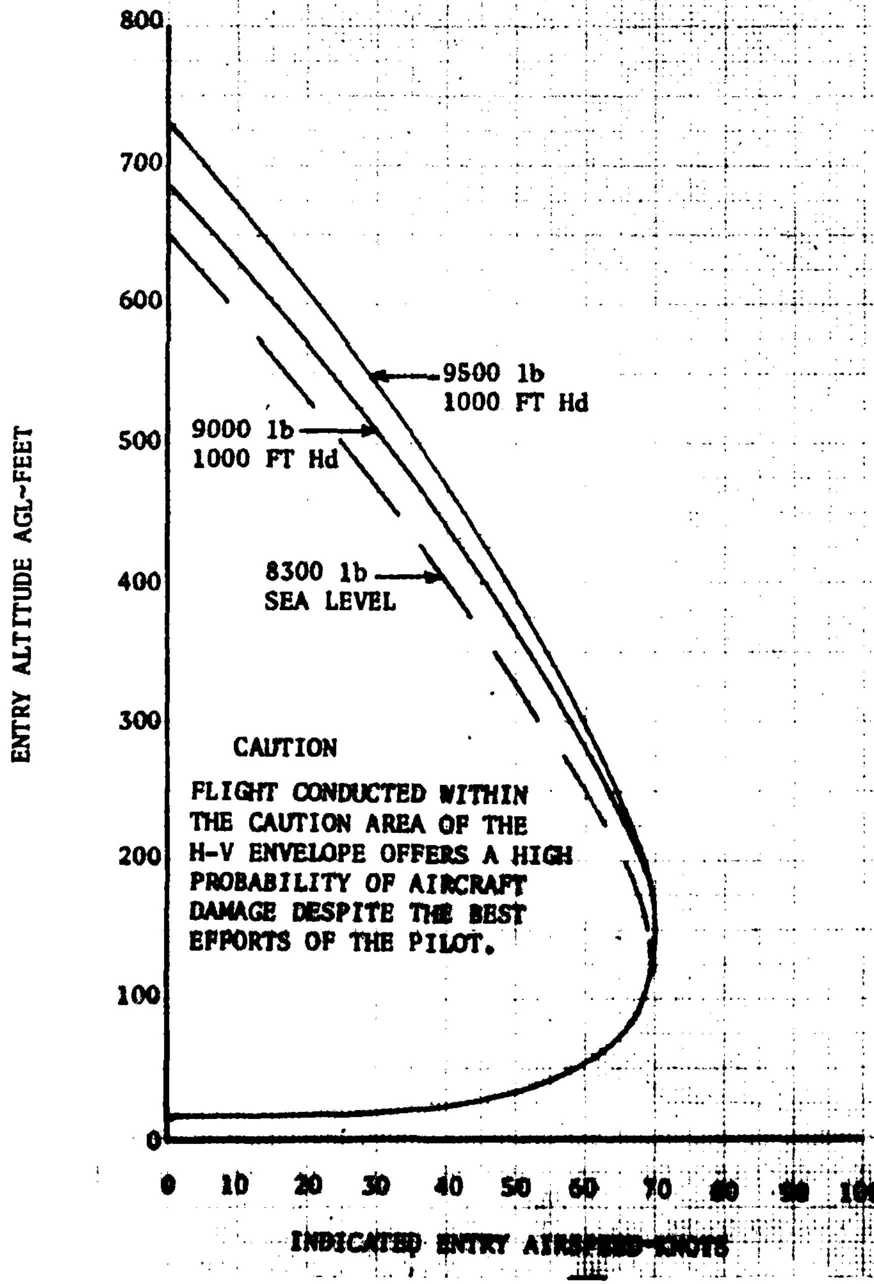
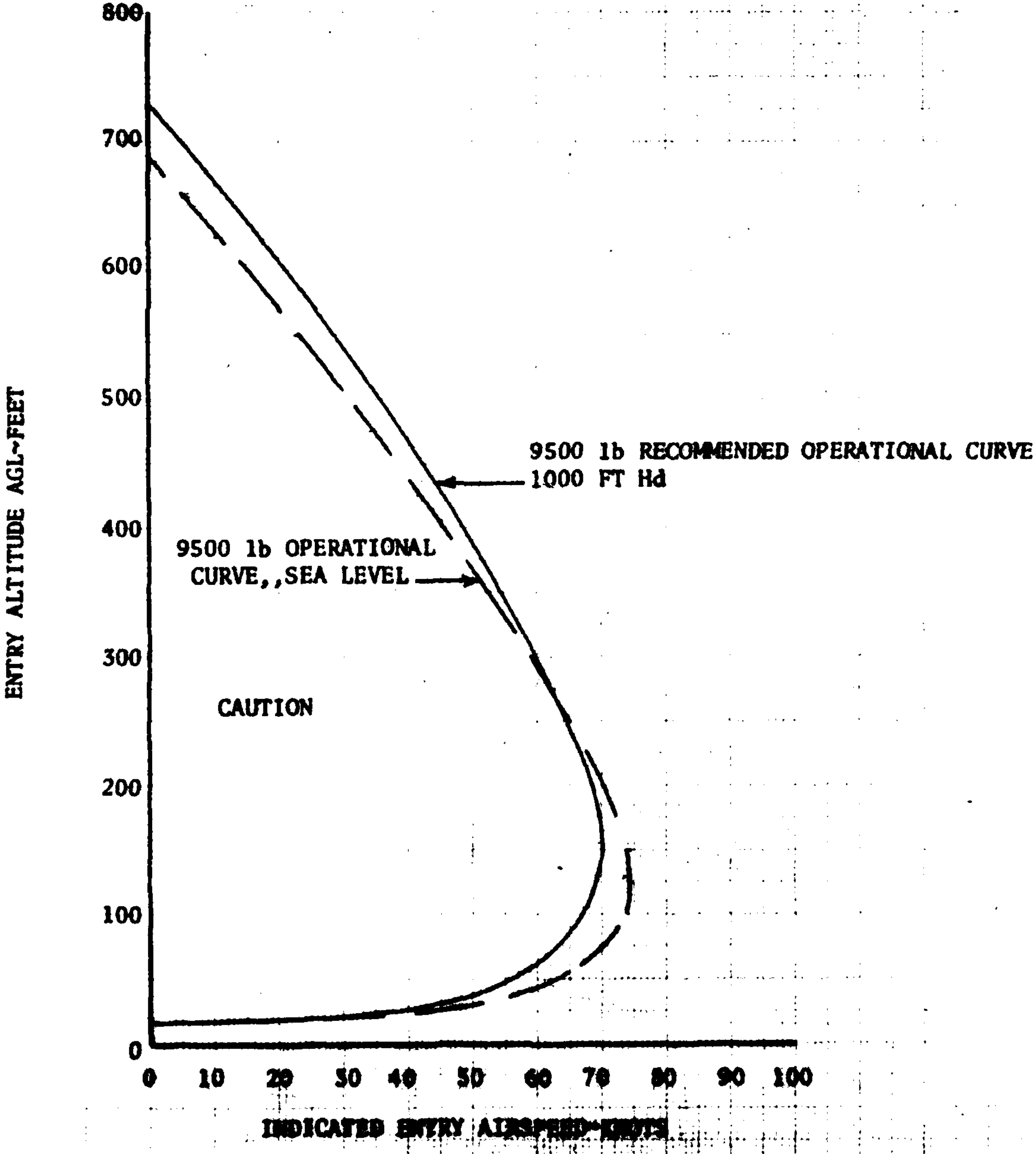


FIGURE 10

AH-1G OPERATIONAL HEIGHT VELOCITY COMPARISON

NOTE: 1. 9500 lb SEA LEVEL CURVE OBTAINED FROM FIGURE 7-4, TM55-1520-221-10.
2. 9500 lb 1000 FT Hd CURVE OBTAINED FROM FIGURE 8.



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