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ENGINEERING EVALUATION AH-56A COMPOUND HELICOPTER WITH ADVANCED MECHANICAL CONTROL SYSTEM

FINAL REPORT

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US ARMY
PROJECT PILOT

MARCH 1973



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UNITED STATES ARMY AVIATION SYSTEMS TEST ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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ABSTRACT

The United States Army Aviation Systems Test Activity conducted an engineering evaluation of the AH-56A compound helicopter with the advanced mechanical control system during the period 19 February to 14 March 1973 at Yuma Proving Ground, Arizona. This evaluation was primarily a handling qualities evaluation to determine the relative merits of the advanced mechanical control system versus the improved control system previously tested. The testing consisted of 20 test flights totaling 18.2 hours. The advanced mechanical control system corrected the major problem of the AH-56A with the improved control system. This problem was loss of aircraft control within the flight envelope resulting from blade moment stall. Some additional benefits of the advanced mechanical control system were a reduction in pilot workload during transition and elimination of the tendency for pilot-coupled roll oscillations, longitudinal trim shift with sideslip, and roll due to lift coupling. One deficiency identified during improved control system testing is still present. This deficiency is the inability to effectively perform low-speed low-level mission tasks below 120 knots calibrated airspeed under reduced visibility conditions due to the lateral-directional stability characteristics. There were four shortcomings identified, all of which existed with the improved control system. Other shortcomings identified during improved control system testing are still present but are not discussed in this report because of the limited scope of this evaluation.

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INTRODUCTION

BACKGROUND

1. The AH-56A is a compound helicopter designed for the Army by Lockheed Aircraft Corporation (Lockheed-California Company). The United States Army Aviation Systems Test Activity (USAASTA) conducted an Army Preliminary Evaluation (APE) and Research and Development Acceptance Test (RDAT) of the AH-56A helicopter (ref 1, app A). The USAASTA also conducted an evaluation of the AH-56A (ref 2) to support the Attack Helicopter Requirements Evaluation (AHRE) conducted by the United States Army Combat Developments Command. For all the above tests, the aircraft used (serial numbers 66-8831 and 66-8834) were configured with the improved control system (ICS). For this test, the aircraft (serial number 66-8832) was configured with the advanced mechanical control system (AMCS). The USAASTA was directed by the United States Army Aviation Systems Command (AVSCOM) to conduct an evaluation of the AH-56A with the AMCS (ref 3).

TEST OBJECTIVE

2. The objective of the AMCS evaluation was to conduct a handling qualities comparison to determine the relative merits of the AMCS versus the ICS.

DESCRIPTION

3. The AH-56A is a compound helicopter configured with a single main "rigid" rotor, a conventional antitorque tail rotor, a pusher propeller located at the aft end of the fuselage, and a wing located low on the mid section of the fuselage. The design concept allows the main rotor to be partially unloaded with lift provided by the wing and thrust supplied by the propeller during high-speed forward flight. The cockpit has a tandem seating arrangement with the pilot seat in the rear. The landing gear is of the conventional wheel type and is retractable. The AH-56A uses a single General Electric T64-GE-716 (ST) turboshaft engine which has a maximum power rating of 4275 shaft horsepower (shp) at sea-level, standard-day conditions.

4. The primary differences between the AMCS and ICS are in the methods of converting control gyro precession into main rotor cyclic pitch change and the methods of feeding back blade flapping signals to the gyro. In both control systems, the pilot cyclic control movement is transmitted mechanically to hydraulic servos which apply force, through springs, to the control gyro, causing it to precess. In the ICS, the gyro was connected directly to pitch arms on the main rotor blades. Therefore, gyro precession was transmitted mechanically to the rotor blades, causing pitch changes. The feedback to the gyro was through these same mechanical links,

which allowed feedback from blade flap, pitch, lead-lag, and other sources. The flapping feedback is desirable, but the other feedbacks caused handling qualities and rotor stability problems. The AMCS is designed to alleviate these problems by transmitting the gyro precession to irreversible hydraulic servos. These servos cause an angular displacement of the sliding spatial lever, which, in turn, results in cyclic blade pitch changes. The irreversible servos eliminate all feedback from the rotor to the gyro through the pitch change linkage. Since blade flapping feedback is stabilizing, a separate flapping feedback system is incorporated. An aircraft description, flight control description, and photographs are contained in appendixes B, C, and D, respectively.

SCOPE OF TEST

5. The AMCS testing was conducted at Yuma Proving Ground, Arizona (elevation 400 feet). During the test program, 20 flights were conducted for a total of 18.2 hours. The evaluation consisted of handling qualities tests which were conducted primarily at the conditions listed below. The flight restrictions and limitations are contained in the operator's manual (ref 4, app A) and the safety-of-flight release (app E).

- a. Density altitude: 5000 feet.
- b. Main rotor speed: 97.5 percent (100 percent is 246 rpm).
- c. Gross weight: 18,300 pounds.
- d. Center-of-gravity (cg) location: fuselage station (FS) 298.
- e. External configuration: clean (belly turret installed, no external stores).
- f. Collective blade angle: 13 degrees indicated (corresponds to +6 degrees with ICS) at 80 knots calibrated airspeed (KCAS) and above; as required below 80 KCAS.

METHODS OF TEST

6. Standard engineering flight test methods were used and are briefly discussed in the Results and Discussion section of this report. Test results were compared to the results of previous AH-56A tests (refs 1 and 2, app A). A Handling Qualities Rating Scale (HQRS) was used during evaluation of mission tasks (app F).

7. The test instrumentation on the aircraft was installed, calibrated, and maintained by the contractor. A detailed list of the instrumentation is presented as appendix G.

CHRONOLOGY

8. The chronology of the AH-56A AMCS evaluation is as follows:

Test request received	15	December	1972
Ground school began	8	February	1973
Ground school completed	14	February	1973
Flight testing began	19	February	1973
Flight testing completed	14	March	1973

RESULTS AND DISCUSSION

GENERAL

9. This evaluation of the AH-56A with the AMCS was primarily a handling qualities comparison. The AMCS corrected the major problem of the AH-56A with ICS, which was loss of aircraft control within the flight envelope resulting from blade moment stall. Some additional benefits of the AMCS were a reduction of the trim shifts during transition and elimination of the tendency for pilot-coupled roll oscillations (PCRO), longitudinal trim shift with sideslip, and roll due to lift coupling. One deficiency identified during ICS testing is still present. This deficiency is the inability to effectively perform low-speed low-level mission tasks below 120 KCAS under reduced visibility conditions due to the lateral-directional stability characteristics. There were four shortcomings identified all of which existed with the ICS. Other shortcomings identified during ICS testing are still present but are not discussed in this report because of the limited scope of this evaluation.

HANDLING QUALITIES

Control System Characteristics

10. The aft cockpit control breakout forces, force gradients, and ranges of travel were determined during ground tests with the rotors stationary and the No. 1A and No. 2 hydraulic systems pressurized. Control forces were measured at the center of the cyclic grip, the base of the pedals, and at the center of the propeller control twist grip on the collective lever. Breakout forces (including friction) were determined by recording the forces required to obtain initial movement of each control. Data from these tests are presented as figures 1 through 4, appendix H, and summarized in table 1.

11. The longitudinal control breakout forces and force gradients were essentially unchanged from those present during the AHRE testing (ref 2, app A). The control harmony has been improved by increasing the lateral force gradient and decreasing the pedal force gradient. The most significant improvement in the control feel system was the 5-pound-per-inch reduction in the pedal force gradient. The control system characteristics of the AH-56A with the AMCS are satisfactory.

Table 1. Control Breakout Forces and Force Gradients.

Test	Improved Control System Test Results ¹	Advanced Mechanical Control System Test Results
Longitudinal breakout	1.0 lb, aft, 1.5 lb, fwd	0.0 lb, aft 1.0 lb, fwd
Longitudinal gradient	3.2 lb/in.	3.5 lb/in., aft, 3.0 lb/in., fwd
Lateral breakout	1.0 lb	2.0 lb
Lateral gradient	1.4 lb/in.	2.1 lb/in., right, 2.5 lb/in., left
Pedal breakout	8.0 lb, right, 7.0 lb, left	8.0 lb, right, 7.0 lb, left
Pedal gradient	13.0 lb/in.	8.0 lb/in.
Collective breakout ²	7.5 lb	8.5 lb
Collective breakout ³	18.0 lb	27.0 lb

¹AHRE tests.

²Electric friction ON; mechanical friction minimum.

³Electric friction ON; mechanical friction maximum.

Sideward and Rearward Flight Characteristics

12. The sideward and rearward flight characteristics of the AH-56A with the AMCS were qualitatively evaluated to 35 knots true airspeed (KTAS), left and right, and 30 KTAS rearward. The propeller pitch control was held constant at the hover setting of -2.2 degrees. The aircraft was then slowly accelerated to the above speeds while tracking a calibrated ground pace vehicle. Rapid lateral accelerations and decelerations were not conducted. Collective pitch was used to maintain an approximate 20-foot height above the runway. The tests were conducted at an average gross weight of 18,410 pounds and an average density altitude of 1400 feet.

13. The large, sudden trim shifts in sideward flight, which were identified during ICS testing (refs 1 and 2, app A), were no longer present. The trim shifts which did occur within the envelope were not abrupt. Frequent and rapid pedal corrections were required to maintain heading; however, directional control margins were

adequate for the conditions tested. Lateral and longitudinal control requirements were normal for the direction of flight, that is, right lateral for right sideward flight, etc. There was no tendency to overcontrol in any axis while accelerating or decelerating. The handling qualities in sideward and rearward flight were qualitatively evaluated as satisfactory (HQRS 3).

Takeoff and Landing Characteristics

14. Takeoff and landing characteristics were evaluated at weights up to 19,200 pounds in winds of approximately 10 knots from various azimuths. The evaluation included lift-off to a hover and touchdown from a hover, hover takeoffs and landings, and rolling takeoffs and landings.

15. Characteristics during vertical lift-off or touchdown were unchanged from those seen in the AHRE testing with the ICS (ref 2, app A). There were no mechanical instabilities observed during the maneuver. Attitude control was positive with no tendency to overcontrol. The lift-off and touchdown required minimal pilot workload (HQRS 3).

16. Two methods of transition to forward flight from a hover were evaluated. The first method was a helicopter mode takeoff which consisted of applying collective control as desired to accelerate while keeping the propeller control constant at a propeller blade angle of +8 degrees to minimize propeller drag and power requirements (hover setting is -2.2 degrees). After accelerating through transition, collective blade angle was reduced to +13 degrees and the propeller blade angle was concurrently increased to that required for climb-out. The second method was the compound mode. This was accomplished by increasing propeller thrust while maintaining height with collective.

17. The two methods of hover takeoff are equally acceptable from the pilot workload and handling qualities standpoint. Neither method presented any significant problem and the sudden trim shifts present with the ICS (refs 1 and 2, app A) were more gradual with the AMCS. Additionally, the lateral trim shift during takeoff was reduced by approximately 50 percent with the AMCS. These improvements, plus the reduction of pedal force gradient (para 11) combine to reduce the pilot workload during transition to an acceptable level (HQRS 3). The overcontrolling and PCRO characteristics encountered during APE I testing (ref 1, app A) were evaluated by one of the APE I project pilots and no such tendencies were noted. The vibration characteristics during takeoff and landing are discussed in paragraph 49. The shortcoming associated with pilot workload during takeoffs, identified during ICS testing (refs 1 and 2), is no longer present.

18. Transition from forward flight to a hover was similar to transition from hover to forward flight. The trim shifts were easily corrected and the vibrations were annoying but acceptable. The slow rate of operation of the directional trim system, identified during the ICS testing (refs 1 and 2, app A), was no longer a shortcoming. The absence of sudden directional trim shifts reduced the requirement for a high trim rate.

19. Rolling takeoffs and run-on landings were made from a hard-surfaced runway. Rolling takeoffs were made by accelerating the aircraft to a lift-off speed of approximately 60 knots indicated airspeed (KIAS) using propeller thrust, with the collective at +7 degrees, and then increasing collective pitch to +13 degrees to become airborne. On lift-off, no abrupt attitude corrections were required and the pilot workload was minimal (HQRS 3). Run-on landings were conducted at speeds up to approximately 60 KIAS and were easily accomplished with minimal pilot workload (HQRS 3).

20. The takeoff and landing characteristics of the AH-56A with the AMCS were improved over the ICS. Except for the vibration level during transition (para 49), the takeoff and landing characteristics of the AH-56A with the AMCS are satisfactory.

Control Positions in Trimmed Forward Flight

21. Control positions in trimmed forward flight were determined through an airspeed range of 85 to 190 KCAS at a nominal gross weight of 18,500 pounds and at a nominal density altitude of 5000 feet. The data were obtained in level flight during the airspeed calibration (para 45). Main rotor collective blade angle was held fixed and zero sideslip was maintained during the test. The results of this test are presented in figure 5, appendix H.

22. The longitudinal trim changes with changes in airspeed were small and in the proper direction, forward trim with increasing airspeed. Attaining and maintaining a desired airspeed were not adversely affected by this small stick position gradient. There was essentially no directional trim shift throughout the airspeed range tested. The lateral trim change was very small from 85 to 125 KCAS and was approximately 0.5 inch left shift from 125 to 190 KCAS, which was not objectionable. The forward flight trim characteristics of the AH-56A with the AMCS are satisfactory.

Static Longitudinal Stability

23. The collective-fixed static longitudinal stability characteristics of the AH-56A with the AMCS were evaluated about trim airspeeds of 100 and 180 KCAS at an average gross weight of 18,500 pounds and at an average density altitude of 5740 feet with the longitudinal stability augmentor ON. Airspeed was stabilized in 10-knot increments above and below the trim airspeed by varying longitudinal cyclic control position. Main rotor collective blade angle and propeller blade angle were held fixed and zero sideslip was maintained during the tests. The results of the tests are presented in figures 6 and 7, appendix H.

24. Static longitudinal stability, as evidenced by the variation of longitudinal control position with airspeed, was slightly positive at both airspeeds tested. The static longitudinal stability (fig. A) of the AH-56A with the AMCS was improved at airspeeds above 170 KCAS as compared to the AH-56A with the ICS (refs 1 and 2, app A). The stick-free static longitudinal stability, as evidenced by the variation of longitudinal control force with airspeed, was positive at both airspeeds tested. The stick-free longitudinal stability (fig. A) was greatly improved over the AH-56A with the ICS (refs 1 and 2, app A). The static longitudinal stability characteristics with the longitudinal stability augmentor are satisfactory and the shortcoming identified during the ICS testing (refs 1 and 2) was no longer present.

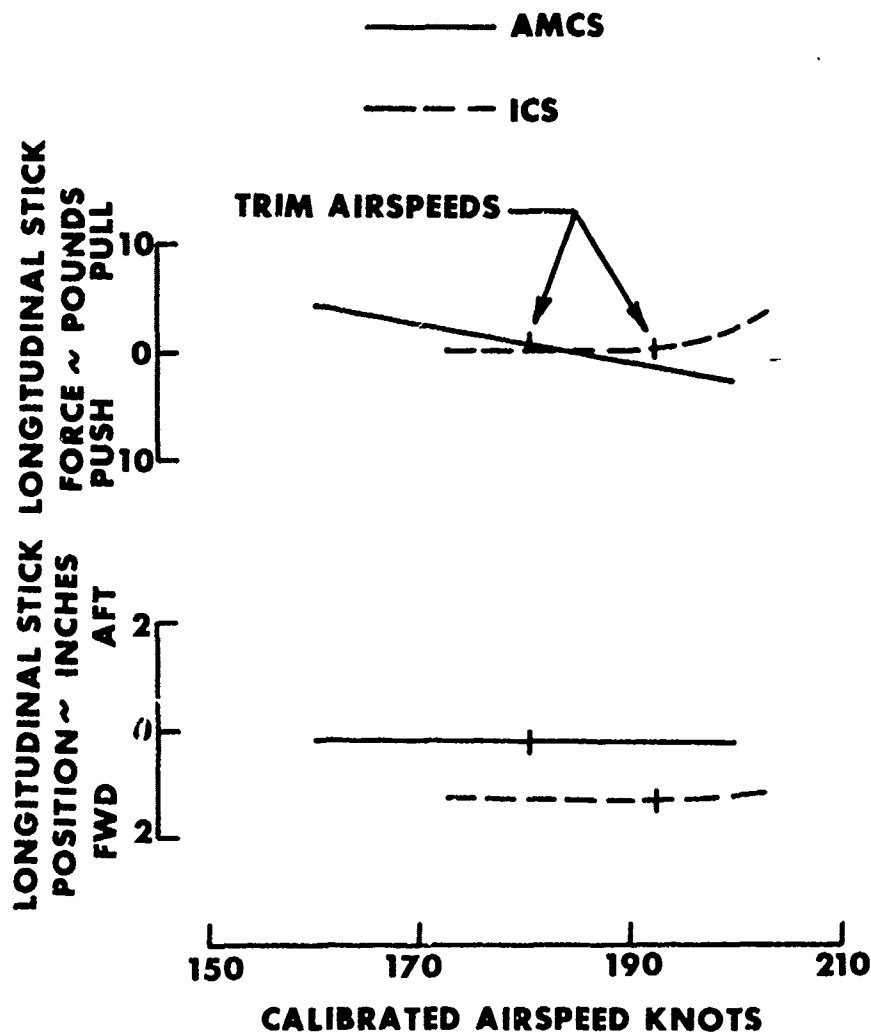


Figure A. Static Longitudinal Stability.

Static Lateral-Directional Stability

25. The static lateral-directional stability characteristics were evaluated quantitatively at trim airspeeds of 60 and 180 KCAS and qualitatively at a trim airspeed of approximately 120 KCAS at a nominal gross weight of 18,300 pounds and a nominal density altitude of 5000 feet. Tests at 60 KCAS were conducted with roll compensator (app C) ON and OFF. Sideslips were increased incrementally, left and right, from the zero sideslip trim condition while main rotor collective blade angle, propeller blade angle, airspeed, and trim settings were held fixed. The quantitative results of the tests are presented as figures 8 and 9, appendix H.

26. Static directional stability, as evidenced by the variation of directional control position with sideslip, was positive about zero sideslip at all airspeeds tested. Directional stability was weakest at 60 KCAS. Indicative of the poor directional stability was the difficulty experienced by the pilot in stabilizing on the desired sideslip angle. Excursions of ± 5 degrees without apparent pedal movement were common. The directional stability is essentially unchanged from that seen during testing of the AH-56A with the ICS (refs 1 and 2, app A). The weak directional stability below 100 KCAS required moderate pilot compensation to adequately control directional attitude (HQRS 4) is a shortcoming and should be corrected in future designs.

27. Dihedral effect, as evidenced by the variation of lateral control position with sideslip, was essentially neutral at 60 KCAS with the roll compensator OFF. With the roll compensator ON, dihedral effect at 60 KCAS was positive to 12.5 degrees sideslip, both right and left (limit of roll compensation). Beyond 12.5 degrees sideslip, it was the same as with roll compensator OFF. Dihedral effect was positive at 120 and 180 KCAS. The dihedral effect was slightly degraded from that seen during ICS testing (refs 1 and 2, app A).

28. Side force, as evidenced by the variation in bank angle with sideslip, was slightly positive at 60 KCAS, more positive at 120 KCAS, and strongly positive at 180 KCAS. The lack of adequate side-force cue to sideslip angle contributes to the difficulty in maintaining coordinated flight below 120 KCAS. The side-force characteristics of the AH-56A with the AMCS were improved as compared to those of the ICS during previous testing (refs 1 and 2, app A). However, maneuvering below 120 KCAS still required moderate pilot effort to maintain control of directional attitude to avoid large sideslip deviations (HQRS 5), is a shortcoming, and should be corrected in future designs.

29. The large longitudinal trim shift with sideslip, identified during ICS testing, was not in evidence during the AMCS testing. The small longitudinal trim shift with sideslip at 180 KCAS was not objectionable.

30. Aircraft handling difficulties which resulted from the lateral-directional stability characteristics became most evident during low-speed, nap-of-the-earth maneuvers. During the AMCS evaluation, nap-of-the-earth flight was conducted at airspeeds from 60 to 120 KCAS by two pilots who previously tested the AH-56A with the ICS. Large sideslip excursions caused spatial disorientation because the direction and magnitude of these excursions could not be immediately discerned due to the lack of normal sideslip cues. External cues were required to regain effective control of the aircraft attitude and flight path. During this test (conducted with good external visibility) external cues were available and the task could be performed. Under reduced-visibility weather conditions, where adequate external cues would not be available, this task could not be effectively performed. Although improvements have been made in the lateral-directional area, such as the elimination of the large longitudinal trim shifts with sideslip (para 29) and improvement in the control force harmony (para 11), the overall lateral-directional deficiency which was identified during the APE I and AHRE testing (refs 1 and 2, app A) still exists. The inability to effectively perform low-speed, low-level mission tasks below 120 KCAS under reduced-visibility weather conditions (HQRS 7), due to the static lateral-directional stability characteristics, is a deficiency which must be corrected in future designs.

Dynamic Stability

31. The short-period dynamic stability characteristics of the AH-56A with the AMCS were evaluated at airspeeds of zero, 60, 150, and 180 KCAS at a nominal gross weight of 18,600 pounds. Gust disturbances were simulated by making 1-inch, 1/2-second pulse inputs about the longitudinal and lateral axes. Following the control input, all controls were held fixed until the aircraft motions damped. Directional dynamic stability was qualitatively evaluated. Hover tests, at an approximate 15-foot wheel height, were conducted at a density altitude of 750 feet and forward flight tests were performed at an average density altitude of 5300 feet. Time history data for aft longitudinal pulse inputs at a hover and 180 KCAS are typical for the entire envelope and are presented as figures 10 and 11, appendix H. Time history data for right lateral pulse inputs at a hover and 180 KCAS are typical for the entire envelope and are presented as figures 12 and 13. The data show that the aircraft is well damped about both axes at all airspeeds. Qualitatively, the directional dynamic stability characteristics are satisfactory. The aircraft handling qualities in turbulent air have been greatly improved with the AMCS. The short-period dynamic stability characteristics of the AH-56A with the AMCS are satisfactory.

Controllability

32. The controllability tests were conducted in conjunction with dynamic stability tests. The tests were accomplished by stabilizing the aircraft at the test airspeed and making rapid step control inputs using an adjustable rigid control fixture to control the input size. Tests were conducted at airspeeds of approximately zero, 60, 150, and 180 KCAS at a nominal density altitude of 750 feet for hover and

5300 feet in forward flight. The aircraft configuration was clean at a nominal gross weight of 18,700 pounds. The test results are presented as figures 14 through 17, appendix H, and summarized in figures 18 and 19.

33. The longitudinal control response (maximum angular velocity per inch of control displacement) and sensitivity (maximum angular acceleration per inch of control displacement) were approximately constant throughout the airspeed range. The control response was 6 degrees per second per inch (deg/sec/in.) and the sensitivity was 9 deg/sec²/in. The longitudinal control response and sensitivity characteristics of the AH-56A with the AMCS are satisfactory.

34. The lateral control response was approximately constant at 16 deg/sec/in. and the lateral control sensitivity varied from 60 deg/sec²/in. at a hover to 53 deg/sec²/in. at 180 KCAS. There was no tendency to overcontrol laterally, a problem encountered during previous ICS tests. The lateral control response and sensitivity characteristics of the AH-56A with the AMCS are satisfactory.

35. Cross-coupling between the pitch and roll axes was encountered during ICS testing. This characteristic has been virtually eliminated with the AMCS.

Maneuvering Stability

Windup Turns:

36. Maneuvering stability was quantitatively evaluated at airspeeds of 80, 120, and 150 KCAS and qualitatively at airspeeds of 130 and 200 KCAS at a nominal gross weight of 18,400 pounds. The tests were accomplished by stabilizing at various bank angle and load factor combinations during left and right steady turns at a constant collective blade angle of 13 degrees. During the test, airspeed and propeller blade angle were held constant and zero sideslip was maintained. The data are presented as figures 20 through 22, appendix H.

37. Stick-fixed maneuvering stability, as evidenced by the variation of longitudinal control position with load factor, and the stick-free maneuvering stability, as evidenced by the variation of longitudinal control force with load factor, were both positive at all airspeeds tested out to the envelope limits (app E). The quantitative results at 80, 120, and 150 KCAS show the gradients to be essentially linear. The aircraft appeared stable throughout the envelope and no uncommanded aircraft motions were encountered. The loss of aircraft control within the flight envelope resulting from blade moment stall, identified during ICS testing as a deficiency (refs 1 and 2, app A), was no longer present. Additionally, the roll-due-to-lift coupling present with the ICS has been eliminated with the AMCS, as evidenced by the negligible lateral control position change with load factor. The maneuvering stability characteristics of the AH-56A with the AMCS are satisfactory.

Symmetrical Pull-ups and Pushovers:

38. The maneuvering characteristics required for terrain-following flight have received increasing attention and criteria have been established for the advanced attack helicopter. The AH-56A with the AMCS was tested using the method stated in USAASTA Final Report No. 71-32, *Utility Tactical Transport Aircraft System (UTTAS) Maneuvering Criteria* (ref 5, app A). The proposed UTTAS specification for USAASTA Project No. 71-32 was as follows:

From a level unaccelerated flight condition at 150 knots equivalent airspeed (KEAS), it shall be possible to attain, within 1.0 second from the initial control input, a sustained load factor of 1.75 in a symmetrical pull-up. Following this load factor buildup, it shall be possible to maintain a minimum load factor of 1.75 for 3.0 seconds after the initial attainment of 1.75. Airspeed at the end of the 1.75g, 3.0-second duration segment of the maneuver shall not be less than 130 KEAS. At no time during this maneuver shall it be necessary to change the main rotor collective control from that required for the initial level unaccelerated flight condition. Also, from a level unaccelerated flight condition at 150 KEAS, it shall be possible to attain, within 1.0 second from the initial control input, a sustained load factor of 0.0 in a pushover. Following the attainment of this load factor, it shall be possible to maintain a load factor of 0.0 for 2.0 seconds. At no time during this maneuver shall it be necessary to change the main rotor collective control from that required for the initial level unaccelerated flight condition. At no time during either the pull-up or pushover maneuvers described above shall angular deviations in roll and yaw, greater than ± 5 degrees from the initial unaccelerated level flight conditions, be permitted.

The AH-56A with the AMCS was tested between 155 and 180 KCAS and 0.25g and 2.5g. The results of the AMCS testing are presented as figures 2 through 26, appendix H.

39. Symmetrical pull-ups were initiated from unaccelerated level flight at an approximate airspeed of 180 KCAS. The maximum load factor achieved was 2.43g and the time required to achieve this maximum was approximately 2.1 seconds (fig. 23, app H). During this pull-up, the proposed specification load factor of 1.75 was attained at the end of approximately 1 second from the initial control input. This load factor was not sustained; however, load factors in excess of 1.75 were maintained for approximately 1.9 seconds. During subsequent maneuvers, load factors in excess of 1.75 were maintained for approximately 3.4 seconds (fig. 24, app H). During this maneuver the airspeed decrease was approximately 30 knots. Pitch attitude during the pull-up maneuvers did not exceed 30 degrees, nose up, and roll and yaw attitude deviations were negligible. Precise control of load factor required continuous longitudinal control changes.

40. Symmetrical pushovers were initiated from approximately 165 KCAS to preclude exceeding the never-exceed airspeed (V_{NE}). A typical time history (presented as fig. 25, app H) shows similar characteristics as pull-ups. During this maneuver, the minimum load factor achieved from the level flight entry was 0.28 and required approximately 2.5 seconds from initial control input. Because of the difficulty in precise load factor control, only 0.48g was maintained for the minimum of 2 seconds. Pitch attitude did not exceed 15 degrees, nose down, and as with pull-ups, roll and yaw attitude deviations were negligible.

41. The time histories (figs. 23 through 25, app H) show the difficulty in rapidly obtaining a given load factor, and then maintaining that load factor for 3 seconds. Although no instabilities were encountered, considerable pilot workload was required to perform this task, because a large initial longitudinal input was required to achieve the load factor within 1 second and this input was far in excess of that required to sustain the same load factor. The above figures also show that the AH-56A with the AMCS has the capability to perform the UTTAS maneuver (except that it is limited by the lower load factor envelope limit of 0.25g). During simulated terrain-following flight, where precise load factor control was not attempted or required, pitch attitude control was accomplished with minimal pilot effort (HQRS 3).

MISCELLANEOUS

Weight and Balance

42. The weight and balance of the test aircraft was determined prior to the start of testing. The aircraft was weighed with test instrumentation installed, external stores and pylons removed, and with no fuel on board. In this configuration, the aircraft weight and cg location were 15,743 pounds and FS 299.3, respectively.

Ground Operation Characteristics

43. The ground operation characteristics of the AH-56A with the AMCS are unchanged from those seen with the ICS during the AHRE testing (ref 2, app A). The only configuration change which affects ground handling is the presence of a parking brake in the AMCS test aircraft. The parking brake is effective for all normal run-up procedures for the AH-56A. The ground operation characteristics of the AH-56A with the AMCS are satisfactory.

Power Management

44. The power management workload of the AH-56A with the AMCS is no different from that seen with the ICS (refs 1 and 2, app A). There are still two limits to be monitored (engine torque and turbine inlet temperature) and two power controls during takeoff (collective and propeller controls). The pilot does have more time available during takeoff to devote to power management because of the improvement of the control trim shifts during transition (para 16). The high

workload during maximum power operations remained the same and is due to large changes in power which accompanied relatively small changes in propeller pitch at propeller blade angles above +28 degrees. The high power management workload, identified as a shortcoming during the ICS testing (refs 1 and 2, app A), is still present and should be corrected in future designs.

Airspeed System Calibration

45. The boom airspeed system on the AH-56A was calibrated using an F-51 calibrated pace aircraft. The data are presented as figure 26, appendix H, and show a nearly constant 4.5-knot position error from 80 to 200 knots. All airspeed data gathered during the AMCS evaluation were corrected using this calibration.

Vibration Characteristics

46. Vibration levels were qualitatively evaluated throughout the flight envelope with quantitative data obtained during unaccelerated (1.0g) flight only. The instrumentation available was not capable of measuring vibration data in accelerated flight. Vibration levels in the vertical and lateral directions were measured on the floor directly beneath both crew seats (app G). Single amplitude accelerations at main rotor harmonic frequencies of 1 cycle per rotor revolution (1/rev), 2/rev, 4/rev, and 8/rev, are presented as a function of airspeed for stabilized level flight airspeeds between 80 and 190 KCAS in figures 27 through 30, appendix H.

47. The 1/rev and 2/rev vibration levels were essentially zero at both locations in both axes measured. The measured 4/rev and 8/rev vibration levels were moderate (generally less than 0.2g) except for the 8/rev vertical vibration at the pilot station, which reached levels of nearly 0.4g. Even though the pilot seat was shock-mounted during these tests, the overall vibration environment during climbs and level flight at approximately 105 KCAS, and during level flight above 170 KCAS was annoying and is a shortcoming.

48. Measurement of vibration levels in accelerated flight was beyond the capability of the instrumentation. Qualitatively, the vibration levels increased with increased load factor and/or roll rate at high airspeeds (above 150 KCAS). The levels of vibration encountered would limit rapid high-speed maneuvering. The vibration levels during steady-state windup turns increased with load factor but were not severe because of the absence of high roll rates. The vibration environment during maneuvers with moderate-to-high roll rates at airspeeds above 150 KCAS was highly objectionable, constitutes a major shortcoming, and should be corrected in future designs.

49. The vibration levels were measured during all takeoffs and landings. Peak vertical vibration accelerations at the pilot station during takeoff were nominal, 0.15g for the helicopter mode and 0.13g for the compound takeoff. These vibrations were measured at the floor and do not reflect the vibrations felt by the pilot, since the seat is shock-mounted. The vibrations felt by the pilot were greater during the compound mode than during the helicopter mode. The uncomfortable vibration

characteristics during takeoff were essentially the same as those with the ICS during the AHRE testing (ref 2, app A), and remain a shortcoming which should be corrected in future designs.

50. The vibration characteristics of the AH-56A with the AMCS have improved when compared to the APE I testing (ref 1, app A) but have deteriorated when compared to the AHRE testing (ref 2). The major area of increased vibrations from the ICS during the AHRE was during maneuvers requiring moderate or high roll rates at high airspeeds (para 48). The vibration levels in the other flight regimes are slightly higher with the AMCS than during the AHRE testing. The vibration increase with the AMCS has adversely affected mission capability and should be corrected in future designs.

CONCLUSIONS

GENERAL

51. The AMCS has greatly improved the handling qualities of the AH-56A compound helicopter. The maneuvering envelope is greatly expanded, with no adverse control problems. The serious problems of blade moment stall, PCRO, and cross-coupling between the pitch and roll axes which were present with the ICS have been eliminated with the addition of the AMCS.

SPECIFIC

52. The following specific conclusions about the AH-56A with the AMCS were reached:

- a. The control system harmony has been improved and the control system characteristics are satisfactory (para 11).
- b. Sideward and rearward flight characteristics are satisfactory (para 13).
- c. Pilot-coupled roll oscillation tendencies have been eliminated (para 16).
- d. Except for the vibration levels during transition, the takeoff and landing characteristics are satisfactory (para 20).
- e. Forward flight trim characteristics are satisfactory (para 22).
- f. Static longitudinal stability characteristics are satisfactory (para 24).
- g. Dihedral effect has been slightly degraded (para 27).
- h. Side-force characteristics have been slightly improved (para 28).
- i. Longitudinal trim shift with sideslip has been eliminated (para 29).
- j. Handling qualities in turbulent air have been improved (para 31).
- k. Short-period dynamic stability characteristics are satisfactory (para 31).
- l. Longitudinal and lateral control response and sensitivity characteristics are satisfactory (paras 33 and 34).
- m. Roll-due-to-lift coupling has been eliminated (para 37).
- n. Maneuvering stability characteristics are satisfactory (para 37).

- o. Ground operation characteristics are satisfactory (para 43).
- p. Vibration levels in portions of the flight envelope have increased (para 50).
- q. One deficiency and four shortcomings were identified.

DEFICIENCY AND SHORTCOMINGS AFFECTING MISSION ACCOMPLISHMENT

53. Correction of the following deficiency, the inability to effectively perform low-speed, low-level mission tasks below 120 KCAS under reduced-visibility weather conditions due to the lateral-directional stability characteristics (HQRS 7), is mandatory (para 30).

54. Correction of the following shortcomings is desirable:

- a. Objectionable vibration levels in portions of the flight envelope (paras 47, 48, and 49).
- b. Weak directional stability below 100 KCAS (HQRS 4) (para 26).
- c. Poor side-force characteristics below 120 KCAS (HQRS 5) (para 28).
- d. High power management workload during maximum power operations (para 44).
- e. Additional shortcomings identified during ICS testing (refs 1 and 2, app A) are still present but are not discussed in this report because of the limited scope of the evaluation.

RECOMMENDATIONS

55. The deficiency must be corrected in future designs (para 53).
56. The shortcomings should be corrected in future designs (para 54).

APPENDIX A. REFERENCES

1. Final Report, USAASTA, Project Nos. 70-02 and 71-17, *Army Preliminary Evaluation I and Research and Development Acceptance Test I, AH-56A Cheyenne Compound Helicopter*, March 1972.
2. Final Report, USAASTA, Project No. 72-08, *Attack Helicopter Evaluation, AH-56A Cheyenne Compound Helicopter*, June 1972.
3. Letter, AVSCOM, AMSAV-EFT, 15 December 1972, subject: USAAVSCOM Test Request No. 72-44, AH-56A Advanced Mechanical Control System Evaluation.
4. Preliminary Operational/Maintenance Manual, POMM 15-1520-222-10, *Operator's Manual, Helicopter, Attack, AH-56A (Lockheed)*, July 1971, as amended February 1973.
5. Final Report, USAASTA, Project No. 71-32, *Utility Tactical Transport Aircraft System (UTTAS) Maneuver Criteria*, April 1972.

APPENDIX B. AIRCRAFT DESCRIPTION

GENERAL

1. The AH-56A is a two-place compound attack helicopter. Power is provided by a single General Electric T64-GE-716 (ST) engine rated at 4275 shp maximum at sea level on a standard day. The main rotor, pusher propeller, and tail rotor share the engine power. Lift is provided by a combination of the main rotor and the wings. The wings provide an increasing proportion of lift with increasing airspeed. Attitude control is accomplished by the main rotor and the tail rotor, as no control surfaces are built into the wings or empennage.
2. Distinctive features of the AH-56A include the rigid-type four-bladed main rotor, a tail-mounted pusher propeller, low wings, conventional retractable landing gear, and a vertical stabilizer mounted below the fuselage. Sponsons are mounted along each side of the fuselage and house fuel tanks, the retracted main landing gear, an auxiliary power unit, an environmental control unit, and the fueling station. The tail wheel retracts into the vertical stabilizer.
3. The cockpit provides tandem seating for the pilot and the copilot/gunner. The pilot flies the aircraft from the aft station and the copilot/gunner operates the swiveling gunner station (SGS) in the forward station.
4. Provisions are made for both internal and external armament in the design of the AH-56A. Internal armament consists of the XM52 area fire system in the belly turret and either the XM51 or XM53 suppressive fire system in the nose turret. Six external pylons are provided for carrying armed stores and/or external fuel tanks. The two fuselage pylons are equipped to carry fuel tanks. The four wing pylons may be used to carry a variety of combinations of stores, including TOW missiles, 2.75-inch folding-fin aircraft rockets (FFAR), or external fuel tanks. An optical display sight is provided for target acquisition and coarse target tracking. The computer central complex (CCC) provides ballistics corrections and prediction calculations for the weapons systems. The test aircraft was not configured with the weapons systems.

MAIN ROTOR

5. The four-bladed main rotor features blade articulation about the feathering axes only, hence is referred to as "rigid." The hub consists of fixed and movable portions. The fixed hub is attached solidly to the rotor mast while the four movable hub elements provide transition structure to the blade roots. Blade feathering motion is provided by a "door hinge" between the fixed and movable hub sections. Blade flapping and lead-lag motion are resisted by structural deflection of the blades and hub. The rotor blade cross section is of constant chord and varying thickness and section. Basically, the root section is a droop-nose modification of an NACA 23012 airfoil, while the tip section is a modified NACA 23006 airfoil.

6. The main rotor is controlled by a gyro which is in series between the rotor blades and the pilot cyclic control. The gyro is gimballed to the rotor mast, hence free to establish its own plane in space. When the blade flaps vertically, a moment is applied to the gyro through a mechanical feedback system. Rotor blade feathering is controlled by gyro tilt; this tilt (plane in space) is determined by the balance of moments caused by pilot control inputs, blade flapping, and gyro precession rates.

7. This arrangement is designated by Lockheed-California Company as a gyro-controlled rotor, and performs two functions: aircraft stability and rotor loads alleviation. The pilot flies the aircraft by his boosted inputs to the control gyro, which then precesses due to the gyro moment imbalance and inputs cyclic blade angle changes to the main rotor through hydraulic servos and sliding spatial lever linkage. When the main rotor is displaced by an external disturbance (such as a vertical gust) and flaps upward, the gyro imbalance due to the flapping moment signal will cause the gyro to precess, changing main rotor blade feathering to "wash out" the gust effects. By this stabilization of the rotor, the control gyro alleviates the rotor loads due to the gust. In addition, the gyro limits the rotor loads due to sudden abrupt cyclic inputs by the pilot, since rate of change of cyclic blade angle is limited by the gyro precessional rate due to the pilot input moment. A detailed description of the flight control system is contained in appendix C.

8. Principal main rotor characteristics are tabulated below:

Blade designation with tip weight	1019765
Fixed hub designation	1022533-101
Movable hub designation	1018578
Pitch arm designation	1022491-103
Built-in coning	2 deg
Shaft incidence	Zero deg
Number of blades	4
Airfoil section:	
Root	NACA (4.6) 3012 (mod)
Tip	NACA (0.6) 3006 (mod)
Radius	25.617 ft

Chord (all computations based on $c = 28$ in. (theoretical)):

Rotor station 79.12	27.50 in.
Rotor station 140.0 (linear taper)	27.60 in.
Rotor station 170.0 (between stations)	27.66 in.
Rotor station 302.4	27.89 in.
Rotor station 302.4 to tip	27.89 in.
Droop	1 deg, 53 min
Sweep	Zero deg
Disc area	2062 ft ²
Blade area	239.1 ft ²
Solidity	0.1159
Geometric twist, from center of rotation to rotor station 302.4	-5 deg
Tab location, rotor station at tab centerline	264.0
Tab size, equivalent	28.1 x 2.0 in.
Collective pitch range	4.5 to 20.8 deg
Normal rotor speed	239.85 rpm (97.5 percent)
Angular velocity	25.11 rad/sec
Normal tip speed	643 ft/sec
Blade inertia about 1/4 MAC	12,295.4 lb-in. ²

TAIL ROTOR

9. A four-bladed teetering antitorque rotor is mounted at the tip of the left horizontal stabilizer. The blades have a constant 14-inch chord with a slab-sided droop-nosed cross section. The thrust is inboard. Direction of rotation is clockwise when viewed from the left side of the ship looking inboard. Principal tail rotor characteristics are tabulated below.

Blade designation	1019380
Hub designation	1019381
Hub location (teeter center):	
Fuselage station	658.5
Water line	114.5
Buttline	72.0, left
Built-in coning	Zero deg
Number of blades	4
Airfoil section	NACA (0.675) 300 (5.89) modified
Radius	5 ft
Chord	1.167 ft
Disc area	78.5 ft ²
Theoretical blade area	23.3 ft ²
Solidity	0.297
Twist	Zero deg
Pitch range	-7.4 deg to 24.2 deg
Maximum allowable tilt	15 deg
Delta-three	37.5 deg
Normal rotor speed	1207 rpm (97.5 percent)
Angular velocity	126.4 rad/sec
Normal tip speed	632 ft/sec
Tail rotor moment arm	29.88 ft
Polar moment of inertia	12.6 slug-ft ²

PROPELLER

10. Longitudinal thrust is provided by a Hamilton Standard pusher propeller mounted at the rear of the fuselage. The propeller is capable of providing forward and reverse thrust. The direction of rotation is counterclockwise when viewed from behind the aircraft looking forward.

11. The pilot controls the propeller by using a twist grip located on the collective lever. The twist grip rotates approximately 130 degrees, corresponding to 52.8 degrees of blade angle change from -12.0 degrees to +40.8 degrees. The relationship is nonlinear, in that increased twist grip rotation is required at large blade angles (*ie*, 3:1 from 35 to 40 degrees of beta versus 2:1 from -10 to -5 degrees of beta).

12. An automatic system (delta beta) senses main rotor shaft torque and load factor to provide a reduction of propeller pitch to approximately +18 degrees or from reverse pitch to approximately -8.5 degrees to minimize rotor speed decay in case of an engine failure. Principal propeller characteristics are tabulated below:

Propeller designation	Hamilton Standard 1311 GB 30/11FA 10A4-0
Hub location:	
Fuselage station	675.7
Water line	114.5
Shaft incidence	Zero deg
Number of blades	3
Radius	5 ft
Activity factor per blade	142
Integrated design lift coefficient	0.411
Pitch range (physical limits at blade station 42)	-12.0 to 40.8 deg
Direction of rotation, viewed from rear	Counterclockwise
Normal propeller speed	1674 rpm (97.5 percent)
Angular velocity	175.3 rad/sec

Normal tip speed	876.5 ft/sec
Polar moment of inertia	13.98 slug-ft ²

WING

13. The wing is of trapezoidal planform and is mounted on the sponsons with the 0.25-percent mean aerodynamic chord (MAC) located at FS 308.2. Originally the section was a four-digit NACA airfoil, but early in the contractor development program additional wing area was added. This was accomplished by extending the wing trailing edge and providing transition fairings in the former aft wing region. The resulting section defies aerodynamic description. Principal wing characteristics are tabulated below:

Wing designation	1016648
Airfoil:	
Root, buttlene zero	12 percent
Tip, buttlene 160.2	8 percent
Area	195 ft ²
Span	26.7 ft
Aspect ratio	3.66
Mean aerodynamic chord	7.6 ft
Fuselage station at 1/4 MAC	308.2
Taper	0.50
Dihedral	5 deg
Incidence:	
Left wing	11 deg, 52 min
Right wing	12 deg, 58 min
Trailing edge deflection, right wing	1 deg, down

Twist:

Left wing	-3 deg, 6 min
Right wing	-3 deg, 2 min

HORIZONTAL STABILIZER

14. The horizontal stabilizer is mounted at the aft end of the fuselage and has a basically trapezoidal planform. The cross section of the stabilizer is a modified symmetric airfoil. The right stabilizer has tapering thickness. The left stabilizer is truncated in the chordwise direction, resulting in a bobtail appearance. Principal horizontal stabilizer characteristics are tabulated below:

Horizontal stabilizer designation:

Left side, Phase II reverse rotation	1019548
Right side	1000667

Airfoil:

Right panel:

Root, buttlene zero	NACA 0018 modified
Tip, buttlene 65.0	NACA 0012 modified

Left panel (highly modified, bobtailed)	NACA 0018
---	-----------

Area:

Left side	16.25 ft ²
Right side	15.58 ft ²
Total	31.83 ft ²

Span	10.83 ft
------	----------

Aspect ratio	3.68
--------------	------

Mean aerodynamic chord:

Left side	36.84 in.
-----------	-----------

Right side	35.40 in.
Average	36.12 in.
Fuselage station of 1/4 MAC:	
Left side	637.38
Right side	636.98
Average	637.18
Taper:	
Left side	0.583
Right side	0.568
Average	0.576
Dihedral	Zero deg
Incidence	2 deg
Twist	Zero deg
Deflection of right-hand trailing edge	2.8 deg, down

VERTICAL STABILIZER

15. The vertical stabilizer is mounted ventrally under the aft end of the fuselage. The cross section is an 18-percent symmetrical airfoil with no incidence relative to the fuselage centerline. The tail wheel is mounted within the lower end of the stabilizer and is retracted into the stabilizer in flight. Principal characteristics of the vertical stabilizer are tabulated below.

Vertical stabilizer designation, Phase II	1000594
Airfoil section:	
Root, water line 114.5	NACA 0018 modified
Tip, water line 37.6	NACA 0018 modified

Area, between water line 37.6 and water line 114.5	24.6 ft ²
Span	6.41 ft
Aspect ratio	1.67
Mean aerodynamic chord	3.92 ft
Location of 1/4 MAC:	
Fuselage station	620.3
Water line	79.4
Taper	0.587
Incidence	Zero deg

APPENDIX C. FLIGHT CONTROL DESCRIPTION

1. Conventional helicopter controls are provided, utilizing a cyclic stick for pitch and roll control, a collective lever for lift control, and pedals for directional control. The reversible pitch propeller is controlled by means of a twist grip mounted on the collective lever. Cyclic control input is transmitted by a hydraulic actuator to a positive spring. The spring converts the control displacement to a force that is transmitted to the control gyro as a moment, causing the gyro to precess. This precession, acting through another hydraulic actuator, causes an angular displacement of the sliding spatial lever (SSL) located inside the main rotor mast (at zero tilt of the SSL, the mast and SSL are coaxial). The upper end of the SSL is attached to a cruciform structure which is attached by pitch links to the four movable hubs. Therefore, an angular displacement of the SSL causes a cyclic blade angle change. Collective control movements are transmitted by a hydraulic servo to move the SSL vertically for collective pitch changes. Main rotor blade flapping is fed back mechanically through springs to the gyro, causing it to precess. The precession is in a direction which causes blade angle changes which relieve the flapping loads. Directional control displacements are transmitted hydromechanically to cause a change in tail rotor collective blade angle.

2. Trim and force feel systems are provided to allow selection of a trim position and to provide control forces when the control is displaced from the trim position. A maneuver gradient system (bobweight) is incorporated in the longitudinal feel system to improve the stick-free maneuvering stability. Additionally, a stability augmentor works through the longitudinal trim motor to increase the stick-free static longitudinal stability. The system senses airspeed and moves the longitudinal control trim position forward with decreased airspeed and aft with increased airspeed.

3. The lateral control system includes a stability augmentation system (SAS) designed to improve the apparent dihedral effect. The system senses airspeed and sideslip angle, and makes a lateral input through a modulation piston in the roll actuator. This has the effect of increasing the gradient of lateral cyclic versus sideslip angle. The airspeed scheduling is zero from a hover to 40 knots, increasing linearly to full gain at 60 knots and continuing at that level at higher airspeeds. Maximum authority of the system is reached at 12.5 degrees of sideslip and is equivalent to 1/2 inch of lateral control travel.

4. Principal control system characteristics are tabulated below.

Cyclic Control System

Gyro designation	1020 420-107
Gyro polar moment of inertia	1.5 slug-ft ²

Gyro diameter	26 in.
Gyro maximum tilt angle:	
Pitch-up	10.11 deg
Pitch-down	18.05
Right roll	12.27
Left roll	18.08
Control throw:	
Longitudinal	9.9 in.
Lateral	5.8 in.
Trim authority:	
Longitudinal	70 percent
Lateral	70 percent

Directional Control System

Pedal travel	6.4 in., total
Trim authority:	
Left pedal	100 percent
Right pedal	90 percent

Collective Control System

Control travel +4.5 to +21.5 deg
(+13 degrees collective pitch is equivalent to +6 degrees on the ICS)

APPENDIX D. PHOTOGRAPHS



Photo 1. Front View.



Photo 2. Front Quartering View.



Photo 3. Rear Quartering View.

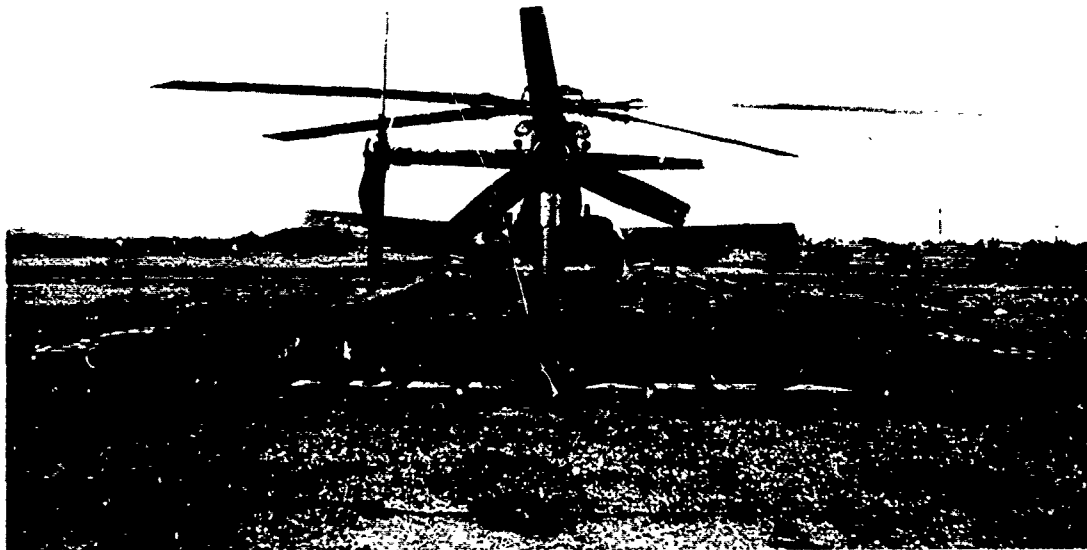


Photo 4. Rear view.

APPENDIX E. SAFETY-OF-FLIGHT RELEASE

This appendix contains the safety-of-flight release, amendments, and flight envelope for the AMCS evaluation of the AH-56A helicopter.



DEPARTMENT OF THE ARMY
HEADQUARTERS, US ARMY AVIATION SYSTEMS COMMAND
PO BOX 209, ST. LOUIS, MO 63166

AMSAV-EFA

13 Feb 73

SUBJECT: Safety-of-Flight Release for AH-56A AMCS Evaluation

Commander
US Army Aviation Systems
Test Activity
ATTN: SAVTE-P
Edwards AFB, Calif. 93523

1. Reference subject Safety-of-Flight Release, dated 9 Feb 73.
2. Revise the reference 1 Safety-of-Flight Release to incorporate the load factor-airspeed envelope forwarded herein as inclosure 1. This revision is in keeping with the basic flight release which permits density altitudes up to 7000 feet.

1 Incl
as

Charles C. Crawford, Jr.
CHARLES C. CRAWFORD, JR.
Chief, Flt Stds & Qual Div
Directorate for RD&E

LOAD FACTOR AIRSPEED ENVELOPE

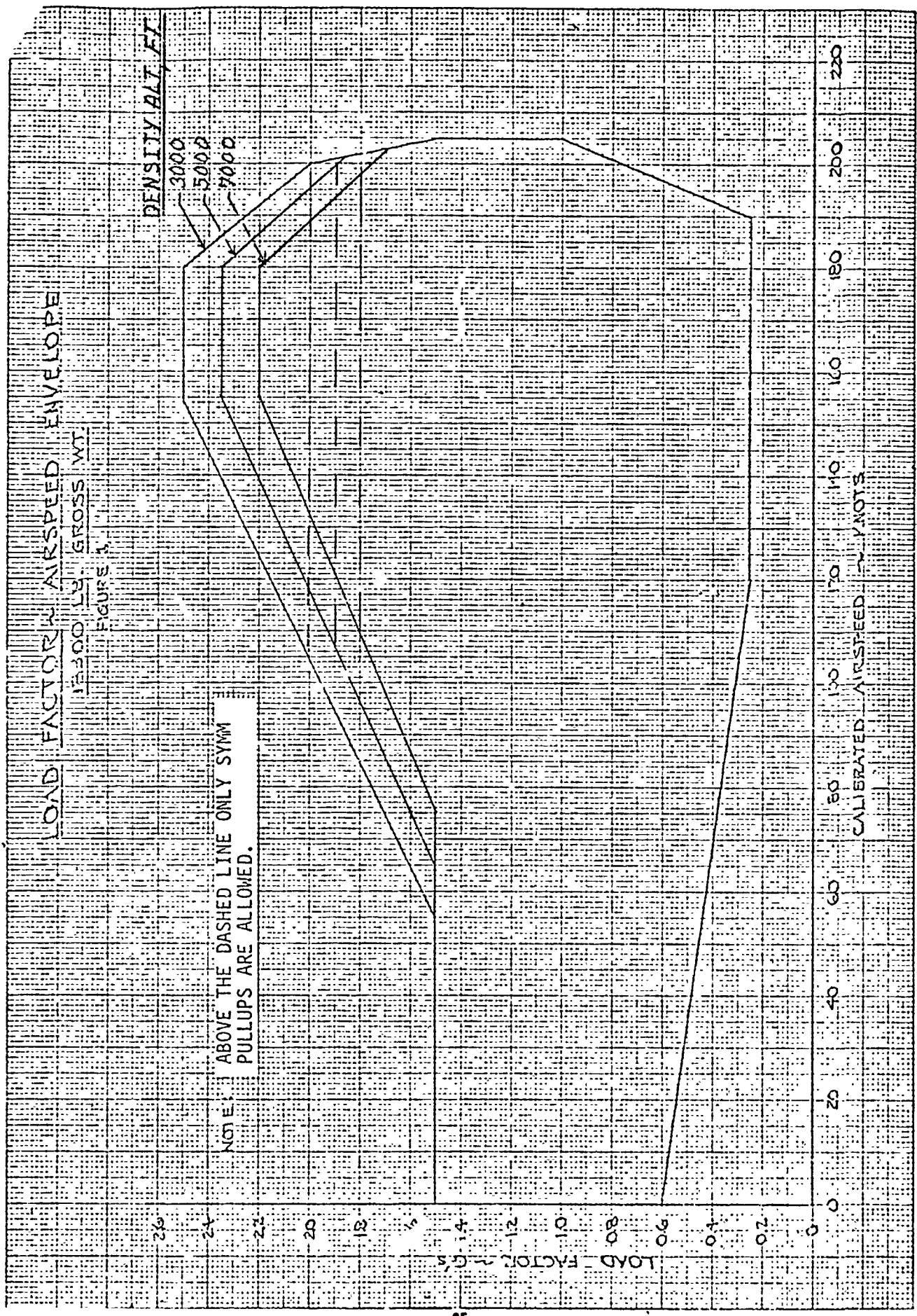
15,300 LB. GROSS WT.

FIGURE 1

DENSITY ALT. FT.

3000
5000
7000

NOTE: ABOVE THE DASHED LINE ONLY SYMM PULLUPS ARE ALLOWED.





DEPARTMENT OF THE ARMY
HEADQUARTERS, US ARMY AVIATION SYSTEMS COMMAND
PO BOX 209, ST. LOUIS, MO 63166

AMSAV-EF

9 February 1973

SUBJECT: Safety of Flight Release for AH-56A/AMCS Evaluation

Commander
US Army Aviation Systems
Test Activity
ATTN: SAVTE-P
Edwards AFB, California 93523

1. This flight release is contingent upon:
 - a. The airworthiness of all onboard flight test equipment and instrumentation being assured by safety inspections performed by USAASTA personnel.
 - b. The flight control systems being rigged in accordance with approved drawings and specifications.
 - c. A functioning radio link directly between ground communications and the test aircraft.
2. The operating limitations to be observed are those set forth in the document AH-56A, Chapter 7, Operating Limitations (AMCS), Issue of 15 Aug 72 (Revised 3 Feb 73), attached hereto as Incl 2 except as noted in the following paragraphs.
 - a. Airspeed Limitations
 - (1) Forward Flight. The maximum authorized gear up flight speed is shown in Figure 1, Incl 1.
 - (2) Side and Rearward Flight. The maximum authorized speed in sideward flight is 35 KTAS and in rearward flight is 30 KTAS.
 - (3) Autorotative Descent. Stabilized autorotative descent airspeed shall be limited to 85 to 95 knots calibrated airspeed.
 - b. Indicated Collective Blade Angle. Collective position is sensed and presented on a cockpit display in degrees. The authorized collective blade angles are:

AMSAV-EF

SUBJECT: Safety of Flight Release for AH-56A/AMCS Evaluation

(1) Power-On: As required from 0 to 80 KCAS and 13 degrees for airspeeds greater than 80 KCAS.

(2) Power-Off (Autorotation): 4.5 to 7 degrees.

c. Bank Angle Limitations.

(1) The maximum authorized transient bank angle is 70° , with load factor not exceeding that shown in Figure 1, Incl 1, for a discrete airspeed.

(2) The maximum authorized sustained bank angle as a function of airspeed will be commensurate with that permitted by the Load Factor Airspeed Envelope of Figure 1, Incl 1.

d. Sideslip Envelope. The maximum authorized sideslip as a function of calibrated airspeed is shown in Figure 2, Incl 1.

e. Practice/Intentional Autorotation. Practice autorotational landings are prohibited. All intentional autorotation descents will be terminated by powered flight at a safe altitude but in no case below 500 feet AGL.

f. Control Input Limits, Cyclic. With rotor turning, cyclic control input shall be limited to ± 2 inches during ground operations.

g. Load Factor. The authorized load factor airspeed envelope is shown in Figure 1, Incl 1.

h. Altitude Limits. Flight above 7000 feet density altitude is prohibited.

i. Gross Weight and C.G. Limits.

(1) Gross Weight - The maximum authorized gross weight is 19200 lb. (Test planned are for 18300 lb)

(2) C. G. - The authorized gear down CG limits are 298 ± 1 inch.

j. Rotor Speed Limits. Transient maneuvers, power on - 95% to 105% N_R , power off - 85% to 110% N_R .

k. Rotor Start/Stop Limits. Planned rotor starts or stops shall not be performed in winds in excess of 20 knots.

AMSAV-EF

SUBJECT: Safety of Flight Release for AH-56A/AMCS Evaluation

1. Touchdown Sink Rates. Touchdown sink rate shall not exceed 9.5 feet per second at 18,300 lb. (570 FPM).

m. Wind Limits. Flight operations shall not be conducted in winds in excess of 20 knots.

3. Emergency Procedures.

a. Checklist Emergency Procedures. The emergency procedures detailed in POMM 55-1520-22-10CL, (dtd Jan 73), Operator's and Crewmember's Checklist, for aircraft S/N 66-8832 shall be followed with special emphasis on:

- (1) Prop System Control Failure
- (2) Stick Centering Malfunction/Failure
- (3) Engine Control Failure

b. Additional Emergency Procedures. In-flight emergency egress from the cockpit should be out the right hand side to avoid possible contact with the tail rotor.

4. Cautions.

a. During pre-engine start system checks insure that the RPM set switch (N_r beeper) has been set in the DECR position for a minimum of five seconds.

b. Landing roll deceleration must be accomplished using reversed propeller thrust and main gear braking only. Aft cyclic inputs during ground operation can overstress main rotor control components or airframe structure.

c. Transmission oil pressure caution light may illuminate if the minimum maneuver load factor is exceeded. Such illumination should prompt the pilot to immediately increase load factor.

AMSAV-EF

SUBJECT: Safety of Flight Release for AH-56A/AMCS Evaluation


5. Limited Life Parts.

a. The maximum allowable operating times (MAOT) for fatigue critical component parts are as listed in the current AH-56A MAOT list.

b. USAASTA personnel shall assure that the special inspections indicated under the S.I. column of the MAOT list are performed at the intervals specified.

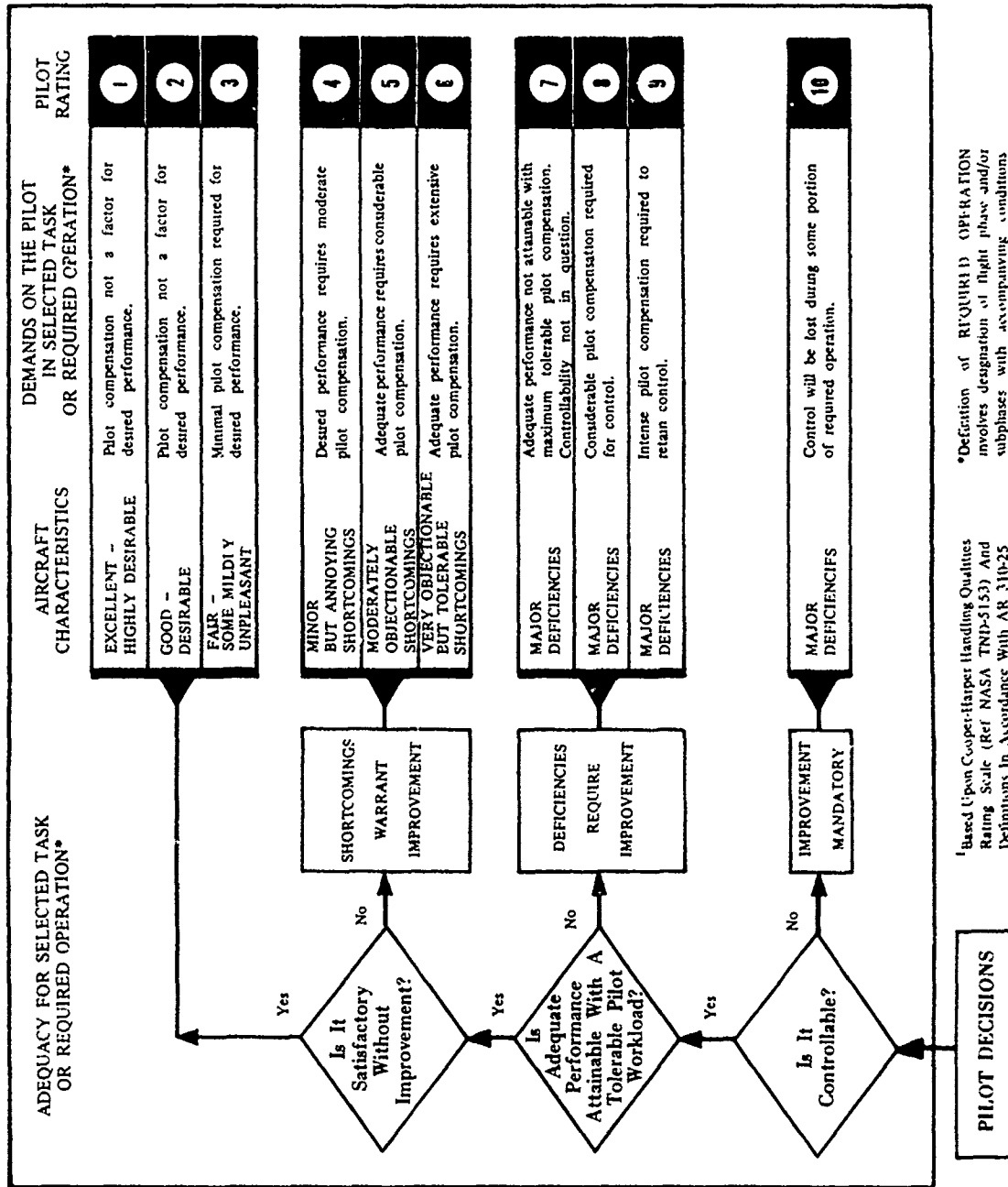
6. Preliminary Operator's Manuals. The helicopter shall be operated in accordance with the Preliminary Operator's Manual POMM 55-1520-222-10, dated 3 Feb 73, except that the operating limitations set forth in this flight release shall apply. The pilot's checklist POMM 55-1520-222-10CL, (dtd Jan 73), Operator's and Crewmember's Checklist, for aircraft serial number 66-8832, with annotated updating furnished by contractor, shall be used.

FOR THE COMMANDER:


CHARLES C. CRAWFORD JR
Chief, Flt Std & Qual Div
Directorate for RD&E

2 Incl
as

APPENDIX F. HANDLING QUALITIES RATING SCALE



*Definition of REQUIRED OPERATION involves designation of flight phase and/or subphases with accompanying conditions

Based Upon Cooper-Harper Handling Qualities Rating Scale (Ref NASA TNP-5153) And Definitions In Accordance With AR 310-25

APPENDIX G. TEST INSTRUMENTATION

GENERAL

1. All test instrumentation was installed, calibrated, and maintained by the contractor during this evaluation. Data were recorded on two oscillographs and a photographic automatic observer panel. Some data were hand recorded from two cockpit instrument panels. Additionally, 18 parameters could be monitored almost in real time via a telemetry link. In addition to structural and other parameters not specifically required for this evaluation, the following were included in the instrumentation package:

Oscillograph

- Main rotor blade angle
- Main rotor azimuth index
- Tail rotor torsion
- Tail rotor blade angle
- Propeller blade angle
- Longitudinal control position
- Lateral control position
- Collective control position
- Pedal position
- Longitudinal control force
- Pitch attitude
- Roll attitude
- Angle of sideslip
- Pitch rate
- Roll rate
- Yaw rate
- Center-of-gravity normal acceleration
(filtered at 2 Hz)
- Pilot event
- Engineer event
- Correlation counter
- Power turbine speed
- Vertical vibration at FS 170
 - Buttline (BL) zero, water line (WL) 98.5
- Lateral vibration at FS 173, BL 4, right; WL 99
- Vertical vibration at FS 130.5, BL 1, right; WL 80.5
- Lateral vibration at FS 130.5, BL zero, WL 82.5
- Left-hand stabilizer aft ring upper
attaching stringer
- Main rotor blade No. 1 flap bending
at station 174
- Collective servo ram force

Sliding spatial lever bending, arm No. 3
Sliding spatial lever bearing support torsion
Left-hand stabilizer aft fitting stress
Left-hand forward stabilizer stress
Fixed hub flap bending, No. 1 at station 18
Fixed hub chord bending, No. 1 at station 18
Fixed hub chord bending, No. 2 at station 18
Cyclic bearing support scissors load
Main rotor shaft bending (lower) at station zero
Main rotor No. 1 pitch link load
Main rotor blade No. 1 chord bending
at station 174
Main rotor blade No. 1 torque at station 131.5

Photopanel

Free air temperature
Turbine inlet temperature
Airspeed (boom)
Altitude (boom)
Time of day
Gas generator speed
Main rotor speed
Engine torque
Fuel totalizer
Correlation counter
Event lights

Pilot Panel

Attitude indicator
Directional gyro
Propeller blade angle
Engine torque
Turbine inlet temperature
Gas producer speed
Power turbine speed
Main rotor speed
Collective blade angle
Airspeed (boom)
Altitude (boom)
Center-of-gravity normal acceleration
Longitudinal control position
Lateral control position
Pedal position
Vertical speed indicator
Angle of sideslip
Fuel quantity

Pilot event
Engine oil temperature and pressure
Hydraulic oil pressure
 (systems 1, 1A, and 2)
Free air temperature
Correlation counter

Engineer Panel

Airspeed (boom)
Altitude (boom)
Rotor speed
Engine torque
Outside air temperature
Time of day
Engineer event
Correlation counter

TELEMETRY

2. A maximum of 18 parameters were transmitted for any one test via telemetry. Different parameters were used, depending on the type of test. Output was provided on a bar scope and oscilloscope in real time, and was recorded on oscillograph and magnetic tape.

APPENDIX H. TEST DATA

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FIGURE 1
 LONGITUDINAL STICK FORCES
 AH-56A USA S/N 66-8832

- NOTES:
- 1) Forces measured at center of grip
 - 2) Rotors stationary
 - 3) Number two hydraulic system operating
 - 4) Hydraulic and electric power provided by auxiliary power unit
 - 5) Full travel = 9.9 inches
 - 6) Stick centering off
 - 7) Lateral control centered

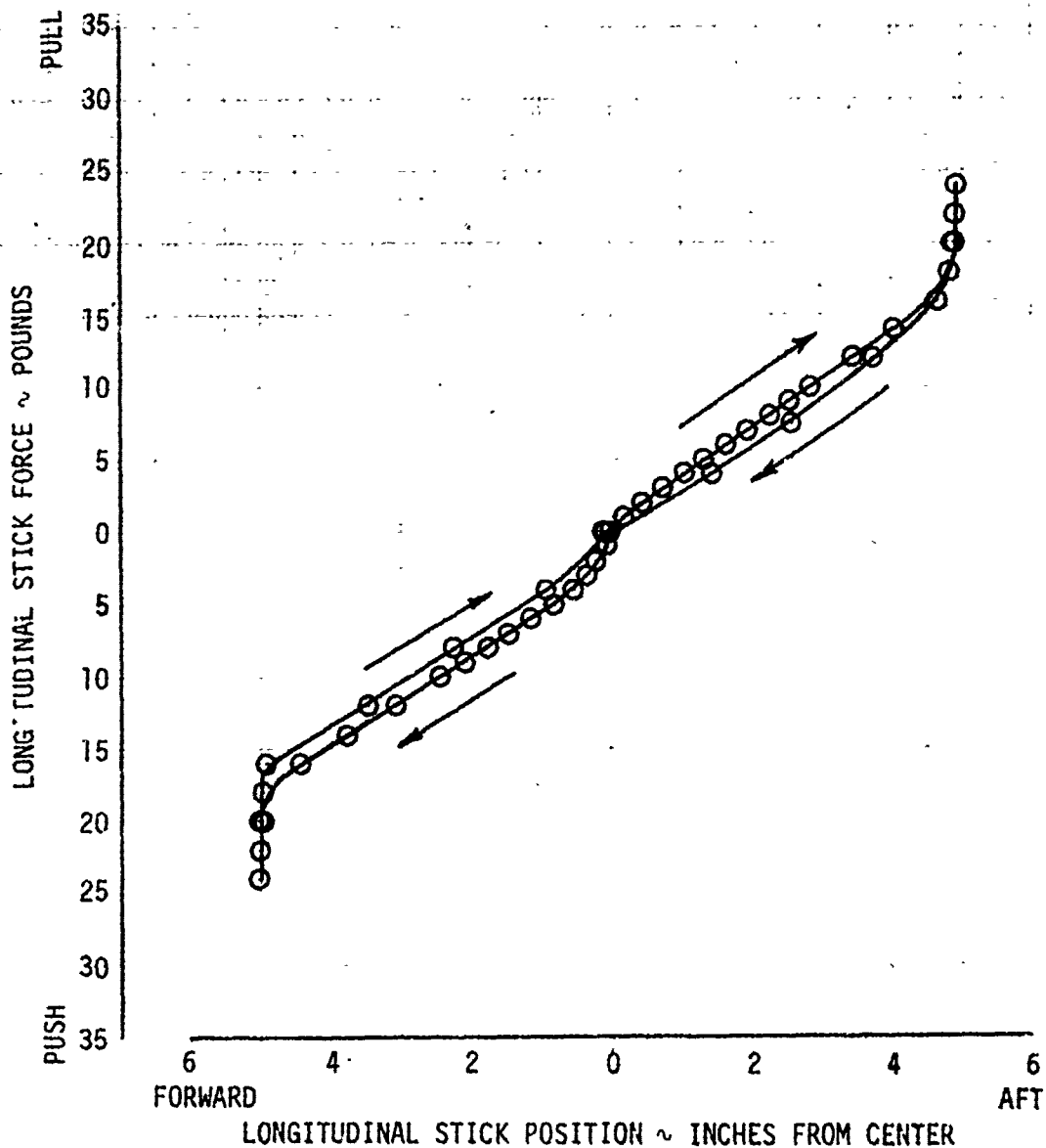


FIGURE 2
LATERAL STICK FORCES
 AH-56A USA S/N 66-8832

- NOTES: 1) Forces measured at center of grip
 2) Rotors stationary
 3) Number two hydraulic system operating
 4) Hydraulic and electric power provided by auxiliary power unit
 5) Full travel = 5.83 inches
 6) Stick centering off
 7) Longitudinal control centered

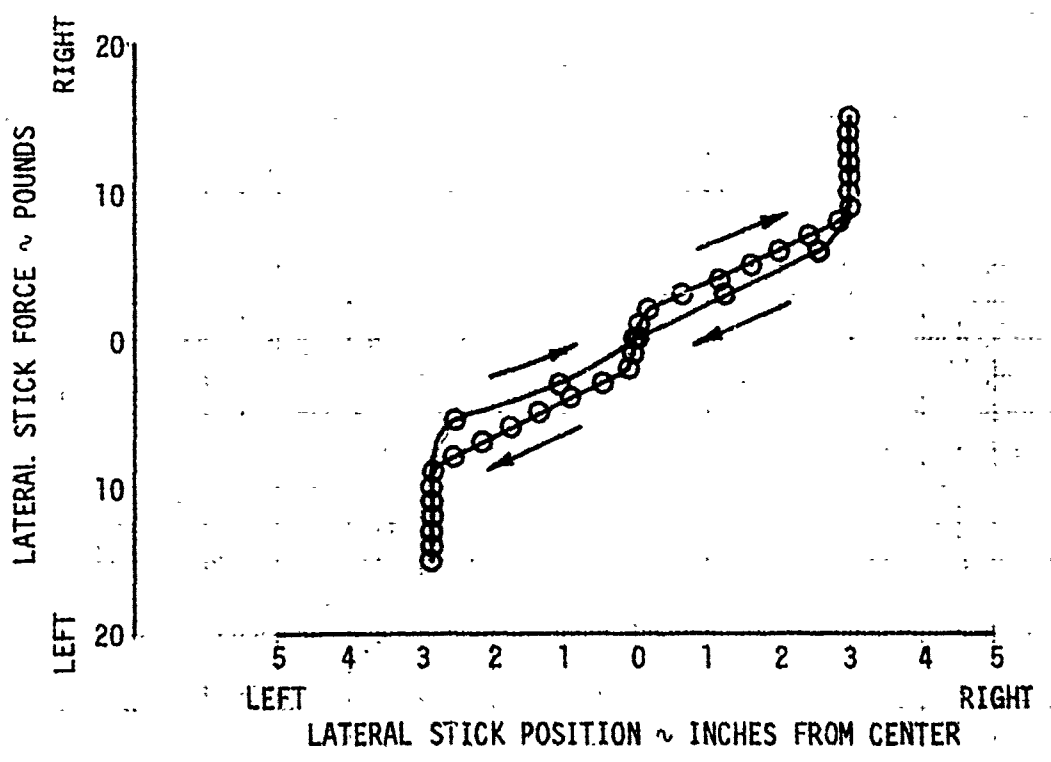


FIGURE 3
 PEDAL FORCES
 AH-56A USA S/N 66-8832

- NOTES: 1) Forces measured at base of pedals
 2) Rotors stationary
 3) Number two sydraulic system operating
 4) Hydraulic and electric power provided by auxiliary power unit
 5) Full travel = 6.35 inches

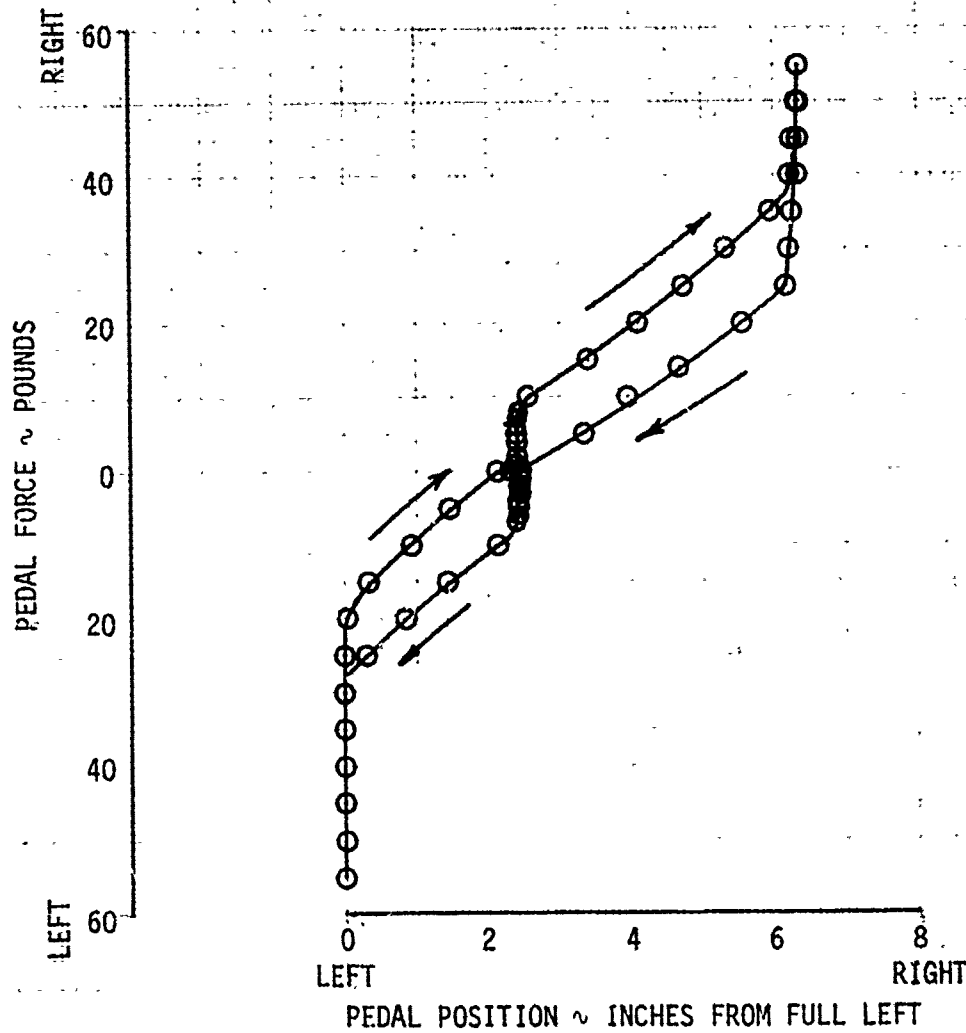


FIGURE 4
LIMITS OF CYCLIC STICK TRAVEL

AH-56A USA S/N 66-8832

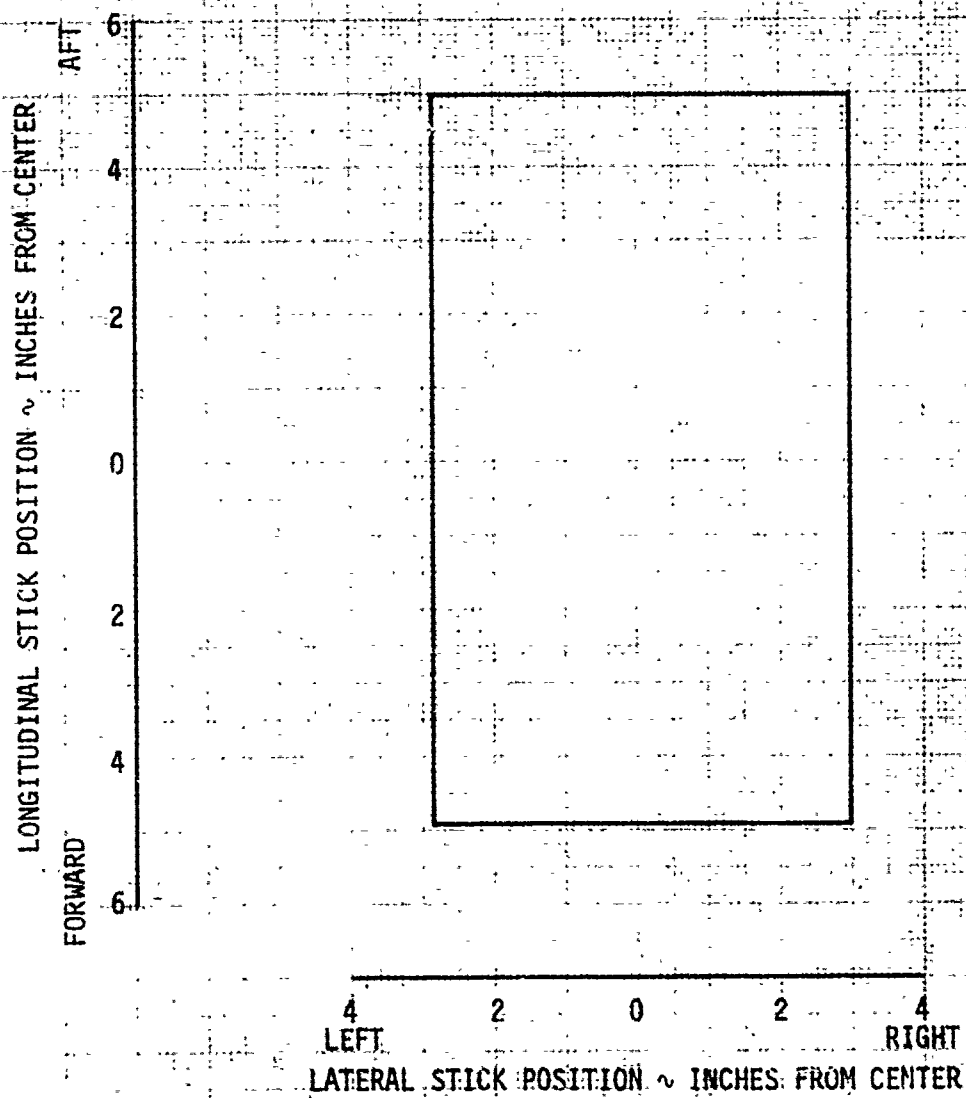


FIGURE 5
FORWARD FLIGHT TRIM REQUIREMENTS
 AH-56A USA S/N 66-8832

SYMBOL	AVG GROSS WEIGHT ~LB	AVG CG LOCATION ~IN	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	ROTOR SPEED ~RPM	COLL BLADE ANGLE ~DEG	CONFIGURATION
○	18500	298.6	4980	9	242	13	CLEAN (GEAR UP)

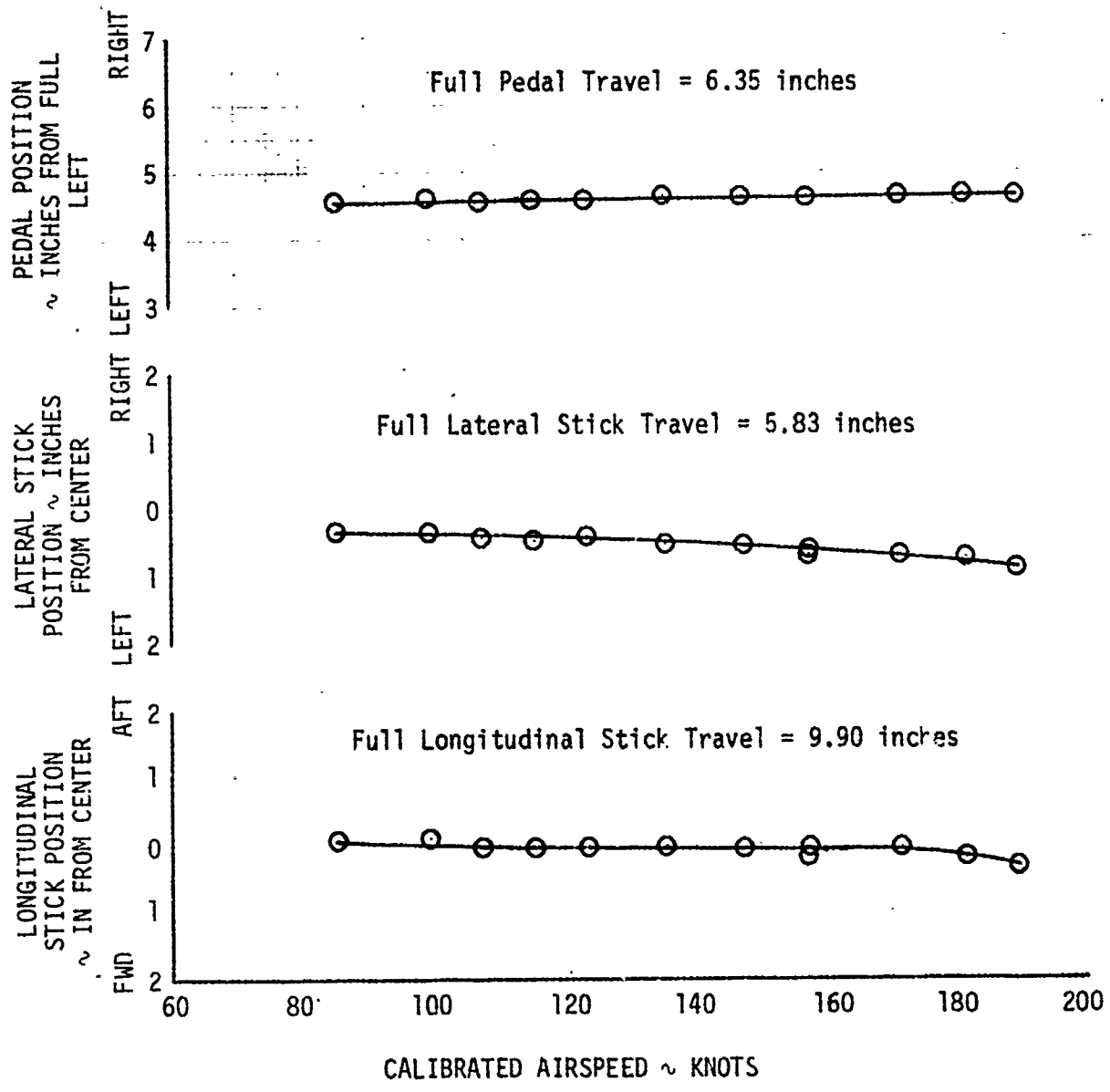


FIGURE 6
 STATIC LONGITUDINAL STABILITY
 AH-56A USA S/N 66-8832

AVG GROSS WEIGHT ~ LB	AVG CG LOCATION ~ IN	AVG DENSITY ALTITUDE ~ FT	AVG OAT ~ °C	ROTOR SPEED ~ RPM	COLL BLADE ANGLE ~ DEG	CONFIGURATION
18500	298.4	5740	7	240	13	CLEAN (GEAR UP)

NOTE: SHADED SYMBOLS DENOTE TRIM POINTS

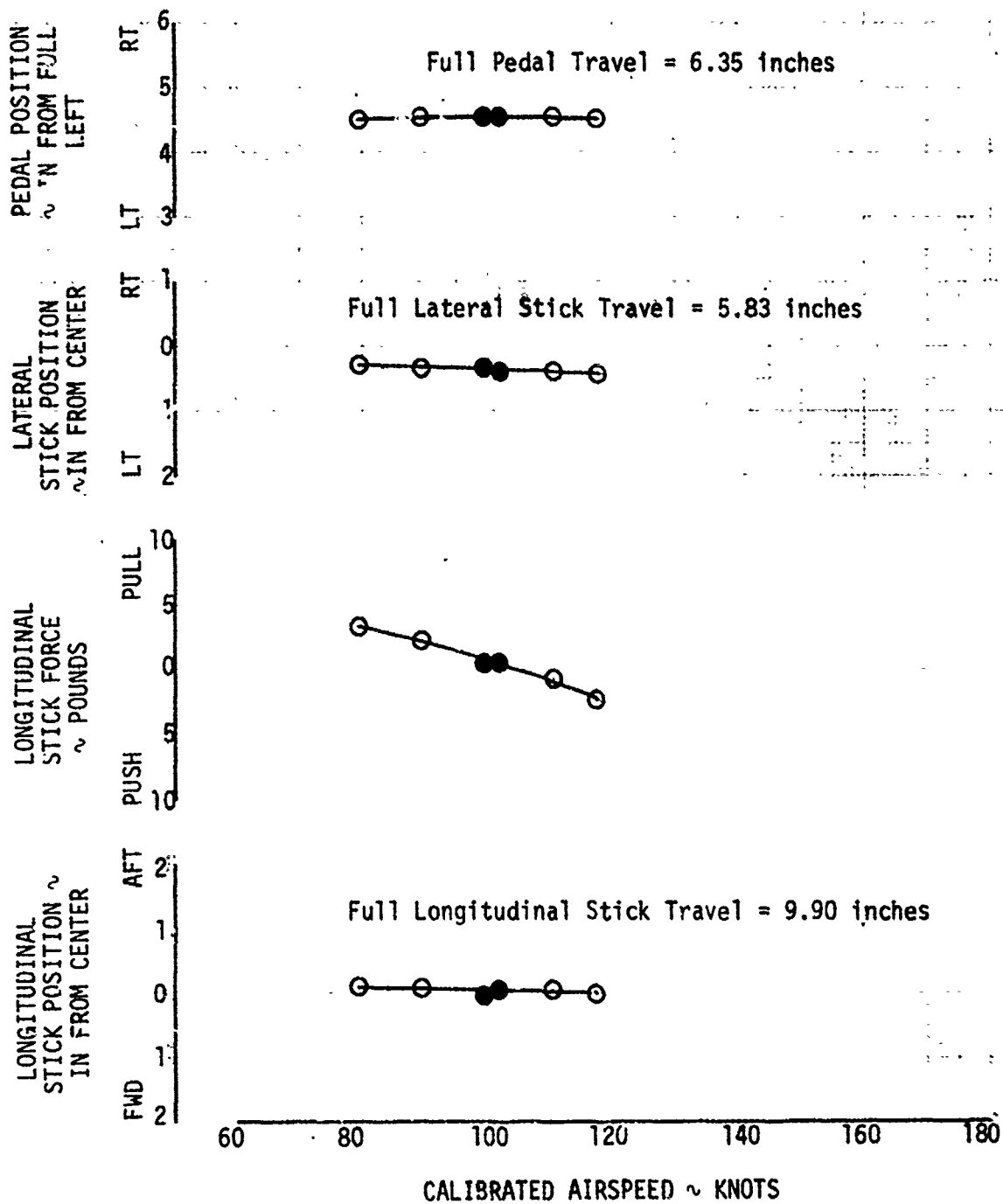


FIGURE 7
STATIC LONGITUDINAL STABILITY
AH-56A USA S/N 66-8832

AVG GROSS WEIGHT ~ LB	AVG CG LOCATION ~ IN	AVG DENSITY ALTITUDE ~ FT	AVG OAT ~ °C	ROTOR SPEED ~ RPM	COLL BLADE ANGLE ~ DEG	CONFIGURATION
18500	298.4	5740	7	240	13	CLEAN (GEAR UP)

NOTE: SHADED SYMBOLS DENOTE TRIM POINTS

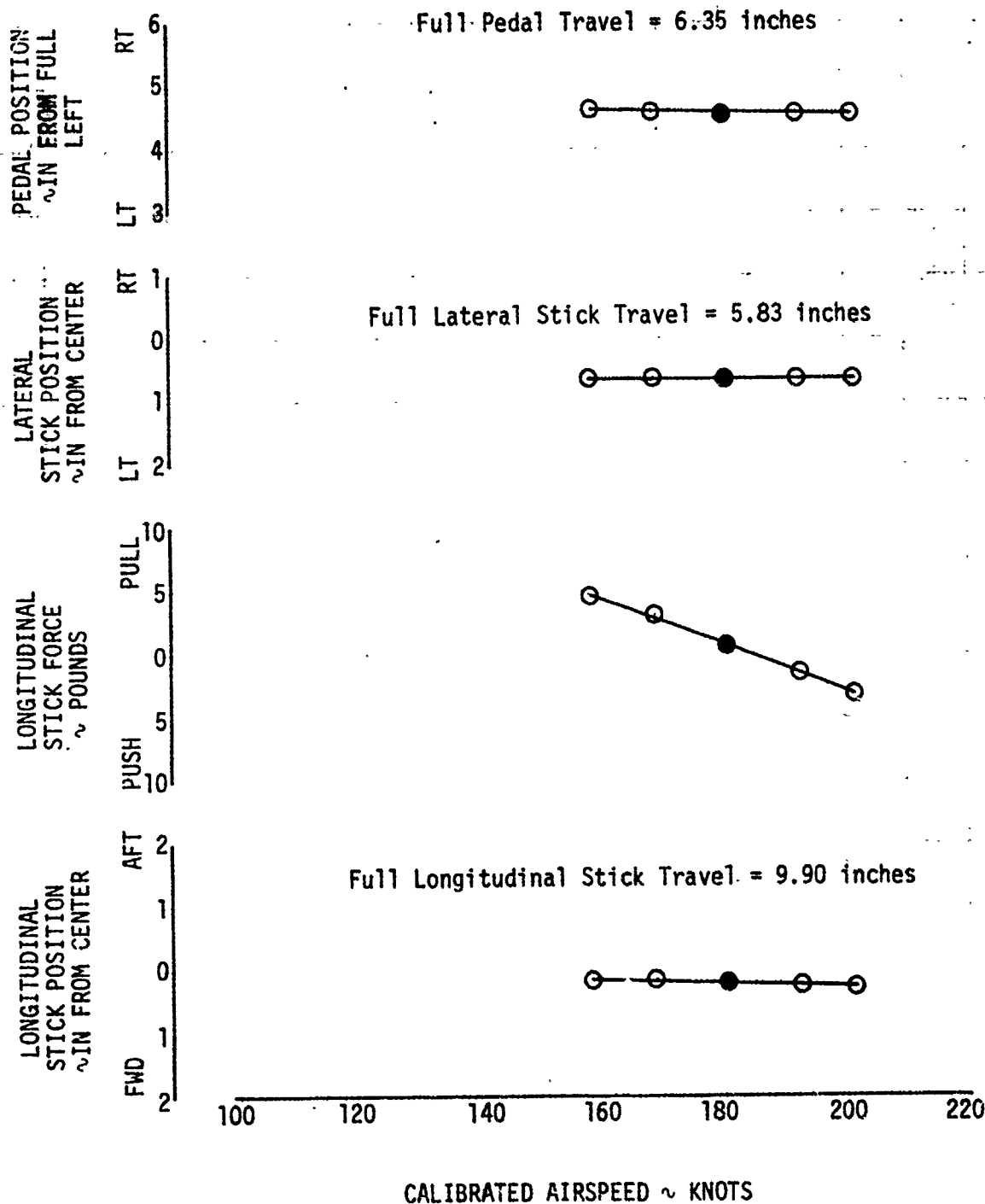


FIGURE 8
STATIC LATERAL-DIRECTIONAL STABILITY
 AH-56A USA S/N 66-8832

AVG GROSS WEIGHT ~LB	AVG CG LOCATION ~IN	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	ROTOR SPEED ~RPM	COLL BLADE ANGLE ~DEG	CALIB AIRSPEED ~KT	CONFIGURATION
18650	297.5	5030	1	239	17	60	CLEAN (GEAR DOWN)

NOTES: 1. SHADED SYMBOLS DENOTE TRIM POINTS
 2. SQUARES DENOTE ROLL COMPENSATOR OFF.

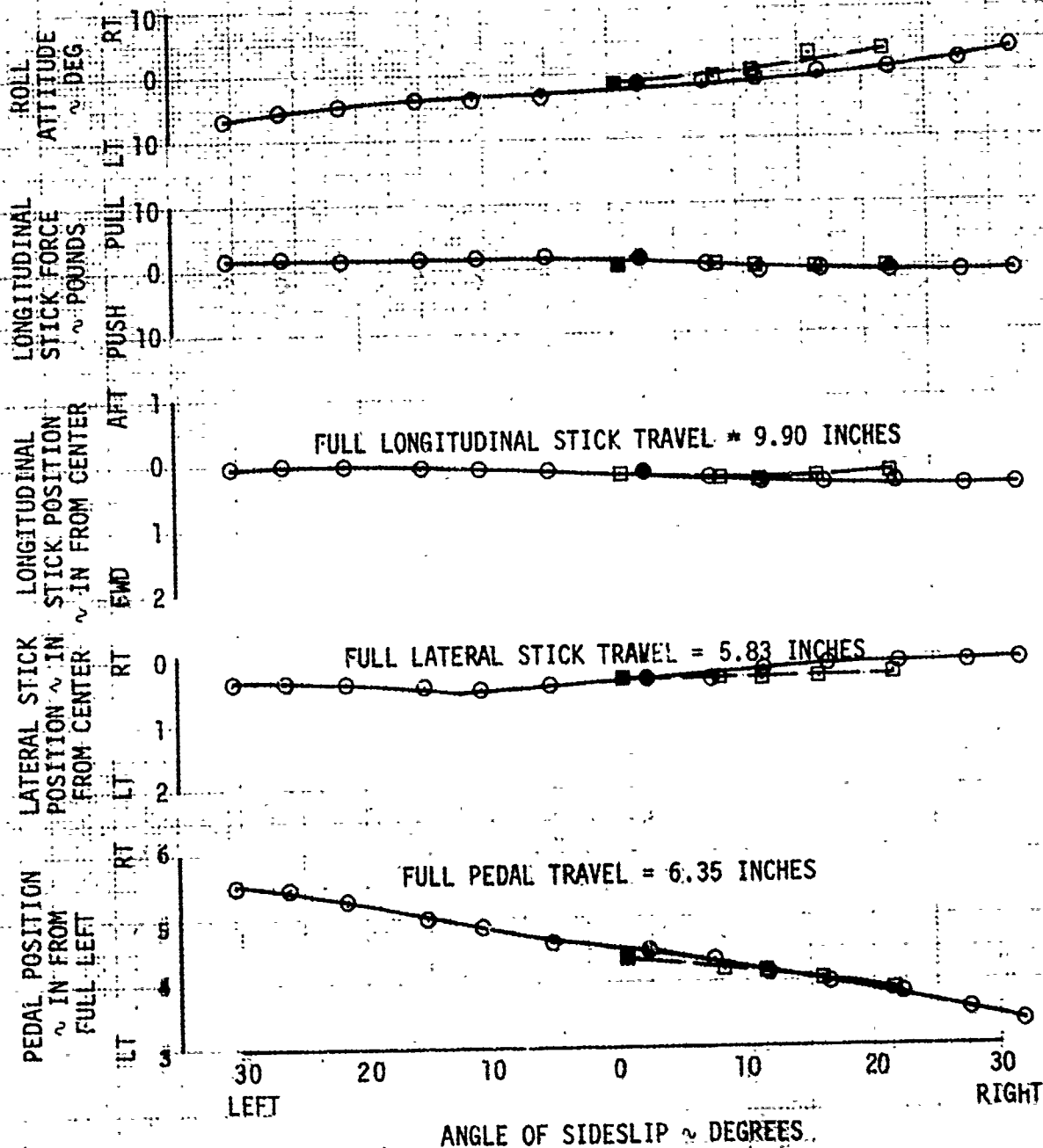


FIGURE 9
STATIC LATERAL-DIRECTIONAL STABILITY
 AH-56A USA S/N 66-8832

AVG GROSS WEIGHT ~LB	AVG CG LOCATION ~IN	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	ROTOR SPEED ~RPM	COLL BLADE ANGLE ~DEG	CALIB AIRSPEED ~KT	CONFIGURATION
18050	298.2	5450	7	240	13	180	CLEAN (GEAR UP)

NOTE: SHADED SYMBOLS DENOTE TRIM POINTS

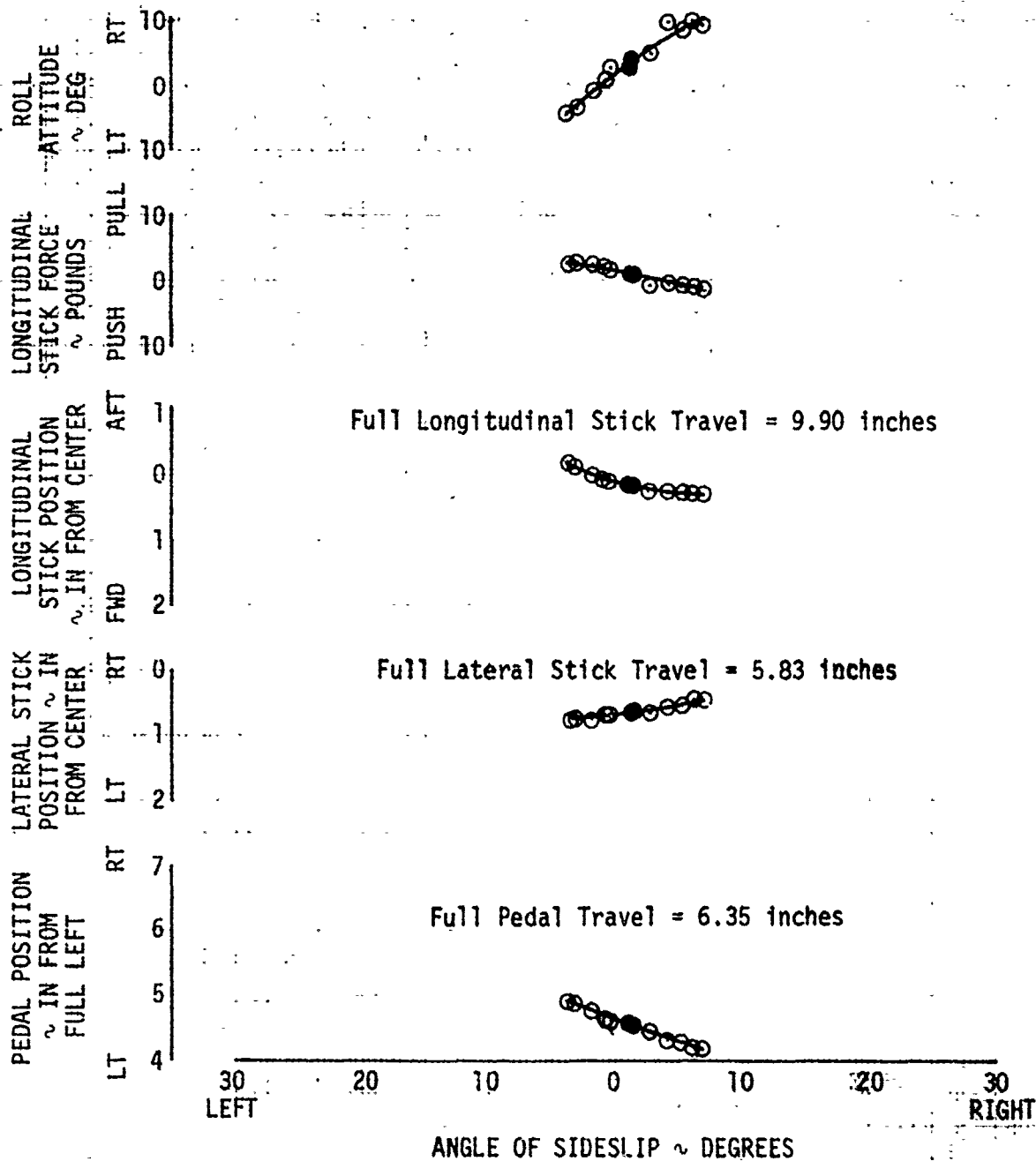


FIGURE 10

AFT LONGITUDINAL PULSE
 AH-56A USA S/N 66-8832

AVG GROSS WEIGHT ~LB	AVG CG LOCATION ~IN	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	ROTOR SPEED ~RPM	COLL BLADE ANGLE ~DEG	CALIB AIRSPEED ~KT	CONFIGURATION
18820	298.3	750	12	241	18	0	CLEAN (GEAR DOWN)

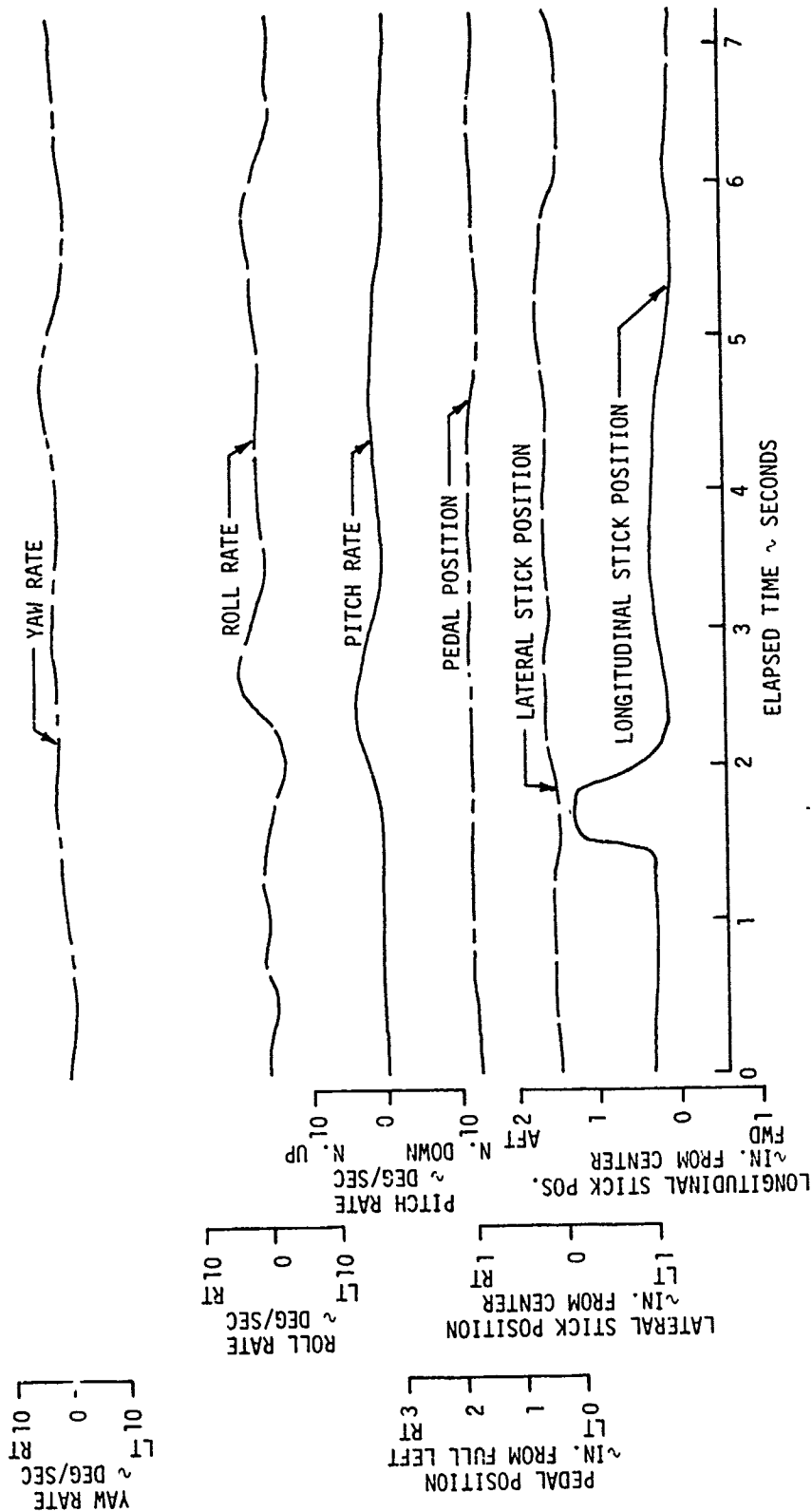


FIGURE 11

AFT LONGITUDINAL PULSE
 AH-56A USA S/N 66-8832

AVG GROSS WEIGHT ~LB	AVG CG LOCATION ~IN	AVG DENSITY ALTITUDE ~FT	AVG ROTOR OAT ~C	AVG SPEED ~RPM	COLL BLADE ANGLE ~DEG	CALIB AIRSPEED ~KT	CONFIGURATION
18590	298.4	5290	8	242	13	180	CLEAN (GEAR UP)

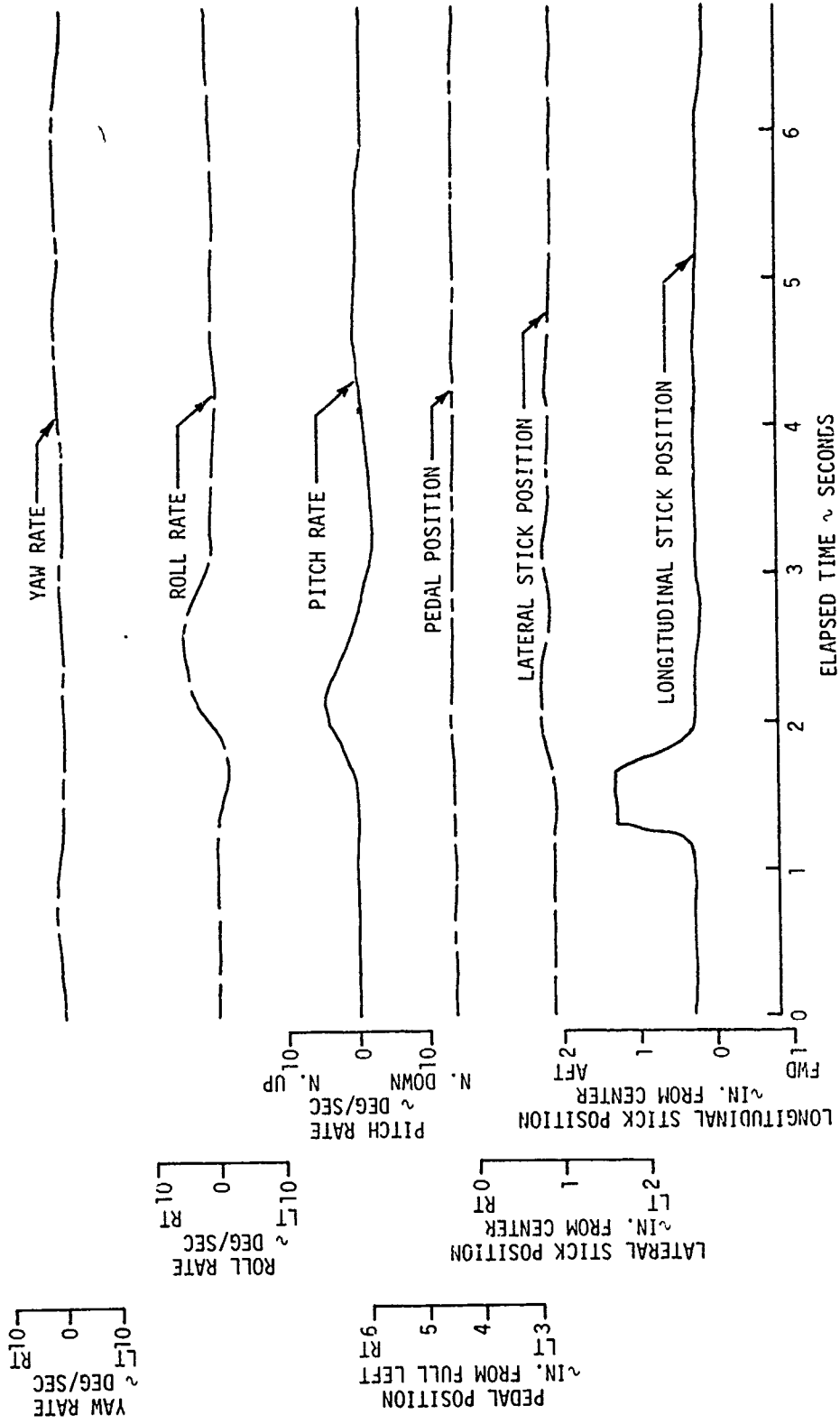


FIGURE 12
RIGHT LATERAL PULSE
AH-56A USA S/N 56-8832

AVG GROSS WEIGHT ~LB	AVG CG LOCATION ~IN	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	ROTOR SPEED ~RPM	COLL BLADE ANGLE ~DEG	CALIB AIRSPEED ~KT	CONFIGURATION
18820	298.3	750	12	241	18	0	CLEAN (GEAR DOWN)

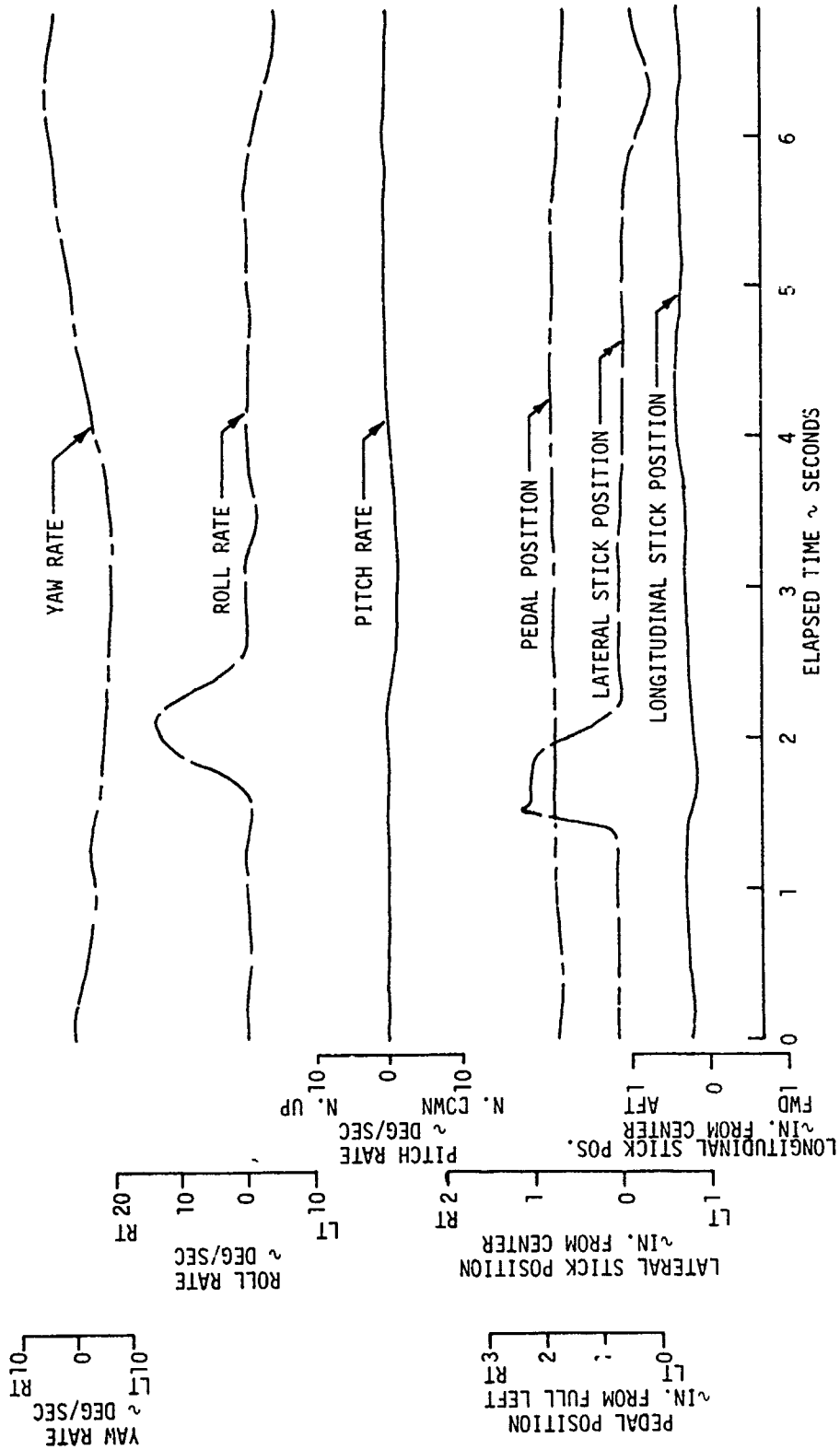


FIGURE 13
RIGHT LATERAL PULSE
AH-56A USA S/N 66-8832

AVG GROSS WEIGHT ~LB	AVG CG LOCATION ~IN	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	AVG ROTOR SPEED ~RPM	COLL BLADE ANGLE ~DEG	CALIB AIRSPEED ~KT	CONFIGURATION
18590	298.4	5290	8	242	13	180	CLEAN (GEAR UP)

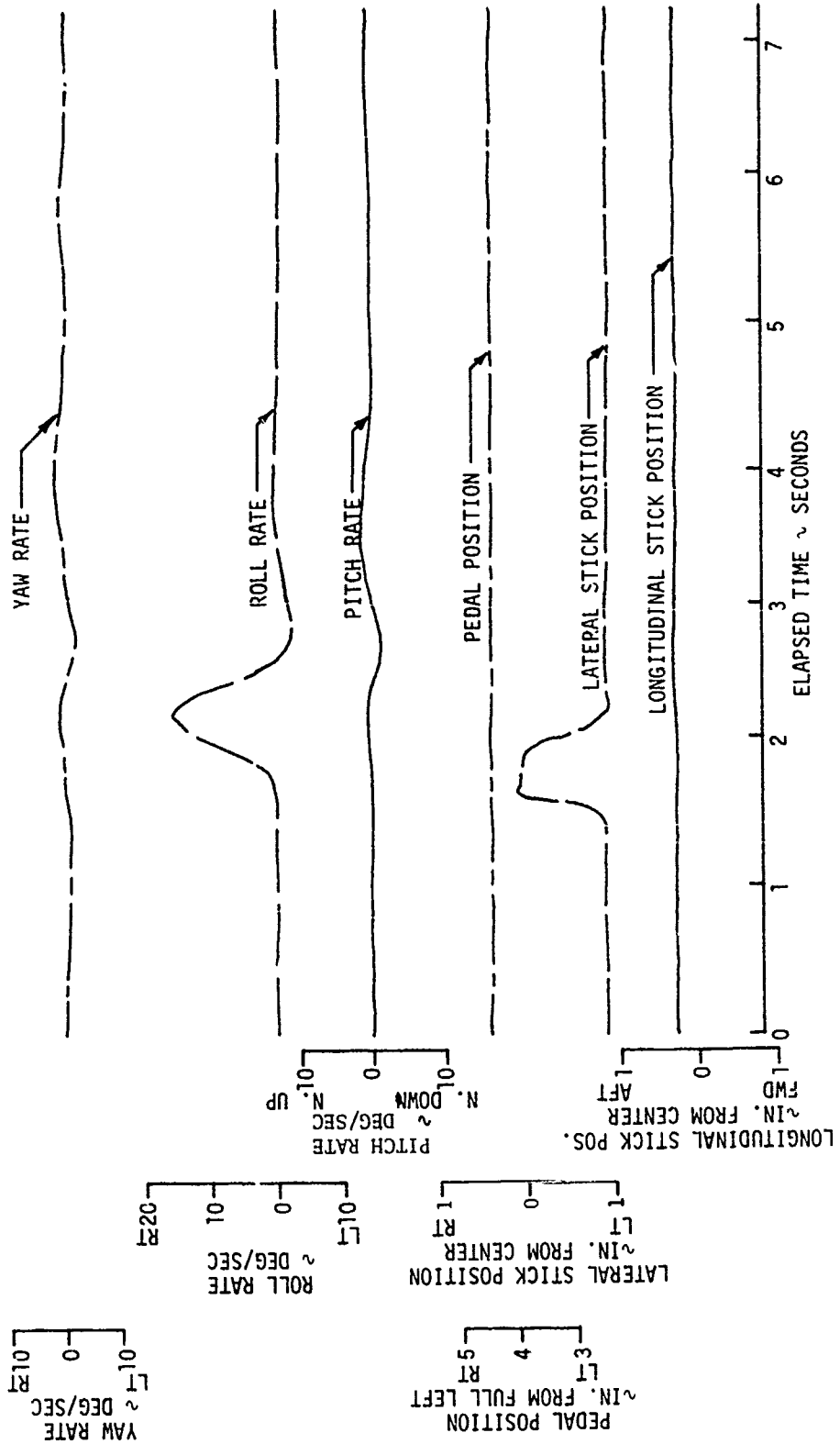


FIGURE 14
SUMMARY LONGITUDINAL CONTROL RESPONSE AND SENSITIVITY
 AH-56A USA S/N 66-8832

NOTE: CURVES DERIVED FROM FIGURES 16 AND 17

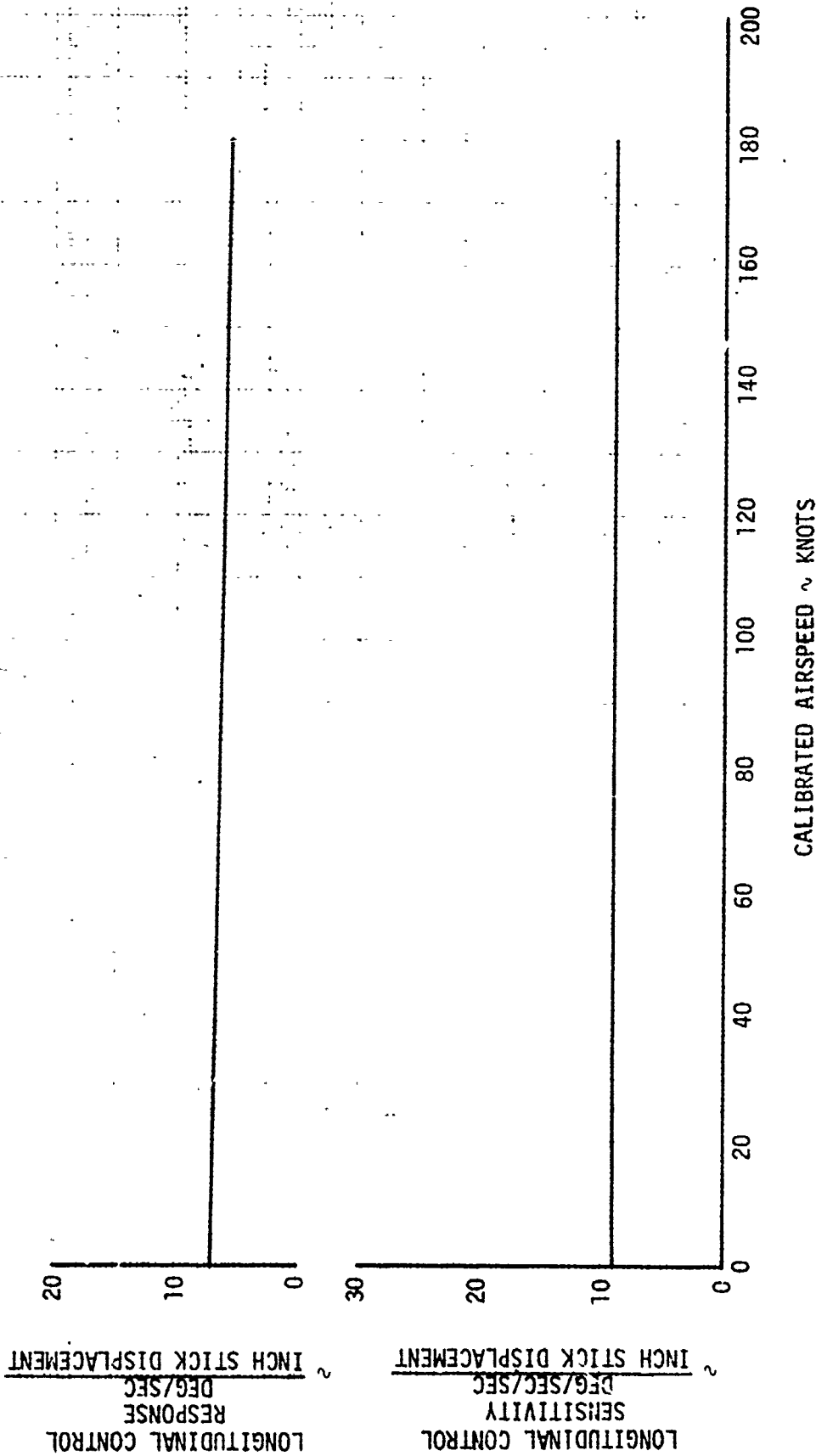
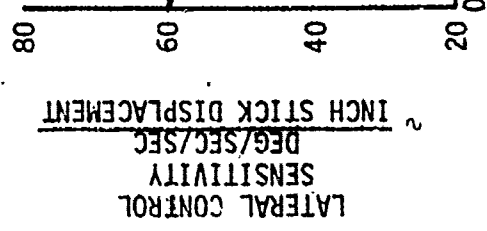
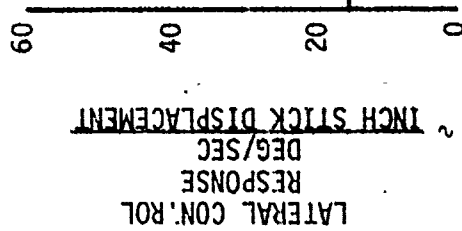


FIGURE 15
SUMMARY LATERAL CONTROL RESPONSE AND SENSITIVITY
 AH-56A USA S/N 66-8832

NOTE: CURVES DERIVED FROM FIGURES 18 AND 19



CALIBRATED AIRSPEED ~ KNOTS

FIGURE 16
LONGITUDINAL CONTROL RESPONSE AND SENSITIVITY

AH-56A USA S/N 66-8832

SYMBOL	AVG GROSS WEIGHT ~ LB	AVG CG LOCATION ~ IN	AVG DENSITY ALTITUDE ~ FT	AVG OAT ~ °C	ROTOR SPEED ~ RPM	COLL BLADE ANGLE ~ DEG	TRIM CALIB AIRSPEED ~ KT	CONFIGURATION
○	18820	298.3	750	12	241	19	0	CLEAN (GEAR UP)
●	18530	297.5	4860	2	239	17	60	CLEAN (GEAR DOWN)

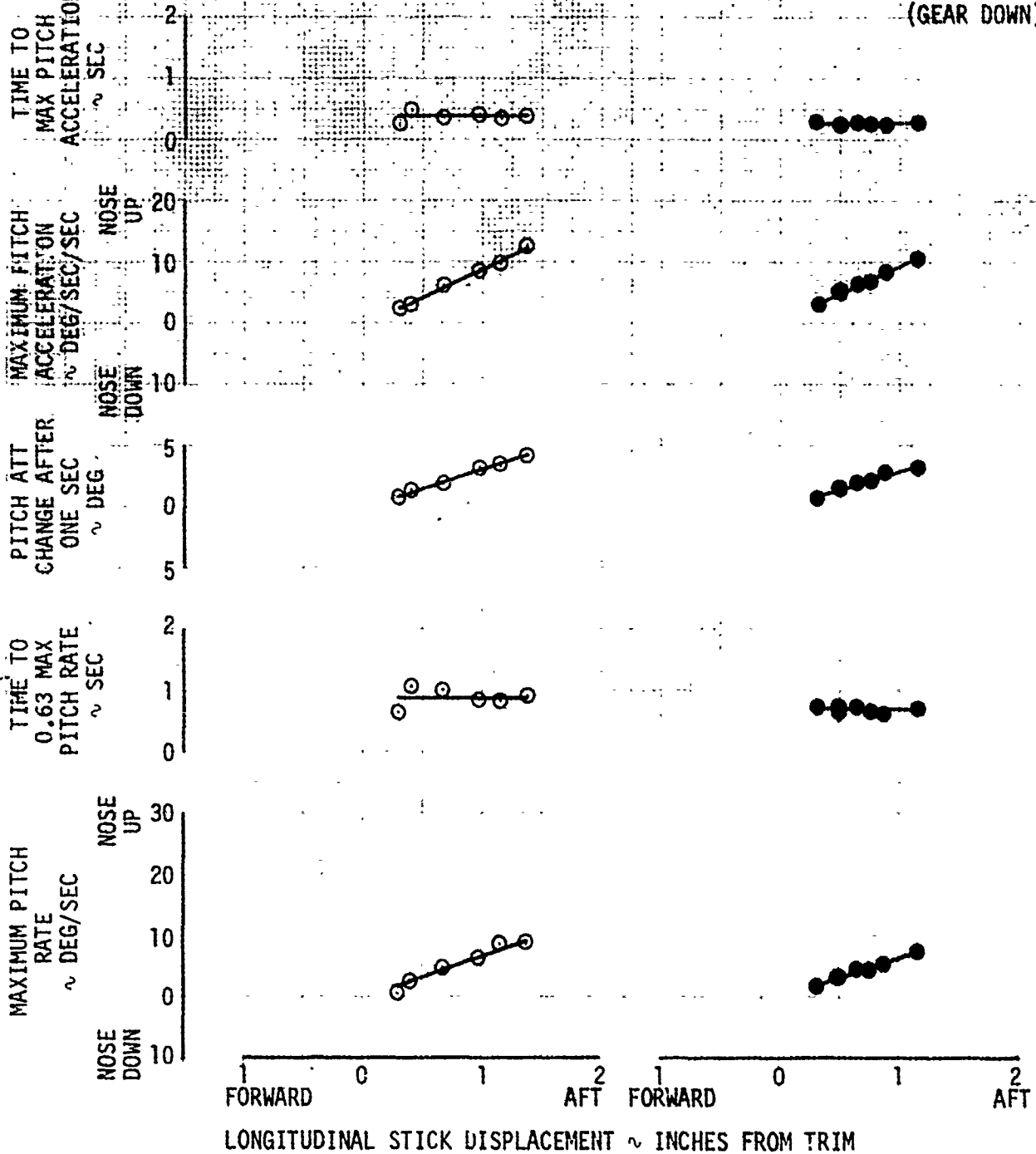


FIGURE 17
LONGITUDINAL CONTROL RESPONSE AND SENSITIVITY
 AH-56A USA S/N 66-8832

SYMBOL	AVG GROSS WEIGHT ~LB	AVG CG LOCATION ~IN	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	ROTOR SPEED ~RPM	COLL. BLADE ANGLE ~DEG	TRIM CALIB AIRSPEED ~KT	CONFIGURATION
○	18580	298.4	5290	11	240	13	150	CLEAN (GEAR UP)
□	18590	298.4	5290	8	242	13	180	CLEAN (GEAR UP)

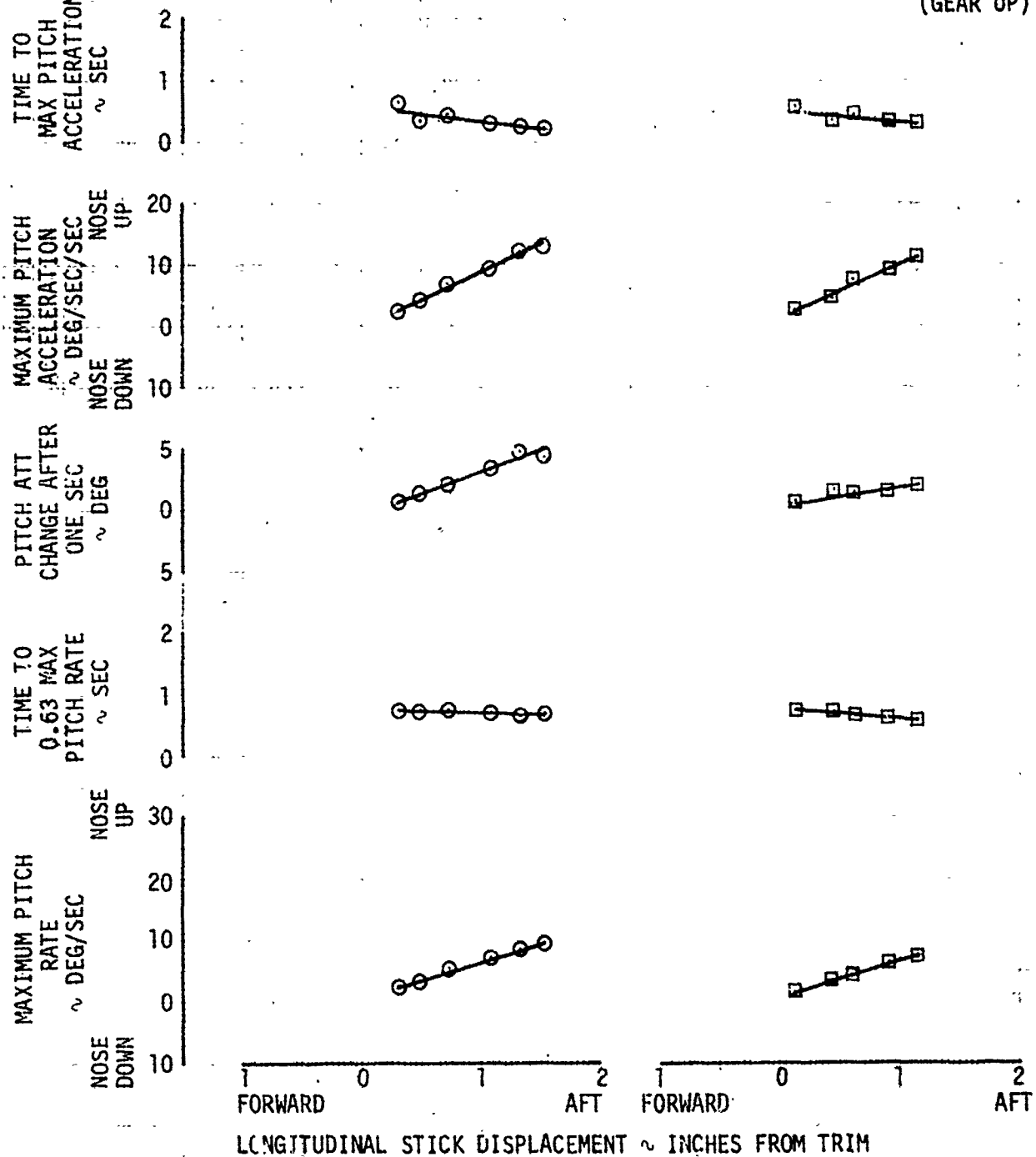


FIGURE 18

LATERAL CONTROL RESPONSE AND SENSITIVITY

AH-56A USA S/N 66-8932

SYMROL	AVG GROSS WEIGHT ~LB	AVG CG LOCATION ~IN	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	ROTOR SPEED ~RPM	COLL BLADE ANGLE ~DEG	TRIM CALIB AIRSPEED ~KT	CONFIGURATION
○	18820	298.3	750	12	241	19	0	CLEAN (GEAR DOWN)
●	18530	297.5	4860	2	239	17	60	CLEAN (GEAR DOWN)

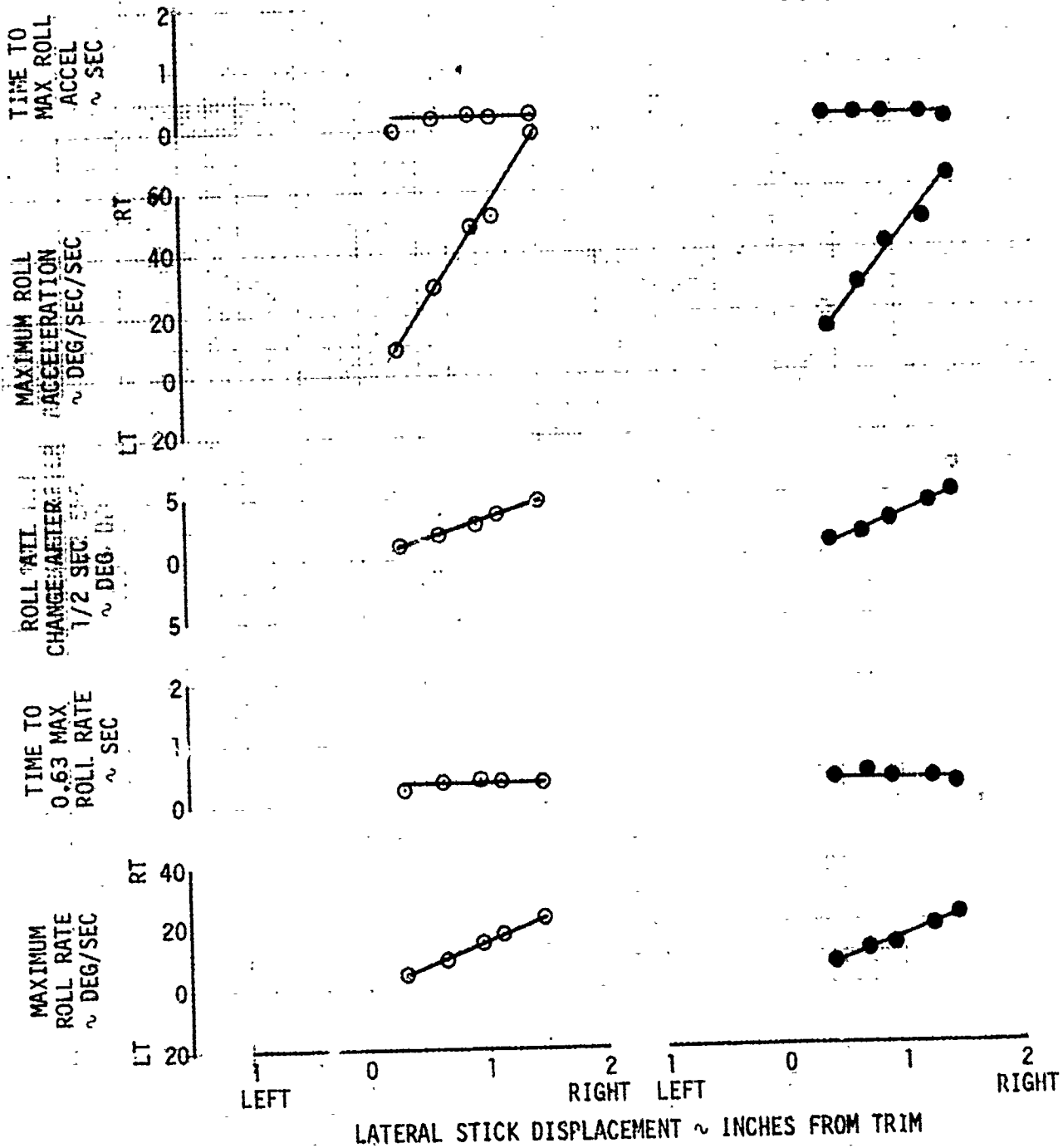


FIGURE 119
LATERAL CONTROL RESPONSE AND SENSITIVITY
 AH-56A USA S/N 66-8832

SYMBOL	AVG GROSS WEIGHT ~ LB	AVG CG LOCATION ~ IN	AVG DENSITY ALTITUDE ~ FT	AVG OAT ~ °C	ROTOR SPEED ~ RPM	COLL BLADE ANGLE ~ DEG	TRIM CALIB AIRSPEED ~ KT	CONFIGURATION
○	18580	298.4	5290	11	240	13	150	CLEAN (GEAR UP)
□	18590	298.4	5290	8	242	13	180	CLEAN (GEAR UP)

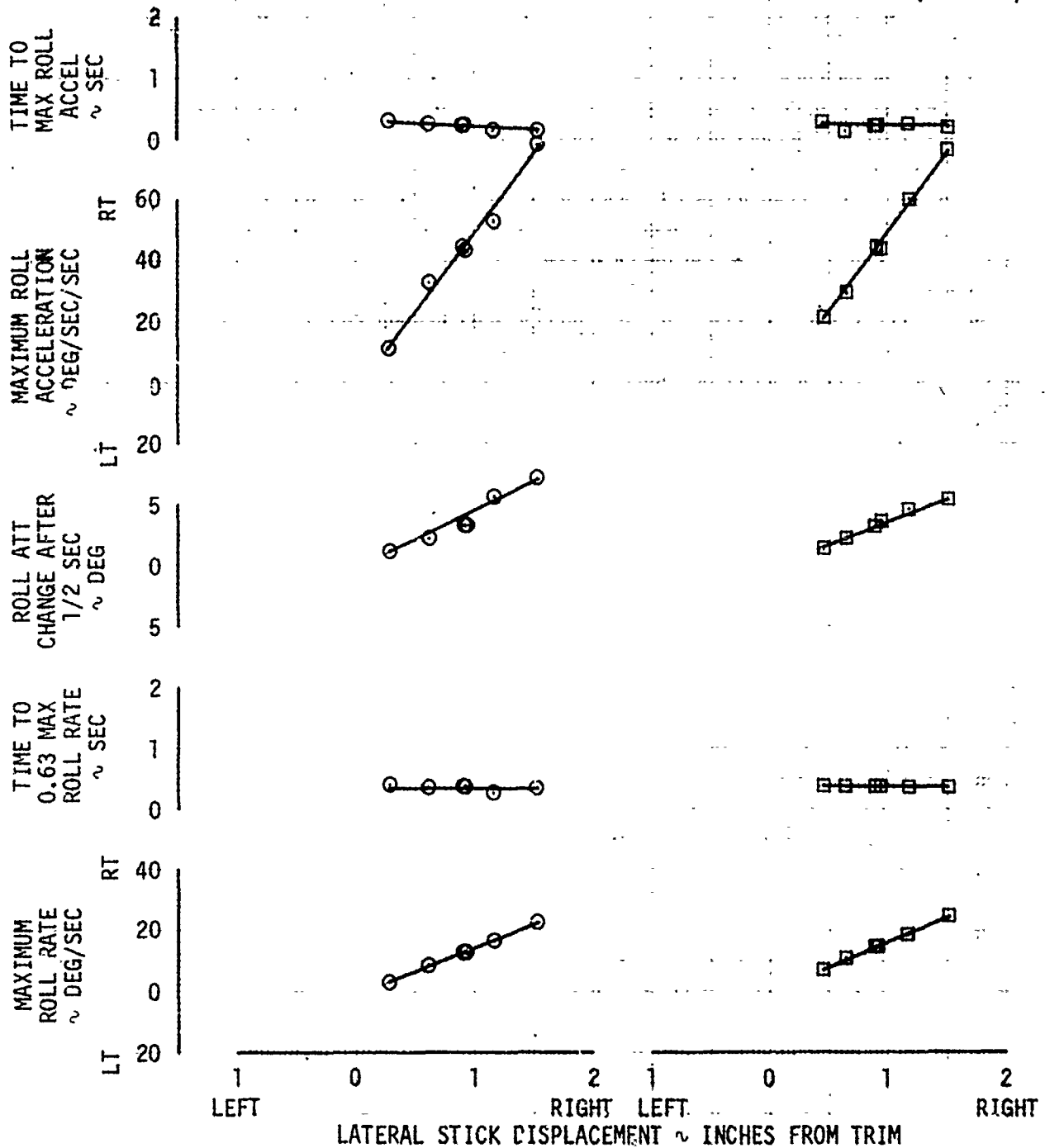


FIGURE 20
MANEUVERING STABILITY
 AH-56A USA S/N 66-8832

AVG GROSS WEIGHT ~LB	AVG CG LOCATION ~IN	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	ROTOR SPEED ~RPM	COLL. BLADE ANGLE ~DEG	CALIB. AIRSPEED ~KT	CONFIGURATION
18610	297.6	5000	12	238	13	80	CLEAN (GEAR UP)

NOTE: FLAGGED SYMBOLS DENOTE RIGHT TURNS
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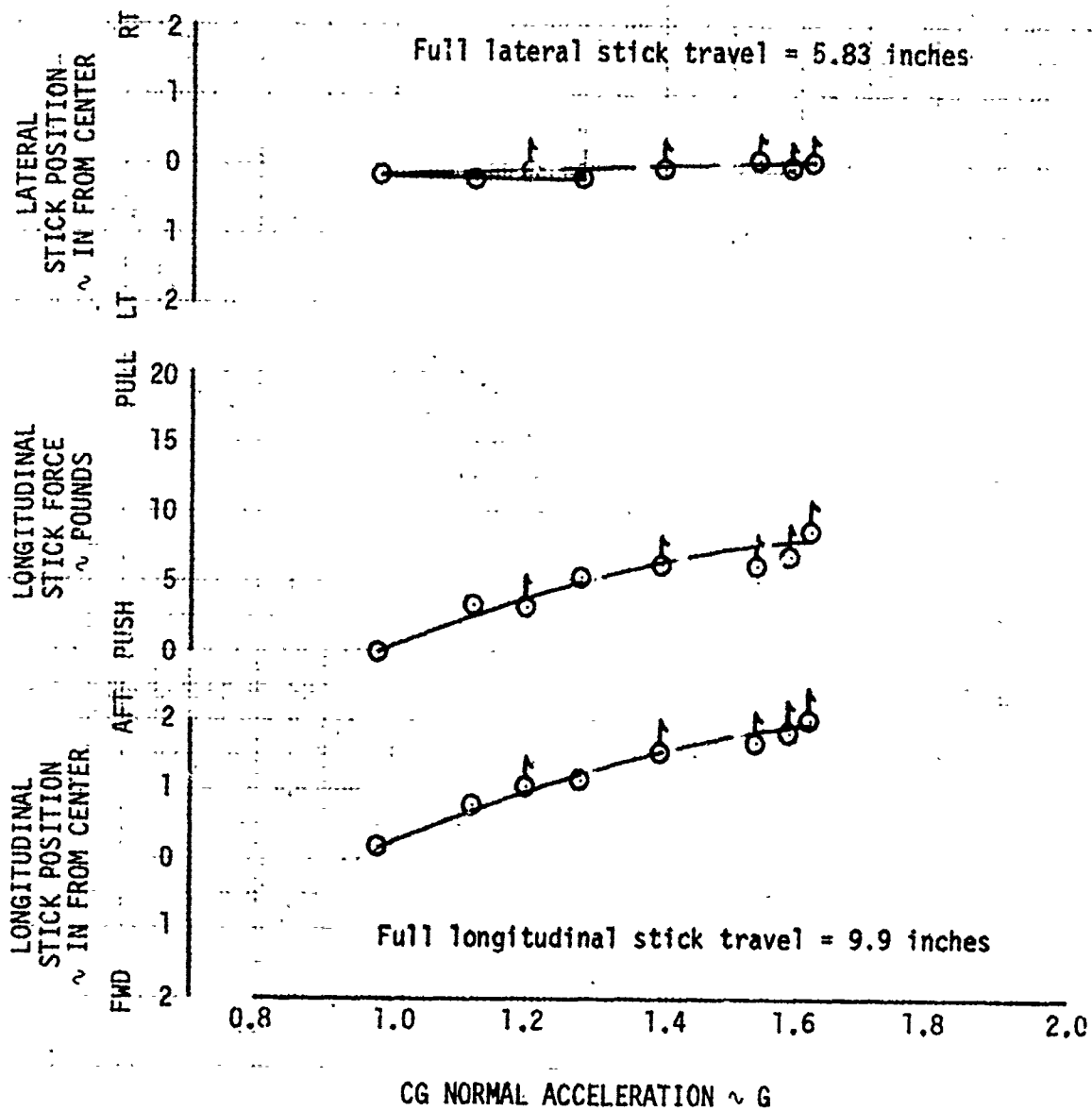


FIGURE 21:
MANEUVERING STABILITY
 AH-56A USA S/N 66-8832

AVG GROSS WEIGHT ~LB	AVG CG LOCATION ~IN	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	ROTOR SPEED ~RPM	COLL BLADE ANGLE ~DEG	CALIB AIRSPEED ~KT	CONFIGURATION
18200	298.3	5220	13	240	13	120	CLEAN (GEAR UP)

NOTE: FLAGGED SYMBOLS DENOTE RIGHT TURNS.
 PLAIN SYMBOLS DENOTE LEFT TURNS

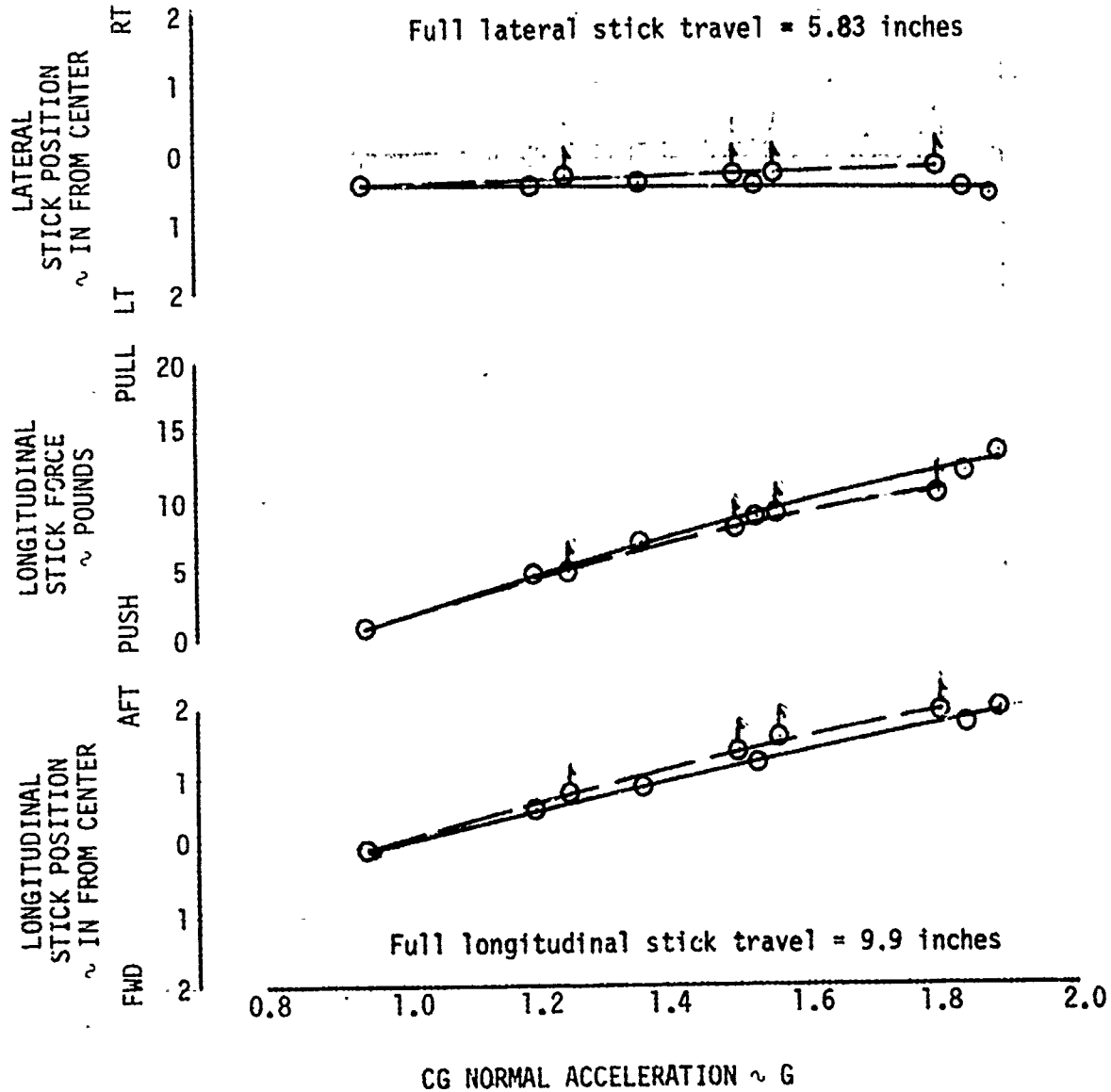


FIGURE 22
MANEUVERING STABILITY
 AH-56A USA S/N 66-8832

AVG GROSS WEIGHT ~LB	AVG CG LOCATION ~IN	AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	ROTOR SPEED ~RPM	COLL BLADE ANGLE ~DEG	CALIB AIRSPEED ~KT	CONFIGURATION
18400	298.4	6550	13	238	13	150	CLEAN (GEAR UP)

NOTE: FLAGGED SYMBOLS DENOTE RIGHT TURNS
 PLAIN SYMBOLS DENOTE LEFT TURNS

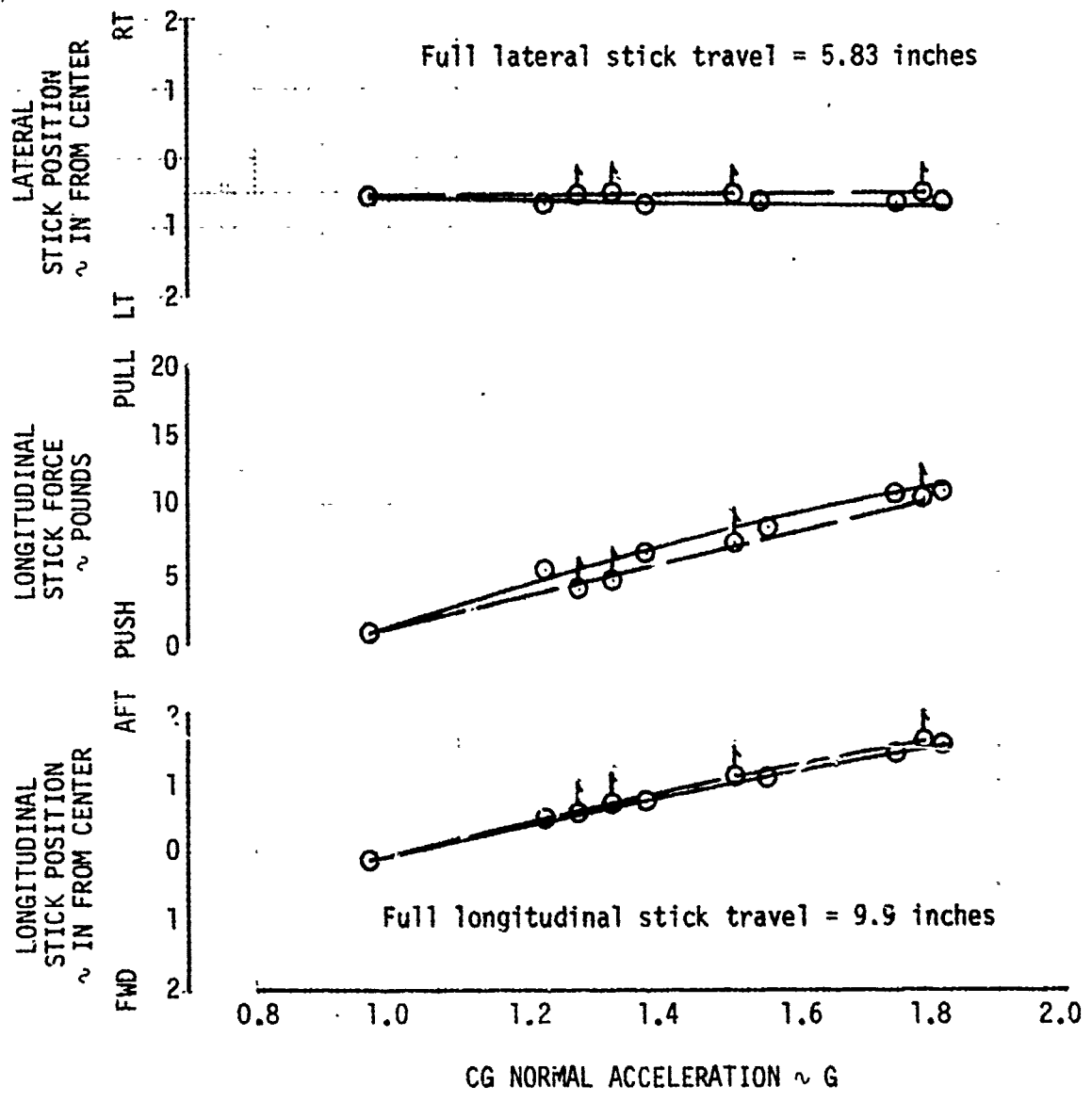


FIGURE 23
PULL-UP MANEUVER
AH-56A USA S/N 66-8832

AVG GROSS WEIGHT ~LB	18530	AVG CG LOCATION ~ IN	298.3	AVG DENSITY ALTITUDE ~FT	3500	AVG QAT ~G	12	ROTOR SPEED ~RPM	242	COLL BLADE ANGLE ~DEG	13	CONFIGURATION	CLEAN (GEAR UP)
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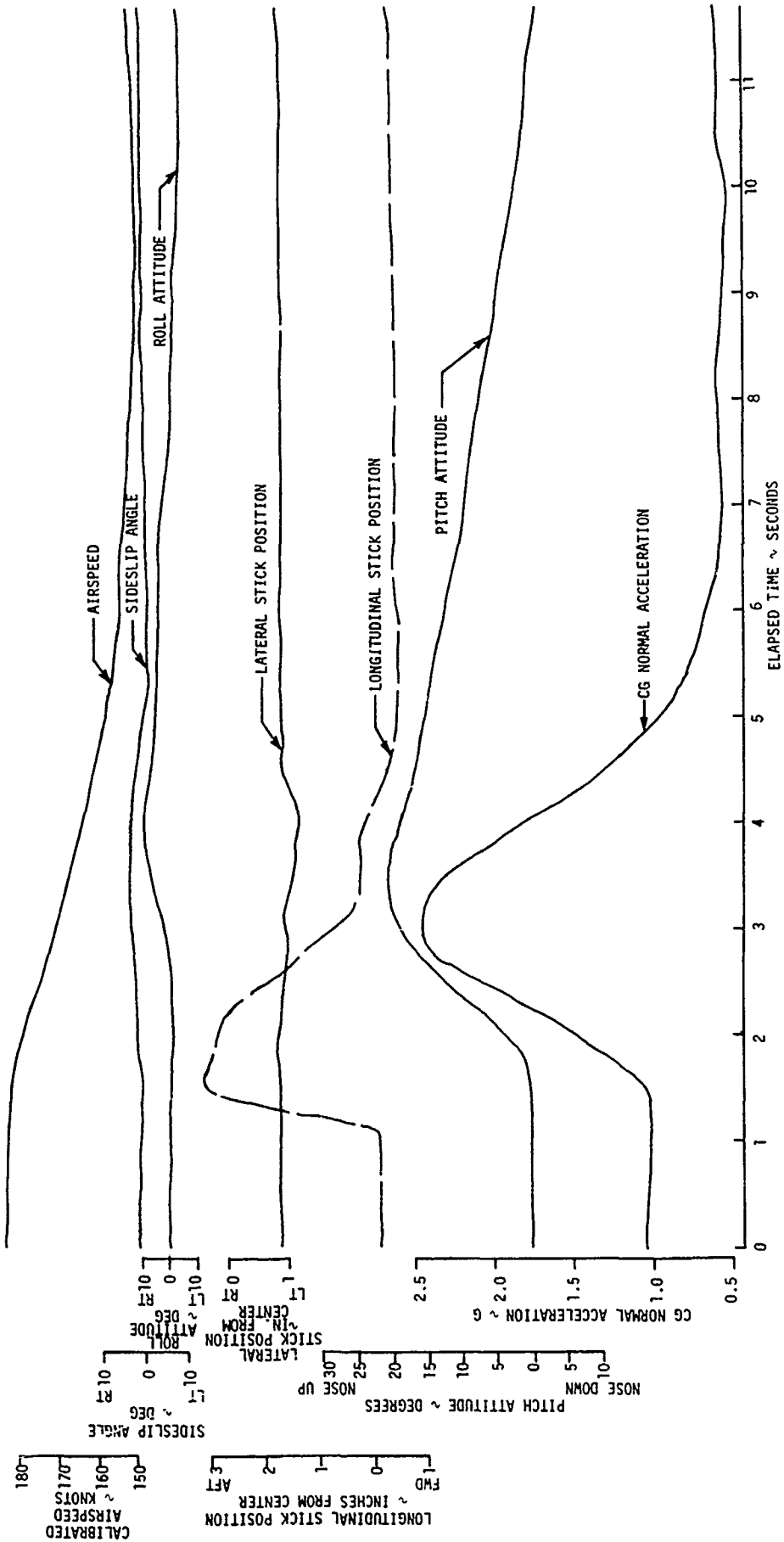


FIGURE 24
 PULL-UP MANEUVER
 AH-56A USA S/N 66-8832

AVG GROSS HEIGHT ~ LB	18690	AVG CG LOCATION ~ IN	298.4	AVG DENSITY ALTITUDE ~ FT	3700	AVG OAT ~ °C	12	ROTOR SPEED ~ RPM	242	COLL BLADE ANGLE ~ DEG	13	CONFIGURATION	CLEAN (GEAR UP)
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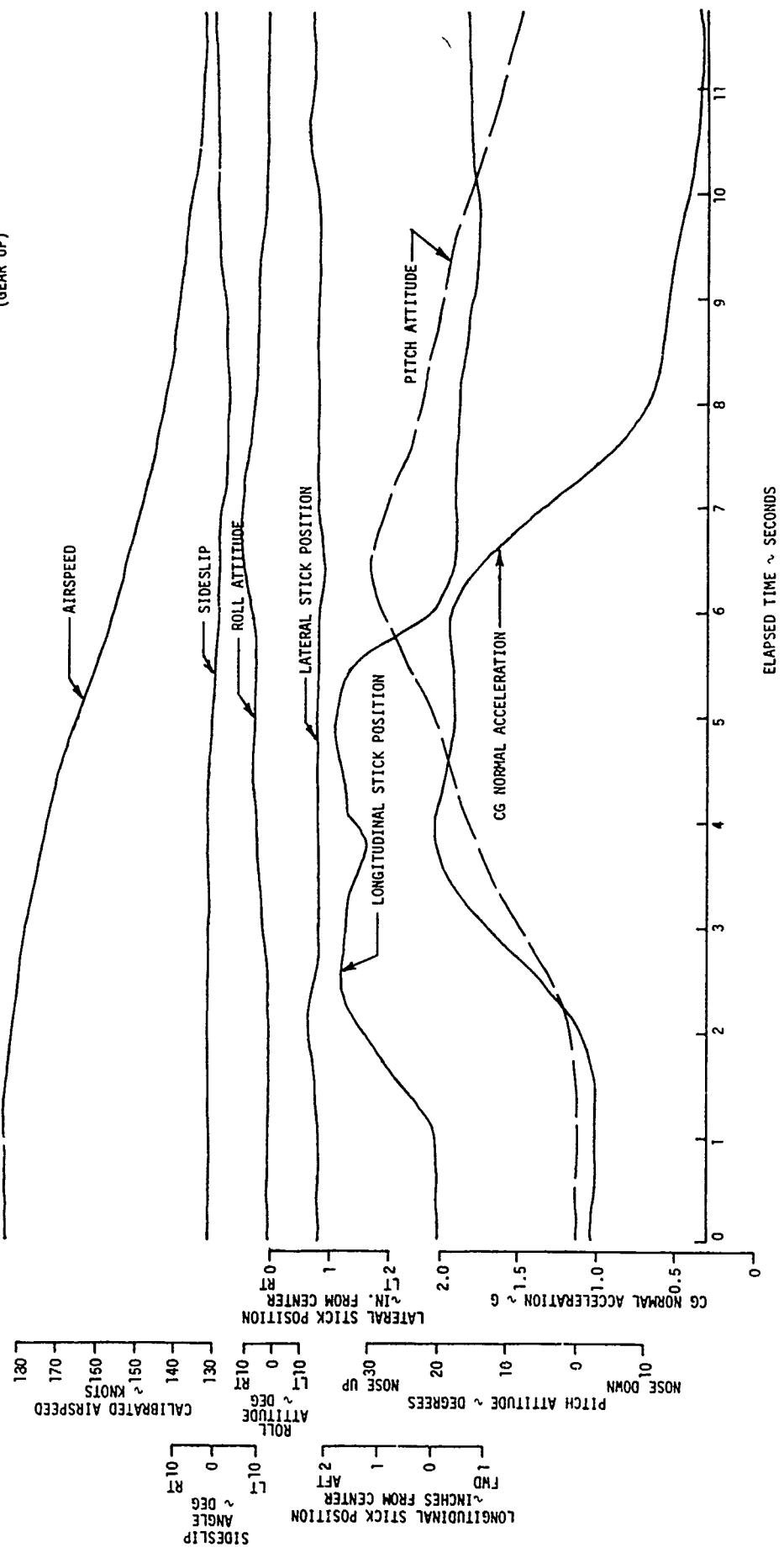


FIGURE 25
 PUSH-OVER MANEUVER
 AH-56A USA S/N 66-8832

AVG GROSS WEIGHT ~ LB	18180	AVG CG LOCATION ~ IN	298.2	AVG DENSITY ALTITUDE ~ FT	3210	AVG OAT ~ °C	12	ROTOR SPEED ~ RPM	242	COLL BLADE ANGLE ~ DEG	13	CONFIGURATION	CLEAN (GEAR UP)
-----------------------	-------	----------------------	-------	---------------------------	------	--------------	----	-------------------	-----	------------------------	----	---------------	-----------------

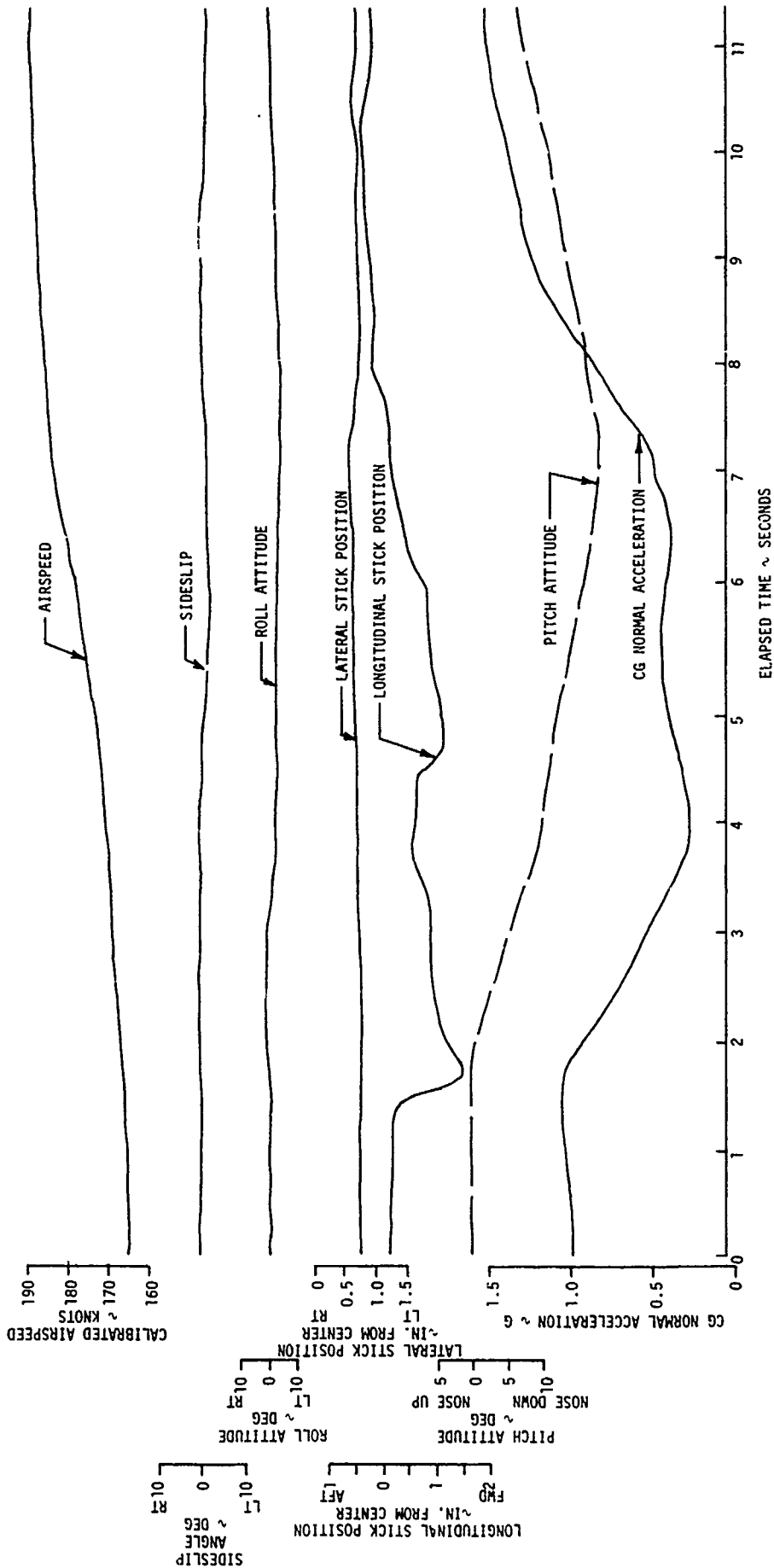


FIGURE 26

AIRSPED CALIBRATION: (BOOM SYSTEM)

AH-56A USA S/N 66-8832

PACER AIRCRAFT METHOD

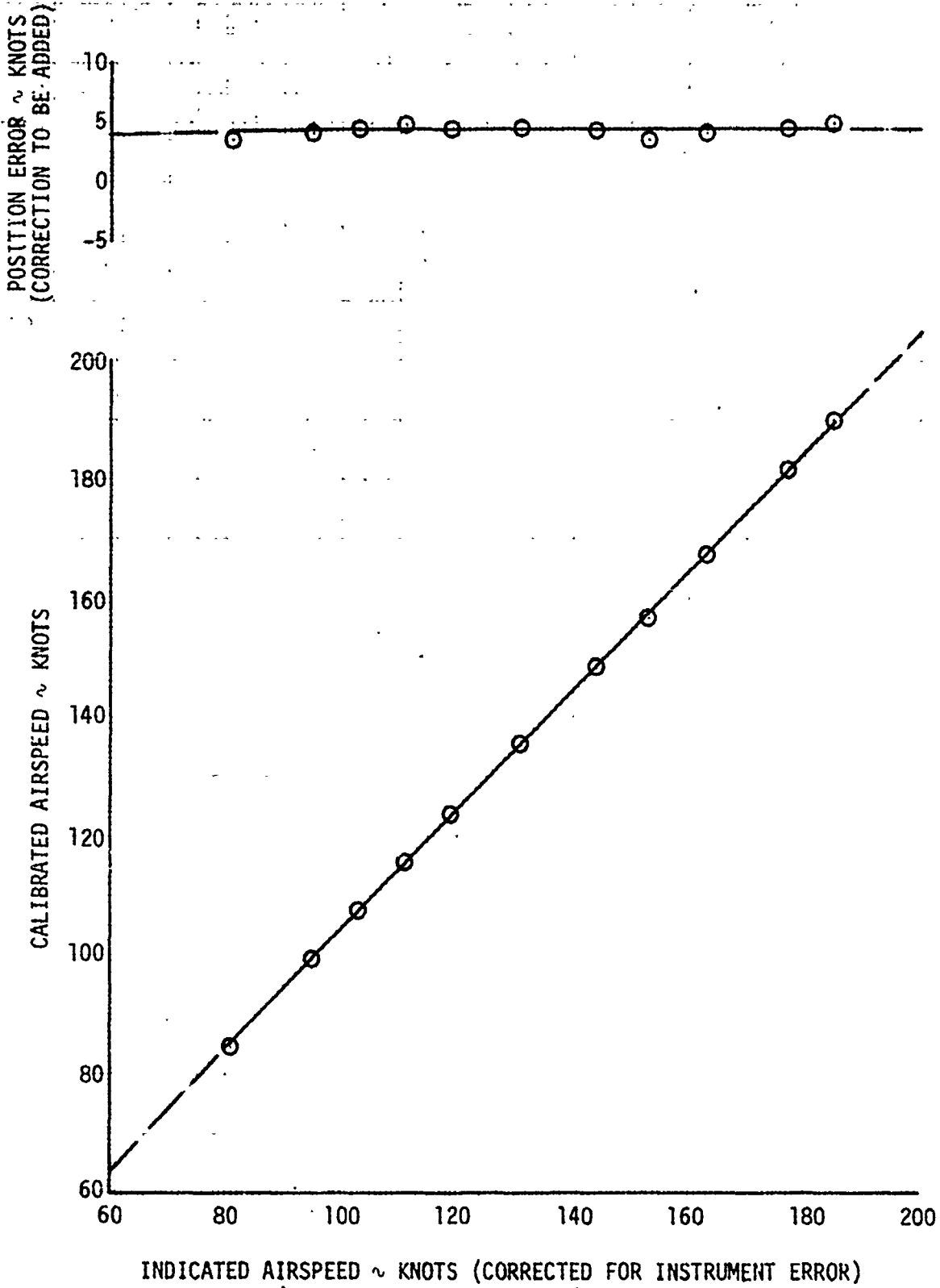


FIGURE 27
PILOT STATION VIBRATION CHARACTERISTICS
 AH-56A USA S/N 66-8832

AVG GROSS WEIGHT ~ LB	AVG CG LOCATION ~ IN	AVG DENSITY ALTITUDE ~ FT	AVG OAT ~ °C	ROTOR SPEED ~ RPM	COLL BLADE ANGLE ~ DEG	CONFIGURATION
18500	298.6	4980	9	242	13	CLEAN (GEAR UP)

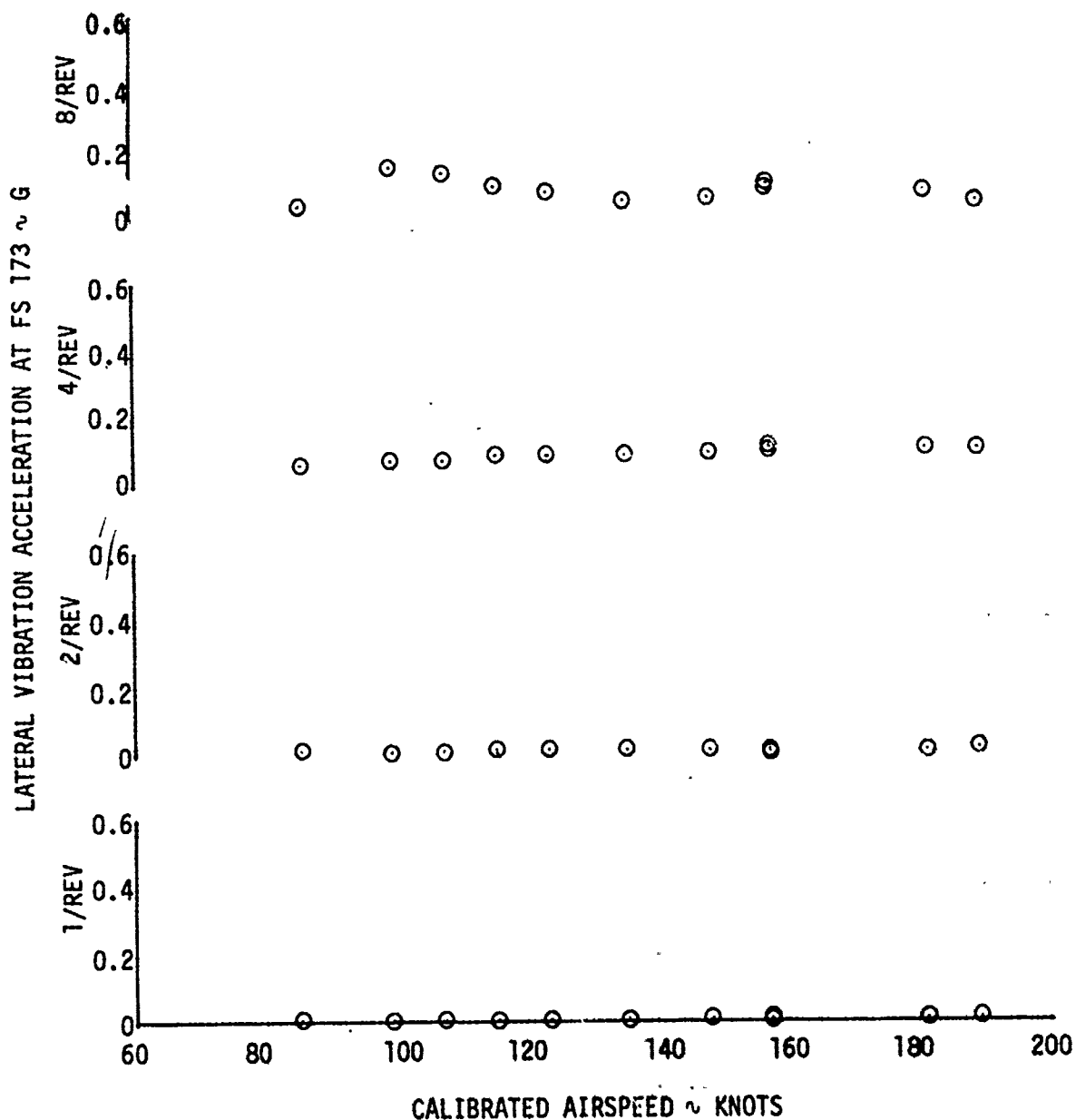


FIGURE 28
PILOT STATION VIBRATION CHARACTERISTICS
 AH-56A USA S/N 66-8832

AVG GROSS WEIGHT ~ LB	AVG CG LOCATION ~ IN	AVG DENSITY ALTITUDE ~ FT	AVG OAT ~ °C	ROTOR SPEED ~ RPM	COLL BLADE ANGLE ~ DEG	CONFIGURATION
18500	298.6	4980	9	242	13	CLEAN (GEAR UP)

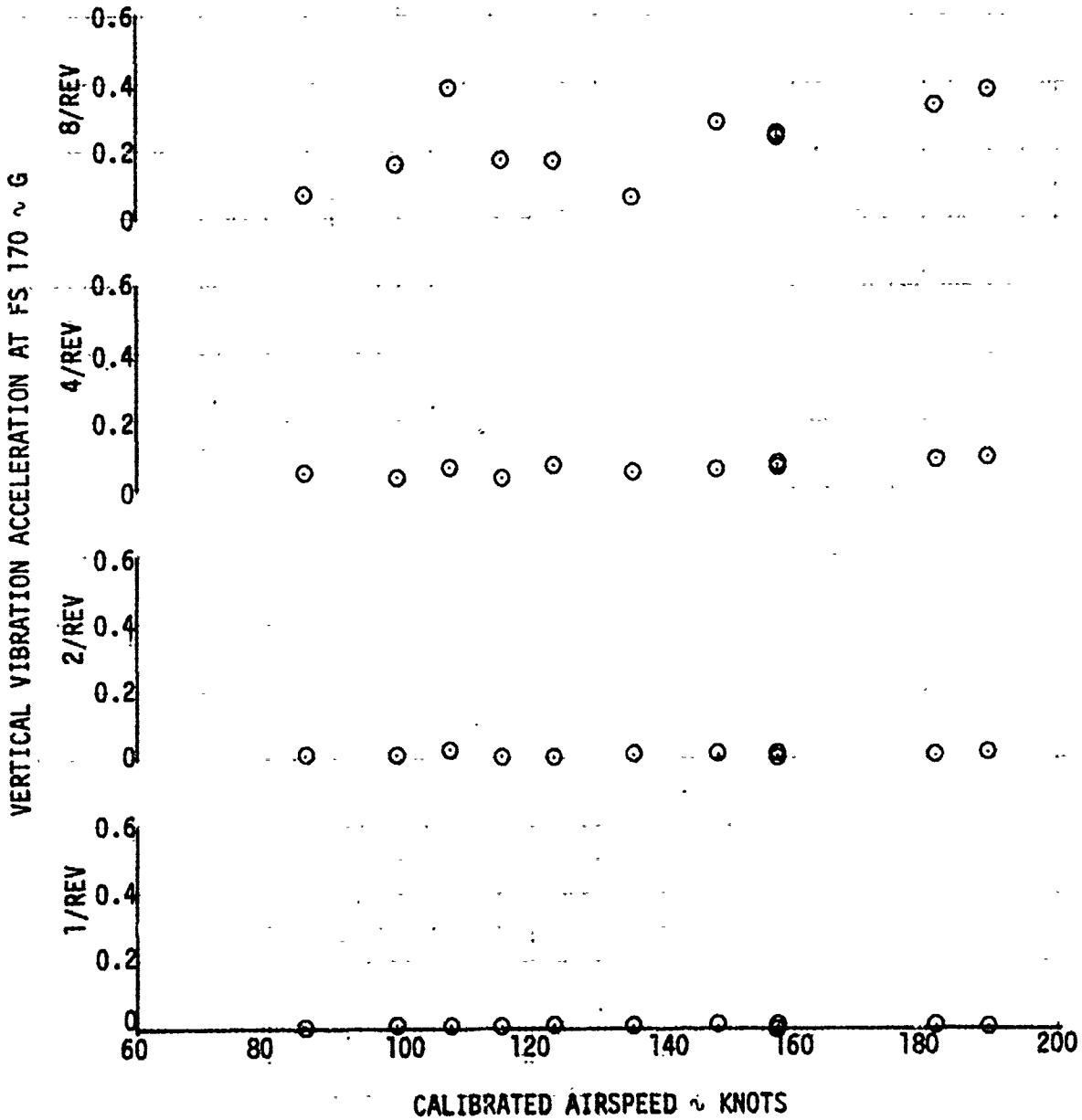


FIGURE 29
COPILOT STATION VIBRATION CHARACTERISTICS
 AH-56A USA S/N 66-8832

AVG GROSS WEIGHT ~ LB	AVG CG LOCATION ~ IN	AVG DENSITY ALTITUDE ~ FT	AVG OAT ~ °C	ROTOR SPEED ~ RPM	COLL BLADE ANGLE ~ DEG	CONFIGURATION
18500	298.6	4980	9	242	13	CLEAN (GEAR UP)

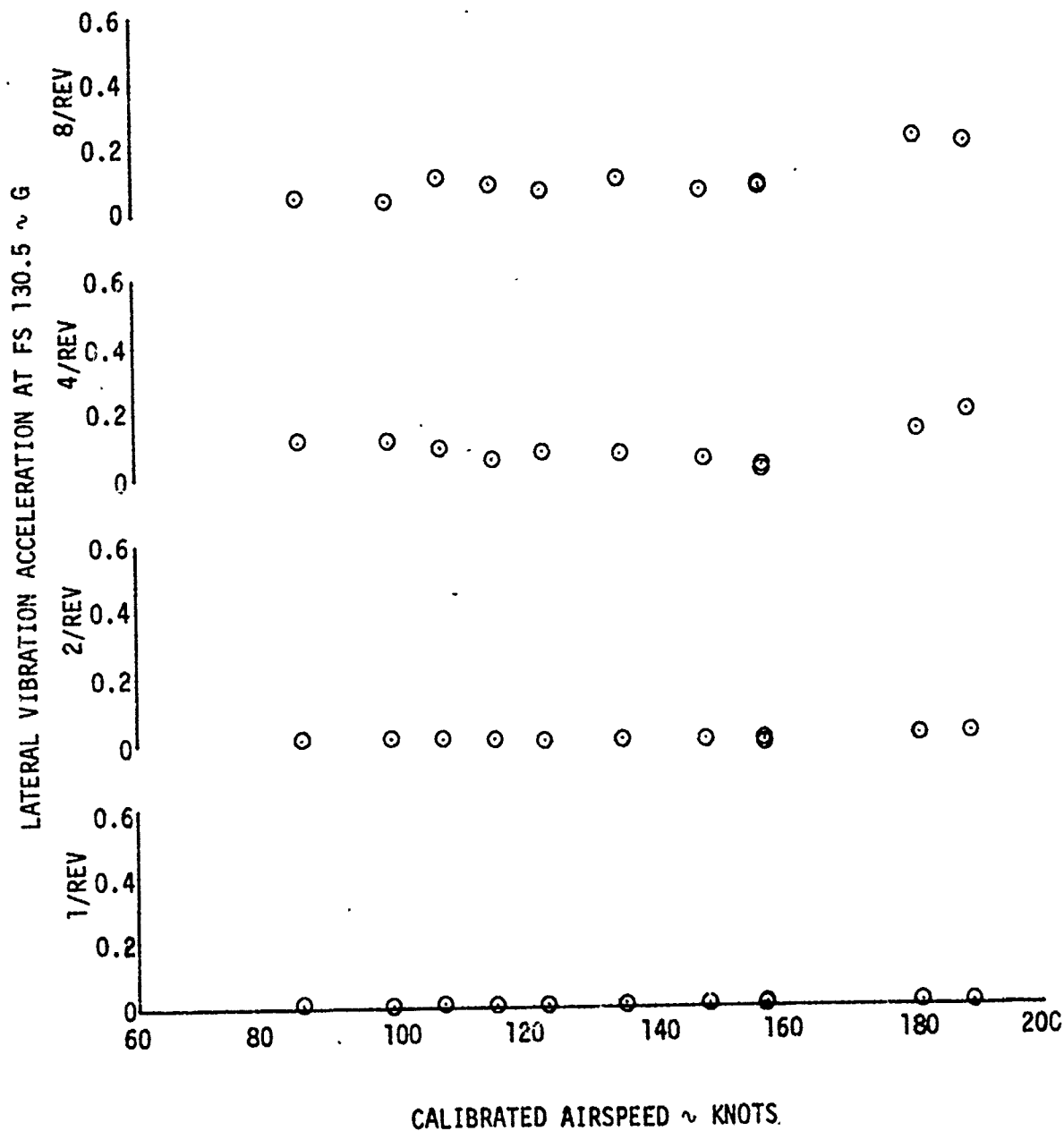
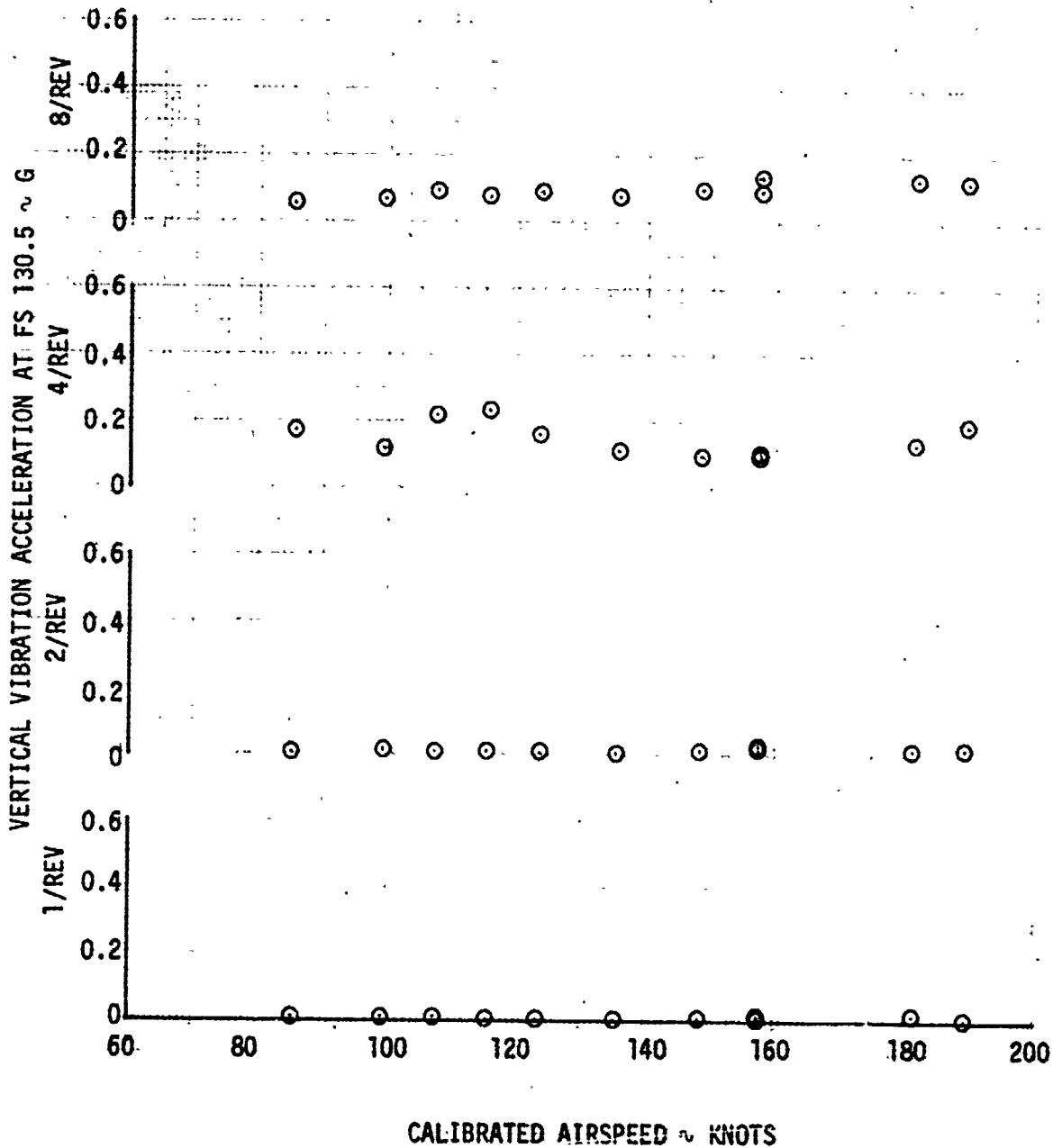


FIGURE 30
COPILOT STATION VIBRATION CHARACTERISTICS
 AH-56A USA S/N 66-8832

AVG GROSS WEIGHT ~ LB	AVG CG LOCATION ~ IN	AVG DENSITY ALTITUDE ~ FT	AVG OAT ~ °C	ROTOR SPEED ~ RPM	COLL BLADE ANGLE ~ DEG	CONFIGURATION
18500	298.6	4980	9	242	13	CLEAN (GEAR UP)



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13. ABSTRACT

The United States Army Aviation Systems Test Activity conducted an engineering evaluation of the AH-56A compound helicopter with the advanced mechanical control system during the period 19 February to 14 March 1973 at Yuma Proving Ground, Arizona. This evaluation was primarily a handling qualities evaluation to determine the relative merits of the advanced mechanical control system versus the improved control system previously tested. The testing consisted of 20 test flights totaling 18.2 hours. The advanced mechanical control system corrected the major problem of the AH-56A with the improved control system. This problem was loss of aircraft control within the flight envelope resulting from blade moment stall. Some additional benefits of the advanced mechanical control system were a reduction in pilot workload during transition and elimination of the tendency for pilot-coupled roll oscillations, longitudinal trim shift with sideslip, and roll due to lift coupling. One deficiency identified during improved control system testing is still present. This deficiency is the inability to effectively perform low-speed low-level mission tasks below 120 knots calibrated airspeed under reduced visibility conditions due to the lateral-directional stability characteristics. There were four shortcomings identified, all of which existed with the improved control system. Other shortcomings identified during improved control system testing are still present but are not discussed in this report because of the limited scope of this evaluation.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Engineering evaluation of the AH-56A compound helicopter Advanced mechanical control system Improved control system Handling qualities evaluation Pilot workload during transition Pilot-coupled roll oscillations Longitudinal trim shift with sideslip Roll due to left coupling Low-speed low-level mission tasks Lateral-directional stability characteristics Limited scope evaluation						