USAAEFA PROJECT NO. 78-03

PRELIMINARY AIRWORTHINESS EVALUATION

AH-1S HELICOPTER INSTALLED WITH ENHANCED COBRA ARMAMENT SYSTEM (AH-1S/ECAS)

FINAL REPORT

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FEBRUARY 1979

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER USAAEFA PROJECT NO. 78-03	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PRELIMINARY AIRWORTHINESS EVALUATION AH-1S HELICOPTER INSTALLED WITH ENHANCED COBRA ARMAMENT SYSTEM (AH-1S/ECAS).		5. TYPE OF REPORT & PERIOD COVERED FINAL REPORT, July - August 1978
		6. PERFORMING ORG. REPORT NUMBER Project No. 78-03
7. AUTHOR(s) CPT PATRICK J. MOE, RALPH WORAT SCHEK CW3 ROBERT WILLIAMS, RAYMOND B. SMITH		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US ARMY AVIATION ENGINEERING FLIGHT ACTIVITY EDWARDS AIR FORCE BASE, CALIFORNIA 93523		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 21-8-R0027-01-21-EC
11. CONTROLLING OFFICE NAME AND ADDRESS US ARMY AVIATION ENGINEERING FLIGHT ACTIVITY EDWARDS AIR FORCE BASE, CALIFORNIA 93523		12. REPORT DATE FEBRUARY 1979
		13. NUMBER OF PAGES 126
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) (12) 138p.		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

M-197 20mm Gun Subsystem
M-197 20 mm Gun, Firing Characteristics
Universal Turret Subsystem
Stability and Control, AH-1G
Vibration Characteristics, AH-1G
Telescopic Sight Unit

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The United States Army Aviation Engineering Flight Activity conducted a preliminary airworthiness evaluation of the Enhanced Cobra Armament System (ECAS) with the universal turret subsystem and M-197 20mm gun installed. The purpose of the test was to evaluate the effects of turret installation and weapons firing on the helicopter. Additionally, a limited stability and control evaluation of the helicopter (gun stowed) was conducted. Flight testing was performed at Yuma Proving Grounds, Arizona, and consisted of 27 flight test hours (15 productive).

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20. Abstract

The handling qualities and vibration characteristics of the aircraft during 20mm gun firing are satisfactory, except that the lateral portion of the armament compensation system is inadequate. The stability and control characteristics (gun stowed) are unchanged from the production AH-1S. The inability to start the aircraft on a hot day (35°C) using the normal start procedure is a deficiency. A modified interim start procedure was used during the evaluation which required turning off the ignition key when the turbine gas temperature reached 750°C. Seven shortcomings noted below were found or alluded to in previous AH-1G or AH-1S reports. During the firing phase of the evaluation, the only shortcoming was the inability to maintain directional control at 30 knots true airspeed in right sideward flight while firing the gun to either side. During the stability and control phase of the evaluation, two shortcomings previously reported on the AH-1S were noted. At airspeeds above 80 knots calibrated airspeed, stability and control augmentation system OFF the lateral-directional oscillation (dutch roll) mode is divergent and easily excited. The helicopter lateral and longitudinal cyclic control has a very high breakout force (including friction), which is detrimental to precise heading and airspeed control. Additional shortcomings include the design of the trigger guard on the Telescopic Sight Unit, the location of the gunner Emergency Hydraulic Control switch, the ability to inadvertently disable the Helmet Sight Subsystem, and the location of the circuit breakers under the pilot collective control. Three shortcomings attributed to the AH-1S/ECAS include the lack of a gun position indicator, and the operation of the "gun-stowed" caution light. A CAUTION is recommended for inclusion in the operator's manual dealing with the difficulty in maintaining heading when firing to either side of the aircraft in a right crosswind greater than 20 knots. A NOTE is also recommended for inclusion concerning the possibility of interruped fire when firing forward while in a tailwind hover. A NOTE is recommended for inclusion in the ECAS checklist warning of the possibility of hitting the cyclic control while reaching for the ignition key when using the modified starting procedure.

DEPARTMENT OF THE ARMY
HQ, US ARMY AVIATION RESEARCH AND DEVELOPMENT COMMAND
P O BOX 209, ST. LOUIS, MO 63166

DRDAV-EQ 28 JUN 1979

SUBJECT: Final Report of USAAEFA Project No. 78-03, Preliminary Airworthiness Evaluation AH-1S Helicopter Installed with Enhanced Cobra Armament System, February 1979

SEE DISTRIBUTION

1. The purpose of this letter is to present the AVRADCOM position on the subject report.

2. This Headquarters agrees with the overall conclusions of the report, but not all of the deficiencies and shortcomings. Specific comments on each follows:

a. Paragraph 41 - The starting procedure was amended by Change 3, effective 17 June 1978, but had not been distributed at time of test. This office feels that the amended starting procedure is acceptable as written.

b. Paragraph 42a - While this is a valid test result it has no practical significance, therefore no corrective action is planned.

c. Paragraph 42b - The never exceed with SAS OFF is 100 KIAS. Since the rate of divergence is quite low with increasing airspeed, the difference between the 80 KCAS test results here and the Operator's Manual limit is not significant. Before the aircraft can be released for Instrument Meteorological Conditions (IMC) flight, the ability to slow down from the maximum speed in level flight and the 80 KCAS value must be fully evaluated. However at the time of this test program no IMC clearance was envisioned.

d. Paragraphs 42c thru 42h - No action is being taken on these shortcomings. They are not unique to the ECAS AH-1S and have not been considered as significant problems on the AH-1S aircraft already deployed.

e. Paragraph 43a - No position indicator is needed because gun automatically will stow with power loss. Automatic storage was a mandatory safety feature.

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f. Paragraph 43b - The shortcomings mentioned in this paragraph is really an enhancing feature whereby the light not illuminating would indicate that the weapons system was inadvertently left in the STBY or ARM position by the pilot.

g. Paragraph 43c - Action has been taken to label the weapons control switches located under the pilot's collective.

3. This Headquarters agrees with all recommendations on page 24 except paragraph 48 because the new starting procedure contained in change 3 to TM 55-1520-236-10 is considered to be adequate.

FOR THE COMMANDER:

CHARLES C. CRAWFORD, JR.
Chief, Sys Dev & Qual Div

AH-1S ECAS
Weapon Firing Configuration

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INTRODUCTION

BACKGROUND

1. The United States Army Aviation Research and Development Command (AVRADCOM) awarded a contract to Bell Helicopter Textron (BHT) to develop an Enhanced Cobra Armament System (ECAS) which included a Universal Turret Subsystem (UTS) and an External Ammunition Stores Management and Remote Set Fuzing Subsystem (EASM/RSF), to be incorporated into a production AH-1S helicopter. BHT became system integrator and subsequently awarded General Electric (GE) the subcontract for development of the UTS and Baldwin Electronics Incorporated (BEI) the subcontract for development of the EASM/RSF. The Department of the Army established an urgent requirement to install the universal turret on the 101st production AH-1S. In January 1978, AVRADCOM directed that a Preliminary Airworthiness Evaluation (PAE) of the ECAS be conducted by the United States Army Aviation Engineering Flight Activity (USAAEFA) at Yuma Proving Grounds (YPG), Arizona (ref 1, app A). A detailed test plan was submitted to AVRADCOM in May 1978 (ref 2).

TEST OBJECTIVES

2. The objectives of the PAE were as follows:

a. To provide a preliminary evaluation and substantiating data upon which to base an airworthiness release for further Government testing.

b. To provide a qualitative assessment of the installation and integration of the UTS (20mm only) and aircraft response to weapons firing.

c. To perform a limited stability and control evaluation of the AH-1S with the UTS installed

DESCRIPTION

3. The AH-1S ECAS is a production AH-1S, which is a 10,000 pound maximum gross weight attack helicopter derived from the AH-1G Huey-Cobra. The AH-1S/ECAS is powered by a single Lycoming T53-L-703 engine with a thermodynamic rating of 1800 shaft horsepower (shp) derated on installation to 1290 shp (main transmission limit). The test aircraft differed from a production AH-1S in that a universal turret with a 20mm gun was installed in place of the standard turret, a transmission mounted alternator was added, and a modified Stability and Control Augmentation System (SCAS) was incorporated. The helicopter was flown in two configurations. During the firing phase, high-speed 16mm motion picture cameras were mounted on the toe of each skid and on the upper surface of the right wing. Instrumentation pods were attached to the inboard stores stations. During the stability and control phase, the aircraft was in the clean configuration with a nose-mounted instrumentation boom attached at fuselage station (FS) 50. The instrumentation package was mounted in the ammunition bay. A more complete description

of the production AH-1S can be found in the operator's manual (ref 3, app A). A more complete description of the ECAS subsystem can be found in appendix B.

TEST SCOPE

4. The flight testing was conducted at YPG from 14 July through 5 August 1978 and including 27 flight test hours (15 productive flight test hours). The installation and maintenance of test instrumentation and test aircraft maintenance was accomplished by BHT. Chase aircraft, fire and medical support, office facilities, and secretarial assistance were provided by YPG. All flight limitations set forth in the operator's manual and supplemented by the airworthiness release (ref 4, app A) were observed. Stability and control testing was analyzed with reference to the requirements of military specification MIL-H-8501A (ref 5) and the deviations there to as specified in the system specification for the AH-1S (ref 6). Testing was conducted at the general conditions noted in table 1.

TEST METHODOLOGY

5. Testing was conducted in two phases. The purpose of the first phase was to evaluate the handling qualities and vibration characteristics during weapons firing, while the purpose of the second phase was to evaluate the stability and control characteristics with the gun stowed. During the gun firing phase, the helicopter was stabilized at the desired conditions. The test maneuver was then performed, and data were recorded with the gun not firing and firing. A comparison of the two conditions was made. Test techniques were derived from previous firing tests conducted by USAAEFA (refs 7 and 8, app A). Stability and control tests were conducted using standard test techniques and data reduction procedures (ref 9). Test methods are briefly described in the appropriate sections in the Results and Discussion section of this report. During all tests, data were recorded on magnetic tape. Hand-recorded data were also taken from cockpit indicators during the stability and control testing. Debris patterns ofthe gun casings and links were recorded on 16mm motion picture film. A detailed listing of test instrumentation is included in appendix C. A Handling Qualities Rating Scale (HQRS) and a Vibration Rating Scale (VRS) were used to supplement pilot comments (app D).

Table 1. General Test Conditions.

Type of Test	Rotor Speed (rpm)	Gross Weight (lb)	Longitudinal Center of Gravity (fs)	SCAS	Airspeed Condition (kt)	Altitude Above Ground Level (ft)	Gun Azimuth[1] (deg)
Gun firing	324	9200 to 9600	194.0 to 196.0	ON and OFF	0[2,3] to 156	10 to 1200	-90 to +90
Stability and control	324	8600 to 9500	194.0 to 196.4	ON and OFF	0[3,4] to 143	10 to 4000	stowed

[1] -90° gun oriented 90° to left of aircraft nose.
+90° gun oriented 90° to right of aircraft nose.
[2] Knots indicated airspeed (KIAS).
[3] Low-speed flight was knots true airspeed (KTAS).
[4] Knots calibrated airspeed (KCAS).

RESULTS AND DISCUSSIONS

GENERAL

6. The handling qualities and vibration characteristics of the AH-1S/ECAS during 20mm gun firing were satisfactory, except that the lateral portion of the armament compensation system was inadequate. The stability and control characteristics of the aircraft (gun stowed) were unchanged from the production AH-1S. The inability to start the aircraft on a hot day (35°C) using the normal start procedure was a deficiency. A modified interim start procedure is recommended in paragraph 30. Seven shortcomings noted below were noted or alluded to on previous AH-1G or AH-1S reports. During the firing phase of the evaluation the shortcoming noted was the inability to maintain directional control in 30 KTAS right sideward flight, while firing 90° to the aircraft's nose. During the stability and control phase of the evaluation, two shortcomings were noted. At airspeeds above 80 KCAS, SCAS OFF, the lateral-directional oscillation (dutch-roll) was divergent and easily excited, and extensive pilot compensation was required to maintain a wings-level attitude. The lateral and longitudinal cyclic control has a high breakout force (including friction) which was detrimental to precise airspeed and heading control. Additional shortcomings included the design of the trigger guard on the Telescopic Sight Unit (TSU), the location of the gunner emergency hydraulic control switch, the ability to inadvertently disable the Helmet Sight Subsystem (HSS), and the location of the circuit breakers under the pilot collective control. Three shortcomings attributed to the AH-1S/ECAS include the lack of a gun position indicator, the operation of the gun stowed caution light, and the lack of ON/OFF markings on the weapon control switches. A CAUTION is recommended for inclusion in the operator's manual concerning the possible loss of directional control when firing off the nose in a right cross-wind greater than 20 knots. A NOTE is also recommended for inclusion concerning the possibility of interrupt fire when firing forward while in a tailwind. A NOTE is recommended for inclusion in the AH-1S/ECAS checklist warning of the possibility of hitting the cyclic control while starting with the modified start procedure.

WEAPON FIRING

General

7. The PAE investigated the effects of turret installation and weapons firing on the flying qualities and vibration characteristics of the AH-1S helicopter with the UTS and M-197 20mm gun installed. Evaluations were made at different gun azimuth and elevation combinations (table 2) both prior to and during weapons firing (750 shots per minute) to obtain handling qualities changes attributed to firing. Gun azimuths and elevations shown in table 2 were approximated due to the lack of a gun position indicator in the cockpit. During hover flight, low-speed flight, and pull-ups, the gun was aimed at a specific target. During all other firing tests, the gun was fired at the specified azimuth and elevation. The aircraft was flown in coordinated (ball-centered) flight, except where specified in table 2. All flights were flown at 324 rpm main rotor speed. All flights started with full fuel and 700 rounds of 20mm ammunition on board, except for one lightweight flight which was conducted

with a reduced fuel load. There was negligible difference between aircraft response to firing at light weight versus heavy weight. Gun noise in the cockpit was acceptable during firing. No gas contamination was observed in the cockpit during firing, although no quantitative measurement was taken. Debris patterns of firing, although no quantitative measurement was taken. Debris patterns of the spent casings and links were photographed with high-speed cameras at selected points throughout the flight regime, especially in those areas where previous testing had indicated possible contact with the fuselage or tail rotor. No impacts with the airframe were noted.

Forward Flight

8. The aircraft response to weapon firing in level flight was evaluated at the conditions shown in table 2. For these tests the gun was oriented at the specified azimuth and elevation, the flight controls fixed, and the gun fired. Aircraft response varied with gun orientation. With the gun oriented forward, aircraft reaction was minimal at all gun elevations tested. SCAS inputs from the armament compensation unit were adequate to hold aircraft attitude. With the gun oriented 90° to the nose of the aircraft, the aircraft rolled in the direction of fire (left roll with gun firing left) while pitch attitude and heading remained constant. Figure 1, appendix E, shows that a change in roll attitude of approximately 5° to the right occurred during the 4-second gun firing to the right at zero elevation; while figure 2 shows that a 5° left roll attitude resulted after 4 seconds of firing to the left. Roll SCAS inputs from the armament compensator (app B) were not adequate to hold the aircraft attitude, using only 30% to 40% of the 59% SCAS authority available. The lack of adequate armament compensation was evident in all firing tests conducted. Minimal pilot compensation was required to overcome the effects of weapon firing (HQRS 3). Aircraft reation would not be a factor in firing the weapon with either the TSU or the HSS. The aircraft response to weapon firing in level flight was satisfactory.

Hovering Flight

9. Aircraft response to weapon firing while in a hover was evaluated at the conditions shown in table 2. The aircraft was stabilized in a hover, the gun aimed at a specific target at the approximate azimuth and elevation required, and the weapon fired. The flight controls were manipulated to keep the helicopter stationary over the ground. Aircraft reaction to firing the weapon forward was minimal. The pilot had to compensate slightly for maximum elevation and depression (HQRS 3), but the control movement was often masked in the movement required to hover. When firing straight ahead or maximum up-elevation, aircraft pitch attitude changed approximatley 5° nose down. The pitch armament compensator provided full authority when firing at maximum elevation (+21°). When firing ±90° to the nose of the aircraft, the aircraft rolled in the direction of the gun firing (left bank with firing to the left). The maximum attitude attained was 15° right bank. Time histories (figs. 3 and 4, app E) show that an initail lateral input was made by the SCAS, but the SCAS ceased to function immediately afterwards. Even though the lateral SCAS was inoperative for a great portion of the burst, the gunner had no problem in maintaining his aiming point. The aircraft response to weapon firing while in a hover is satisfactory.

Table 2. Gun Firing Test Conditions.[1]

Test Condition		Trim Indicated Airspeed[1] (kt)	Average Gross Weight (lb)	Average Density Altitude (ft)	Gun Azimuth (deg)	Gun Elevation (deg)
Trimmed level flight		78, 114, 126	9500	5000	0, ±90	0
		78, 114, 126	9500	5000	0	-50
Hover		0	9560	3300	0, ±90	0
		0	9560	3300	0	+14
		0	9560	3400	0	-50
Low-speed[2]		15, 30	9500	4000	0, ±90	0
Dives		156	9420	5000	0, ±90	0
Pull-up[3]		150	9600	5000	0, ±90	0
Out-of-trim flight[4]		40, 110	9200	5000	± 90	0
SCAS degraded modes[5]	Hover	0	9360	4000	0,± 90	0
		0	9360	4000	0	+14
	Trimmed level flight	100	9540	5000	0, ±90	0

[1] Instrumentation pods installed, 324 rpm rotor speed, SCAS ON, average cg at fs 195.0 (mid).
[2] Approximate true airspeeds; left, right, forward, and rearward flight.
[3] Symmetrical, left rolling, right rolling.
[4] Trimmed one ball width out.
[5] Single axis disengaged, and all axes disengaged.

Low-Speed Flight

10. The aircraft response to weapon firing in low-speed flight (0 to 30 KTAS) was evaluated at the conditions shown in table 2. Ground speed was estimated by the pilot. During these maneuvers the gun was aimed at a specific target, the aircraft accelerated to the desired ground speed, and the weapon fired. Controls were moved to adjust aircraft attitude when necessary. Changes in aircraft attitude and/or changes in control positions between firing and nonfiring events were indicative of aircraft reaction.

11. Aircraft reaction to gun firing during low-speed forward flight was minimal. With the gun aimed forward some pitch-down tendency was noticed during firing; however, no control compensation was needed (HQRS 2). With the gun aimed 90° off the nose, the aircraft banked 10° in the direction of weapon fire. The input from the armament compensator was 40% to 50% of roll SCAS authority, which was inadequate to hold the bank attitude of the aircraft. Aircraft reaction to gun firing in low-speed forward flight did not affect the gunner's ability to aim and fire at a target, and is satisfactory.

12. Aircraft response to gun firing in low-speed rearward flight was large nose-down pitch excursions, causing the gun to hit the upper stop (+12°). This resulted in interrupted fire at rearward airspeeds of approximately 30 KTAS. With the gun firing forward a pitch-down change of 5° resulted when flying rearward at 15 KTAS. The aircraft also accelerated rearward due to gun firing. At a rearward airspeed of 30 KTAS when the gun was fired forward, the aircraft tended to pitch further nose-down, eventually interrupting fire when gun elevation limits were reached. This test simulated firing the gun in a hover with a tailwind. With the gun oriented 90° to the nose, the excessive pitch attitudes were alleviated. Due to a possible momentary loss of the ability to fire the weapon the following NOTE should be included in the operator's manual.

NOTE

> When firing the 20mm gun near 0° azimuth with a direct tailwind, the possibility of interrupted fire exists due to the nose-low attitude of the aircraft.

13. Aircraft reaction to sideward low-speed flight generally resulted in larger roll attitudes when the aircraft was translating in the direction of gun firing. At 15 KTAS, pitch and yaw SCAS compensations were adequate to maintain pitch and yaw attitudes, requiring no pilot compensation in these axis. Minimal pilot compensation was required to control all excursions (HQRS 3). At 30 KTAS in left sideward flight, the reactions noted at 15 KTAS were repeated. In right sideward flight, with the gun firing 90° left, the pilot was unable to maintain directional heading. While firing 90° right, directional control was maintained, but full pedal was required (figs. 6 and 7, app E). This test demonstrated that when hovering in a right crosswind greater than 20 knots, the pilot may not be able to maintain directional control when firing 90° to the nose. At 30 KTAS right sideward flight (simulated right crosswind), the inability to maintain directional control) while firing the gun ±90° is a shortcoming. The following CAUTION should be included in the operator's manual.

CAUTION

When firing the 20mm gun 90° right or left while hovering in a right crosswind greater than 20 knots, the pilot may have inadequate directional control to maintain aircraft heading.

Pull-Ups

14. Aircraft response to weapon firing during maneuvering flight was evaluated using symmetrical and rolling pull-ups at the conditions shown in table 2. The aircraft was trimmed in level flight at 72% torque, dived to approximately 150 knots indicated airspeed (KIAS), and the pull-up and firing were initiated simultaneously. In this maneuver the weapon was aimed at a target at approximately 0° azimuth and 0° elevation to the aircraft. The gunner then maintained this target throughout the maneuver. A symmetrical pull-up was initiated by a smooth aft cyclic input, attaining an approximate load factor of 2.0 in 3 seconds. Firing was commenced simultaneously with the pull-up and maintained until after the maximum load factor was reached. Rolling pull-ups were accomplished in a similar manner with the exception that a lateral input was initiated with the aft input resulting in a 40° bank angle. Nonfiring data were obtained on separate maneuvers using the same techniques. Aircraft response to weapon firing during the pull-up was negligible and did not interfere with the maneuver. The gunner noticed some blurring of the target through the TSU during weapons firing in the pull-out, but the target remained distinguishable and impacts observed. As with hovering flight (para 9) the lateral SCAS failed for a period of time (figs. 8 through 11, app E) during four of the pull-ups. The failure caused a control input to the aircraft when the SCAS returned to center which was uncomfortable but controllable. Except for the occasions when the lateral SCAS failed, the aircraft response to weapon firing during maneuvering flight was satisfactory.

Dives

15. Aircraft response to weapon firing at airspeeds greater than the maximum airspeed for level flight (V_H) was evaluated at the conditions shown in table 2. The aircraft was trimmed in level flight at 72% torque (recommended dive torque setting), nosed over into a dive, stabilized at 150 KIAS with the gun oriented at the specified azimuth, and the firing sequence initiated. Aircraft controls were held fixed throughout the maneuver. The aircraft maintained a constant pitch and yaw attitude during firing, although directional pedal control was very sensitive at that airspeed. The aircraft rolled in the direction of gun firing when it was displaced in azimuth. The armament compensator lateral inputs averaged only 40% SCAS authority when the gun was ±90° azimuth. Maximum roll attitudes did not exceed 10° from level flight and were no hindrance to the pilot. The aircraft response to weapon firing in a dive is satisfactory.

Out-of-Trim Flight

16. The aircraft response to weapon firing while firing in an out-of-trim condition was evaluated at the conditions shown in table 2. The test was conducted by trimming the aircraft in level flight one ball width from coordinated flight and holding flight controls fixed. The gun was then oriented in the direction of the sideslip and fired. In all cases the aircraft responded by increasing the sideslip angle (ball to end

of the race); however, the aircraft remained under full control (HQRS 3), and the side forces provided adequate cues to the pilot of the out-of-trim condition. The out-of-trim response of the aircraft to weapons firing is satisfactory.

Stability and Control Augmentation System OFF Flight

17. Aircraft response to weapon firing with the SCAS partically and totally disabled was tested at the conditions shown in table 2. In both hover and forward flight the gun was fired with each individual SCAS axis failed and also with all axes failed. With any SCAS axis disengaged, the aircraft reacted more than with the SCAS engaged, requiring moderate compensation to control (HQRS 4). In a hover, a maximum of 1 inch of control movement in the failed SCAS axis was required to counteract the moments generated by the gun at critical azimuths and elevations. At 100 KIAS approximately 0.5 inch was required. Aircraft response to weapon firing with the SCAS disengaged is satisfactory.

STABILITY AND CONTROL CHARACTERISTICS

General

18. The stability and control characteristics of the AH-1S/ECAS were evaluated at the conditions listed in table 3. The trim conditions for the test were wings-level coordinated (ball-centered) flight. The evaluation encompassed both engineering flight tests and mission maneuvers. The installation of the UTS did not adversely affect the stability and control characteristics of the ECAS. Handling qualities ratings were used to quantify the degree of difficulty or pilot effort required to accomplish a specific task.

Control System Characteristics

19. Mechanical characteristics of the helicopter flight controls were evaluated on the ground with the engine secured and the rotor static. Electrical and hydraulic power were furnished by external sources. Control forces were measured on the pilot flight controls (aft cockpit) with the force trim ON. Cyclic displacements and forces were measured from the middle of the cyclic counter grip. The cyclic on the AH-1S/ECAS is preloaded with a 2-pound breakout force designed to prevent SCAS feedback. Control system forces as a function of control position are presented in figures 12 through 14, appendix E. The results of the control system evaluation are summarized in table 4. During maneuvering flight the high cyclic breakout forces (including friction) required minimal pilot compensation (HQRS 2); however, during precise tasks, such as maintaining exact airspeed, pilot workload increased (HQRS 4) and pilot-induced oscillations occurred. The high cyclic breakout forces (including friction) are a shortcoming and have been noted on other AH-1S reports.

Static Longitudinal Stability

20. The static longitudinal stability characteristics of the test aircraft were evaluated in a clean (no wing stores) configuration at the conditions shown in table 3. Tests were conducted by trimming the aircraft in level flight (62 and 131 KCAS) and then stabilizing at incrementally higher and lower airspeeds with collective position held fixed at the trim setting. Data were recorded at each stabilized air-

Table 3. Handling Qualities Test Conditions.[1]

Type of Test		Average Gross Weight (lb)	Average Longitudinal Center-of-Gravity Location (fs)	Average Density Altitude (ft)	Trim Calibrated Airspeed (kt)	SCAS Condition
Static longitudinal stability		9060	194.1 (fwd)	5500	63	ON
		8860	194.2 (fwd)	6000	131	ON
Static lateral-directional stabiltiy		9100	194.0 (fwd)	5800	65	ON
		8920	194.1 (fwd)	6200	116	ON
Maneuvering stability		8540	194.2 (fwd)	6800	116	ON
		8320	194.3 (fwd)	6500	116	ON
Dynamic stability	Dutch roll	8900	194.1 (fwd)	6300	62, 78, 98, 101, 108, 128, 138	ON & OFF
	Long-term response	9060	194.1 (fwd)	6500	52, 122	ON & OFF
	Short-term response	8700	194.2 (fwd)	6300	62, 116, 127 137	ON & OFF
	Spiral stability	8640	194.2 (fwd)	6100	63, 116	ON & OFF
Controllability		8600	194.2 (fwd)	6400	64	ON
Low-speed flight characteristics	Forward-rearward	9040	194.1 (fwd)	2300	0-55[3]	ON & OFF
	Left & right sideward	8760	194.2 (fwd)	2700	0-35[3]	ON & OFF
	65° (crit azimuth)	8560	194.2 (fwd)	2900	0-35[3]	ON & OFF
Mission maneuvers		9500	196.4 (mid)	2600	0-35	ON

[1] Clean configuration, rotor speed 324 rpm for all tests.
[2] Lateral cg 0.1 in. (rt) for all tests.
[3] KTAS

Table 4. Control System Mechanical Characteristics.

Test Parameter	Control System		
	Longitudinal	Lateral	Directional
Breakout force (including friction) (lb)	2.1 fwd, 4.0 aft	3.3 left, 3.0 right	2.5 left, 2.0 right
Full control travel (in.)	9.85	9.75	5.50
Control oscillation	None	None	None
Free play (in.)	Negligible	Negligible	Negligible
Mechanical coupling	None	None	None
Force to move control 0.5 inch from trim (lb)	3.0 fwd, 4.2 aft	4.8 left, 4.0 right	NA
Control centering	Positive	Positive	Positive
Control jump	Negligible	Negligible	Negligible
Control forces trimmable to zero	Yes	Yes	Yes
Force gradient (lb/in.)	1.1 fwd, 1.2 aft	0.92 left, 0.85 right	3.6 left, 4.1 right

speed, and the test results are presented in figures 15 and 16, appendix E. Static longitudinal stability, as indicated by the variation of longitudinal cyclic control position with airspeed, was stable (increasing forward cyclic with increasing speed) throughout the airspeed ranges tested and is satisfactory.

Static Lateral-Directional Stability

21. The static lateral-directional stability characteristics of the test aircraft were evaluated at the conditions shown in table 3. Tests were conducted by first trimming the aircraft at zero sideslip in level flight (65 and 116 KCAS) and then stabilizing at incrementally increasing left and right sideslip angles. Data were recorded at each stabilized flight condition with ship's system indicated airspeed, collective control position, aircraft ground track, heading, and sideslip angle held constant. Test results are presented in figures 17 and 18, appendix E. Static directional stability was positive (increasing left directional control with increasing right sideslip) throughout the sideslip envelope for both trim airspeeds and was satisfactory. Dihedral effect was also positive (increasing right lateral cyclic control with increasing right sideslip) throughout the sideslip envelope for both trim airspeeds and is satisfactory. The side-force characteristics are essentially the same as the AH-1G with the 212 tail rotor (ref 11, app A), and are satisfactory.

Maneuvering Stability

22. The maneuvering stability characteristics of the test aircraft were evaluated in steady-state turns at the conditions shown in table 3. Evaluations were conducted at normal rated power and power for level flight at 116 KCAS. The steady-state turns were conducted by trimming at 116 KCAS and then stabilizing in coordinated flight at incrementally increasing roll attitudes while maintaining collective control and airspeed constant. Data were recorded at each stabilized condition and are presented in figures 19 and 20, appendix E. The variation of longitudinal control position with normal load factor (stick-fixed stability) was positive (aft cyclic control movement with increasing load factor) and was essentially unchanged from the AH-1R (ref 12, app A). The variation of control force with normal load factor (stick-free stability) was positive (aft cyclic control force with increasing load factor). Considerable pilot compensation was required to maintain precise airspeed control above approximately 1.35 normal load factor (HQRS 5). At these load factors, airspeed tended to drift 3 to 5 knots above and below trim airspeed. Small longitudinal cyclic control inputs resulted in comparatively larger changes in airspeed so that the pilot tended to "chase" the desired airspeed. Although the pilot had difficulty in maintaining precise trim airspeeds, no divergent tendencies were noted. The undesirable maneuvering stability characteristics above 1.35 normal load factor significantly increased pilot workload and are a shortcoming previously reported in the AH-1R (ref 10).

Dynamic Stability

23. The longitudinal and lateral-directional dynamic stability of the test aircraft was evaluated at the conditions shown in table 3. Short-term dynamic testing was conducted, SCAS ON and SCAS OFF, by trimming the aircraft in level flight (62 to 140 KCAS), rapidly displacing the desired flight control 1 inch from trim for a duration of 0.5 second, and then returning the control to the original trim position. The SCAS ON time histories are presented in figures 21 through 29, appendix E.

With SCAS ON, the short-term response was heavily damped at trim airspeeds below 116 KCAS and was satisfactory. The short-term response at airspeeds between 116 and 135 KCAS (SCAS ON) was also satisfactory. At airspeeds between 116 and 135 KCAS with the cyclic fixed and no pulse inputs, oscillatory yaw rate excursions of 3 deg/sec were recorded but were not perceived by the pilot. The damping of the yaw rate oscillation decreased as airspeed increased. Previous tests (ref 10, app A) indicate that this condition will be aggravated at higher gross weights. At 135 KCAS the yaw rate oscillations were neutrally damped, but further analysis is required to evaluate the oscillatory yaw rate effect upon fixed weapon accuracy at airspeeds above 135 KCAS.

24. During the SCAS OFF evaluation of the short-term response, significant roll - yaw coupling (dutch roll) was observed. The dutch roll mode was easily excited and required significant pilot effort to maintain aircraft heading and attitude. As indicated airspeed was increased, yaw response to the 1 inch - 1/2 second pulse was relatively constant, but roll response increased significantly. This resulted in extensive pilot workload to maintain level flight above 100 KIAS (HQRS 6). Between 64 and 98 KCAS, roll rates and attitudes reached a maximum of 22 deg/sec and 21 degrees, respectively (figs. 30 through 33, app E). Between 80 and 140 KCAS the dutch roll became increasingly unstable as airspeed increased (figs. 35 through 37). At 128 KCAS the aircraft reached roll rates of 46 deg/sec approximately 4.0 seconds after the pulse input. The period of the oscillation was approximately 4.5 seconds throughout the airspeed range tested. The easily excited, divergent dutch roll above 80 KCAS (SCAS OFF) is a shortcoming.

25. Spiral stability characteristics were evaluated SCAS ON and SCAS OFF at 64 and 116 KCAS. The evaluation was performed by rolling the aircraft with directional control only from trimmed level flight and then returning the control to trim and observing the resultant roll attitude change with controls fixed. At 64 KCAS (SCAS ON and OFF) and 116 KCAS, SCAS ON, spiral stability was positive and the aircraft returned to a trimmed level attitude. Spiral stability evaluation could not be accomplished at 116 KCAS, SCAS OFF, due to the dutch roll instability (para 24). The spiral stability characteristics are satisfactory.

26. The long-term longitudinal dynamic characteristics were evaluated SCAS ON and OFF at the conditions stated in table 3. The test was conducted by slowing the aircraft with aft cyclic control to an airspeed 5 and 10 knots below the trim airspeed, then slowly returning the control to the trim position and noting aircraft response. With SCAS ON the long-term longitudinal response was oscillatory with only two or three overshoots before convergence (figs. 38 and 39, app E). At 64 KCAS, SCAS OFF, with a 5 knot reduction in airspeed, the long-term response was oscillatory with essentially the same characteristics as SCAS ON (fig. 40).The SCAS OFF evaluation was not accomplished at 116 KCAS due to the dutch roll instability (para 24) which masked all lont-term response. At the conditions tested the long-term longitudinal response of the aircraft is satisfactory.

Controllability

27. Controllability characteristics were evaluated in forward flight, SCAS ON. The aircraft was trimmed at 64 KCAS, and control step inputs of varying magnitudes were applied to each axis, using a mechanical fixture to obtain the desired input.

The inputs were held until a maximum rate was established or until recovery was necessary. Test results are presented in figures 41, through 43, appendix E. The controllability characteristics of the ECAS are essentially the same as the AH-1G with the 212 tail rotor (ref 11, app A), and are satisfactory.

Low-Speed Flight Characteristics

28. The handling qualites of the test aircraft during low-speed flight were evaluated at the conditions listed in table 3. The test aircraft was flown in ground effect at an approximate skid height of 10 feet. A calibrated radar speed gun mounted on a pace vehicle was used to obtain ground speed. Winds during this test were less than 5 knots, and the aircraft true airspeed and relative wind angle were determined by a vector sum of aircraft and wind velocities. The variation of control positions (figs. 44 through 47, app E) during low-speed flight shows varying gradients depending on the direction and magnitude of the relative winds. The only apparent changes in control position gradient noticeable to the pilot were (1) longitudinal cyclic position changes passing through translational lift in rearward flight, and (2) the shift in pedal position passing translational lift in left sideward flight. During the SCAS OFF portion of the evaluation, pilot workload was increased slightly due to larger directional control excursions (HQRS 3), but was not detrimental to the low-speed flying qualities.

29. The critical azimuth was determined by varying the relative wind in 10° increments between 0 and 180° aircraft azimuth. The critical azimuth was approximately 65° right of the nose. The results of the critical azimuth evaluations are presented in figures 48 and 49, appendix E. The minimum directional control margin (11% travel remaining) was reached at approximately 20 KTAS; however, it should be noted that the configuration tested was approximately 1000 pounds lighter than the configuration tested during firing. During firing at the higher gross weight a directional control limit was reached (para 13). Handling qualities in low-speed flight simulating a hover in varying wind conditions are unchanged from the production AH-1S and are satisfactory.

HUMAN FACTORS/COCKPIT EVALUATION

Engine Start

30. During the ECAS evaluation, the average ambient temperature for starting was 30° Celsius (°C) with a maximum of 50°C. At these temperatures normal starting procedures were ineffective because the turbine gas temperature (TGT) limit would have been exceeded (973°C momentary limit) before 40% gas turbine speed (N_1) was reached. At the maximum TGT noted (950°C), N_1 was only 27% to 30%. A modified starting procedure was used which consisted of turning off the ignition key when TGT reached 750°C (N_1 = 21% to 25%) and turning it back on when N_1 reached 40%. This method always achieved a start. Turning off the ignition key cuts off the starting fuel, lowering the total amount of fuel going to the engine, and thus reducing the temperature. Turning on the key at 40% N_1 does not affect TGT since the automatic start sequence cuts off start fuel at 40%, but it does allow for emergency restart. At the conditions tested 750°C was generally achieved at 21% to 25% N_1. The inability to achieve a start on a hot day (35°C) using the normal starting procedure is a deficiency. An interim hot day starting procedure should be adopted and the checklist (Engine Start) be changed to read:

a. Pull ignition trigger.

b. Ignition key OFF at 750°C.

c. Release trigger at 40% N_1.

d. Ignition key ON at 40% N_1.

31. The interim procedure recommended in paragraph 30 requires the pilot to use both hands for the start. This allows the cyclic to initially remain free. Additionally, the pilot's right hand must move across the cockpit to reach the ignition key which is located on the left forward panel. There is a possibility of hitting the cyclic. The following NOTE should be added to the interim checklist after Engine Start.

NOTE

Initially during the starting procedure the cyclic will be free to move. Inadvertently hitting the cyclic when reaching for the ignition key can cause damage to the input quill seal and main drive shaft.

Telescopic Sight Unit

32. The TSU is the unit used by the gunner to sight and fire either the TOW missile or the M-197 20mm gun. This unit has a trigger that is covered with a guard. The trigger guard is adjusted with an Allen screw (photo A). When in the "gun" mode, the trigger has two positions (detents). The first detent allows a 16-round burst to be fired, while the second detent allows continuous fire. During the evaluation, the gunner was able to squeeze off a 16-round burst with the trigger guard covering the trigger, because the Allen screw had loosened. The screw was tightened, but after 2 flight hours was found to be loose. A lock-tight compound was used to secure the screw in place. Because of the vibrations present in flight, this is a temporary solution. The trigger guard on the TSU which allows the 20mm gun to be inadvertently fired is a shortcoming.

Gun Position Indicators

33. The position of the gun can not be readily determined from the cockpit. There is no cockpit indicator which shows the position of the gun, and the pilot can only see the gun when it is oriented to the side of the aircraft. The lack of a gun position indicator required the pilot to obtain outside help to position the gun for landing, and is a shortcoming.

34. The weapon system was equipped with a caution light which indicated when the gun was stowed. However, this light only illuminated when the master arm switch was OFF. With the control is standby (STBY) or ARM, the light would not illuminate, and the pilot did not know if the weapon was stowed. The inability to determine when the gun is in the stowed position with the master arm switch in the STBY or ARM positions is a shortcoming.

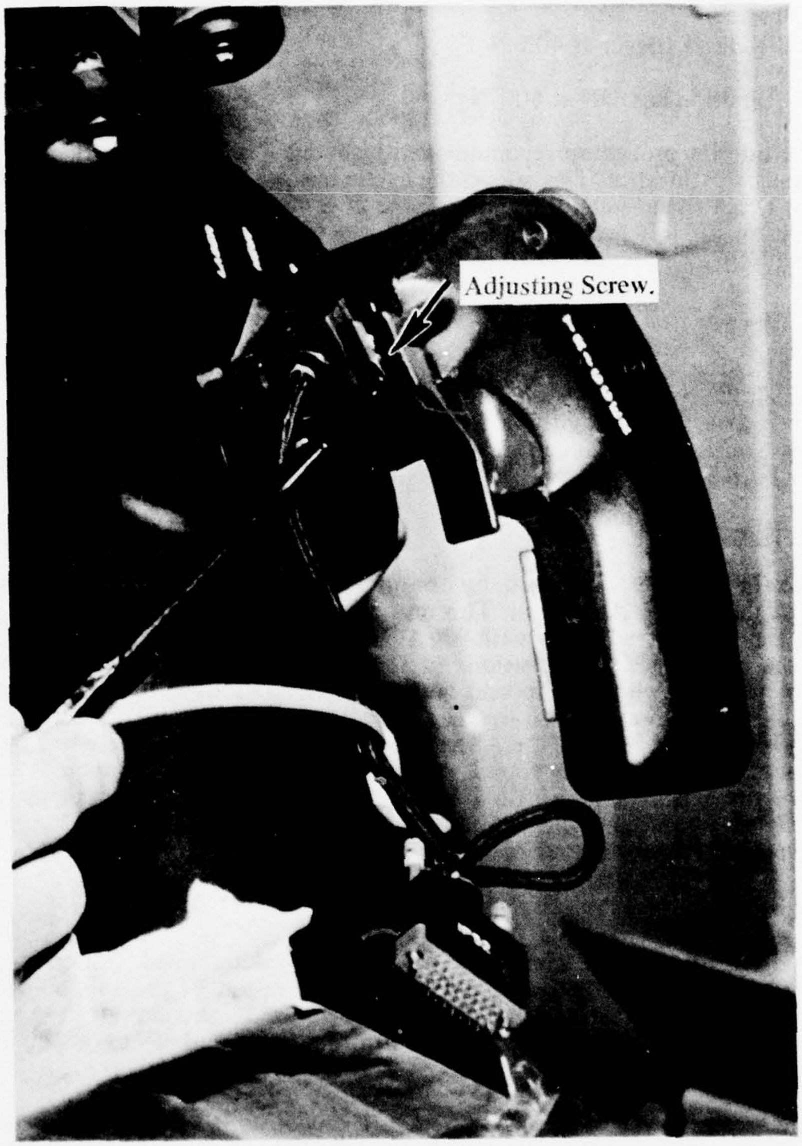


Photo A. TSU Trigger Assembly.

Helmet Sight Subsystem

35. The HSS is an electromechanical system which is attached to the helmet of the pilot and/or gunner and is designed to enable the pilot to aim the 20mm gun while keeping both hands on the aircraft controls. By sighting on a target using a reticle attached to his helmet and depressing an actuator bar on the cyclic, the pilot can maneuver and fire the 20mm gun. In order to check that the system is operational, the attaching end of the electromechanical arm is placed in a Built-In-Test (BIT) magnet socket (fig. A), and a BIT button is actuated in the gunner cockpit (fig. B). If this BIT button is actuated with the system connected to the pilot helmet the system is failed, and the pilot is unable to fire the weapon using the HSS. To reactivate the system the procedure is to disconnect the pilot linkage arm from the helmet (a two-handed operation), place the arm in the test socket, activate the BIT button, and then reattach the arm to the helmet. This procedure is not practical in combat and would seriously diminish the ability of the aircraft to defend itself if the BIT button were the ability of the aircraft to defend itself if the BIT button were inadvertently pushed. The ability to inadvertently disable the HSS by depressing the BIT button is a shortcoming.

Emergency Hydraulic Switch

36. On
two occasions, the gunner inadvertently struck the emergency hydraulic switch with his foot. The switch is located on the left forward panel and is unprotected (photo B). *Damage to a primary* emergency control is possible. The location of the gunner emergency hydraulic switch on the ECAS is a shortcoming.

37. Additional cockpit items which were considered to be shortcomings included:

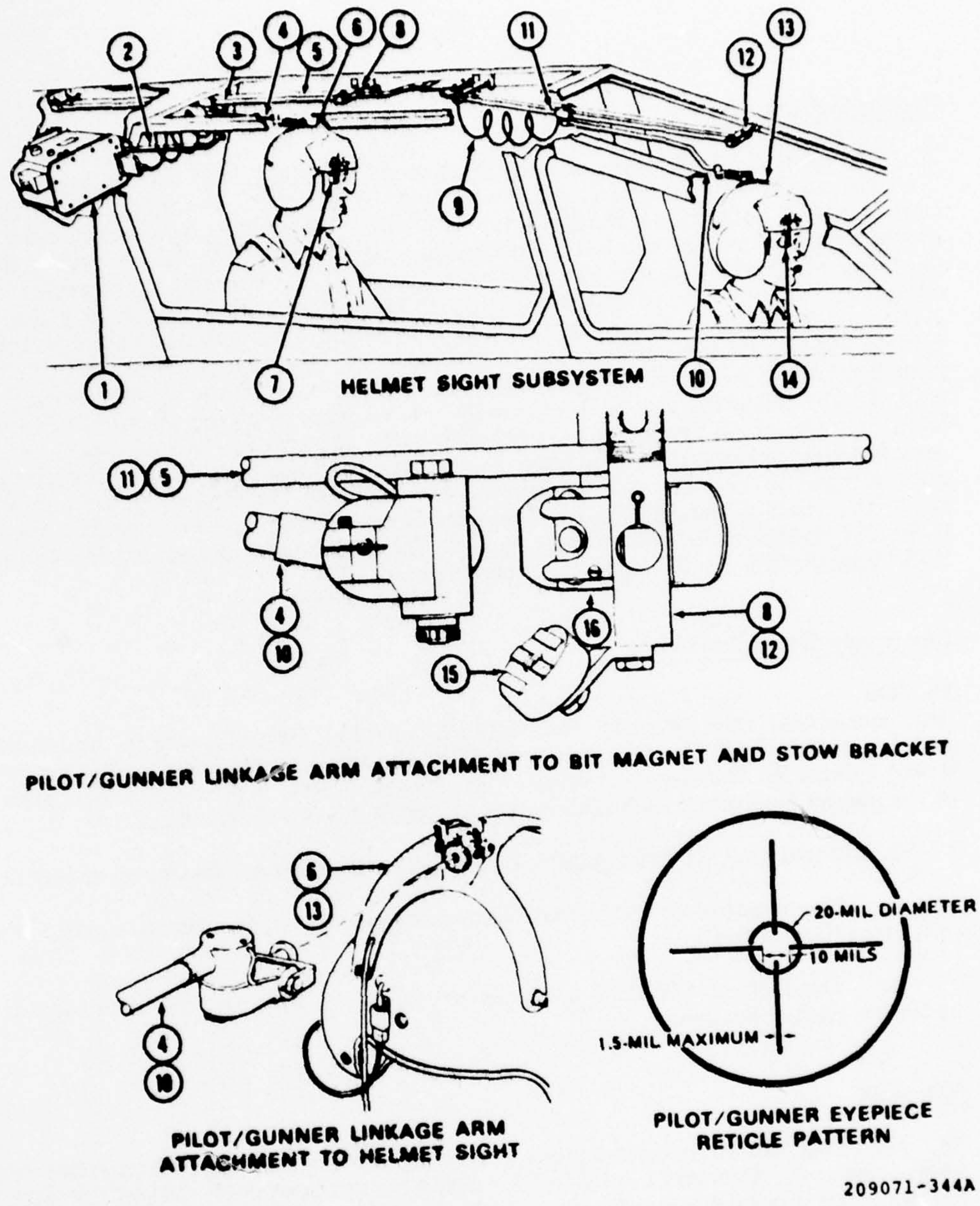
a. The location of the circuit breakers under the pilot collective noted on other reports (photo C).

b. The lack of ON/OFF markings on the weapon control switches located under the pilot collective.

Vibration

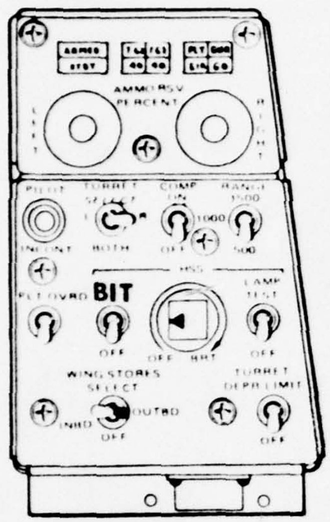
38. Nonfiring vibrations throughout the flight envelope were representative of levels seen in previous AH-1 tests (ref 12, app A). Vibrations in level flight for rotor harmonics of 1 per-rotor revolution (1/rev), 2/rev, 4/rev, 6/rev, and 8/rev are shown in figures 50 through 65, appendix E.

39. Gun firing vibrations varied in amplitude depending on gun elevation and azimuth angles. Vibrations due to gun firing were not considered to be uncomfortable or objectionable at any time (VRS 4). Representative spectral plots showing gun firing vibrations are shown in figures 66 through 70, appendix E.



1. Electronic interface assembly
2. Gunner extension cable
3. Pilot linkage cable
4. Pilot linkage arm
5. Pilot linkage rails
6. Pilot helmet sight
7. Pilot eyepiece
8. Pilot linkage front support
9. Gunner linkage cable
10. Gunner linkage arm
11. Gunner linkage rails
12. Gunner linkage front support
13. Gunner helmet sight
14. Gunner eyepiece
15. BIT magnet
16. Stow bracket

Figure A. Helmet Sight Subsystem.



LOCATION: GUNNER RIGHT CONSOLE

ITEM		FUNCTION
TURRET DEPR LIMIT Switch	OFF	— Permits turret travel between minimum to maximum elevation.
	DEPR LIMIT	— Limits downward travel to prevent turret weapons from striking ground.
WING STORES SELECT Switch	OFF	— Deactivates wing stores (not TOW) circuits.
	INBD/ *OUTBD*	— Permits gunner to fire inboard/outboard wing stores.
		Functions only when PLT OVRD switch in OVRD.
PLT OVRD Switch	OFF	— Permits pilot armament control panel to control the weapons.
	PLT OVRD	— Overrides pilot armament control panel. Permits gunner to fire turret using HSS, and wing stores (not TOW) without sight.
HSS BIT SWITCH	OFF	— Deactivates pilot and gunner HSS built-in test circuit.
	BIT	— Tests pilot and gunner HSS when linkage arms attached to BIT magnets.
HSS RETICLE OFF/BRT Switch	OFF	— Deactivates gunner HSS reticle lights.
		Varies intensity of gunner HSS reticle lights when turned

Figure B. Gunner Armament Control Panel.

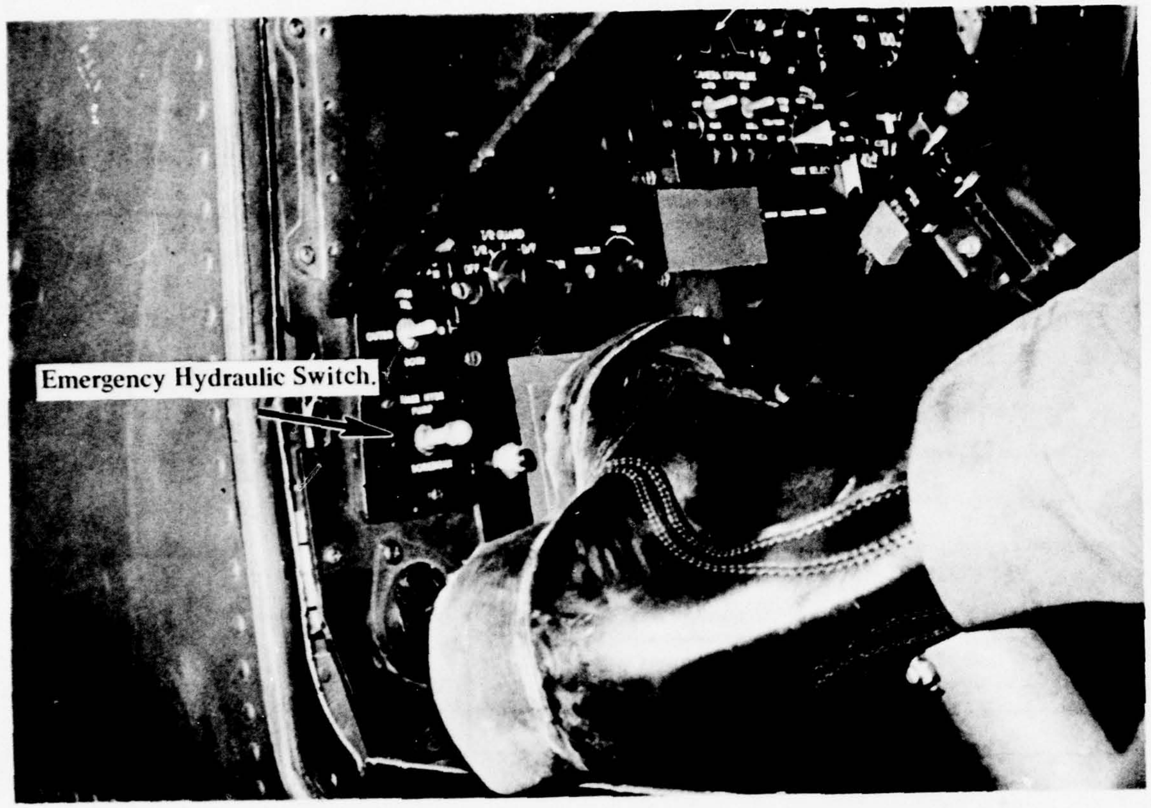


Photo B. Left Forward Panel Gunner's Cockpit.

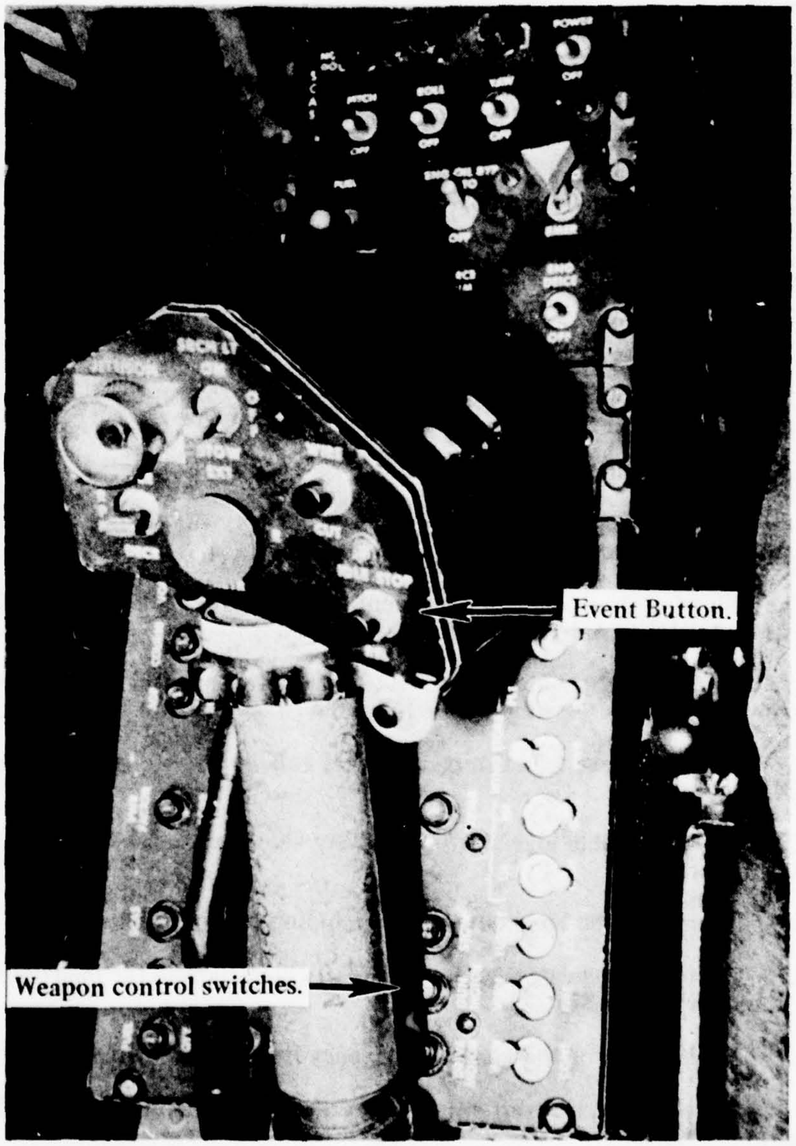


Photo C. Right Lower Console Pilot's Cockpit.

CONCLUSIONS

GENERAL

40. The following conclusions were reached upon completion of the PAE of the AH-1S/ECAS helicopter with the Universal Turret Subsystem installed.

a. The aircraft response to 20mm weapon firing is satisfactory.

b. The stability and control characteristics of the aircraft were essentially unchanged from the production AH-1S.

c. The lateral armament compensation portion of the system during firing is inadequate.

d. One deficiency and 11 shortcomings were identified.

DEFICIENCY AND SHORTCOMINGS

41. The following deficiency was identified.

a. The inability to start the engine on a hot day (35°C) using the published starting procedures (para 30).

42. The following shortcomings were identified and have been noted or alluded do on previous AH-1G or AH-1S reports.

a. The inability to maintain directional control at 30 KTAS right sideward flight (simulated right crosswind) while firing the gun ±90° (para 13).

b. The easily excited, divergent dutch roll above 80 KCAS (SCAS OFF) (para 24.)

c. The undesirable maneuvering stability characteristics above 1.35g normal load factor (para 22).

d. The high cyclic breakout forces (including friction) (para 19).

e. The trigger guard design on the TSU which allowed the inadvertent firing of the 20mm gun (para 32).

f. The location of the gunner emergency hydraulic control switch (para 36).

g. The ability to inadvertently disable the HSS by depressing the BIT button (para 35).

h. The location of the circuit breakers under the pilot collective (para 37).

43. The following shortcomings are attributed to the AH-1S/ECAS.

a. Lack of a gun position indicator (para 37).

b. The inability to determine when the gun is in the stowed position with the master arm switch in STBY or ARM position (para 34).

c. The lack of ON/OFF markings on the weapons control switches located under the pilot's collective (Para 37).

RECOMMENDATIONS

43. The deficiency identified in paragraph 41 must be corrected.

44. The shortcomings listed in paragraph 42 should be corrected.

45. Further analysis should be accomplished to evaluate the effect of the SCAS ON oscillatory yaw rate upon fixed weapons accuracy at high airspeed (para 23).

46. Incorporate the following CAUTION in the operator's manual (para 13).

CAUTION

> When firing the gun 90° right or left while hovering in a right crosswind greater than 20 knots, the pilot may have inadequate directional control to maintain aircraft attitude.

47. Incorporate the following NOTE in the operator's manual (para 12).

NOTE

> When firing the gun near 0° azimuth with a direct tailwind, the possibility of interrupted fire exists due to the nose low attitude of the aircraft.

48. An interim starting procdure should be adopted and the checklist starting procedure of the AH-1S/ECAS be changed to read as follows (paras 30 and 31).

a. Pull ignition trigger.

b. Ignition key OFF at 750°C TGT.

c. Release ignition trigger at 40% N_1.

d. Ignition key ON at 40% N_1.

NOTE

> Initially during the start procedure, the cyclic will be free to move. Inadvertently hitting the cyclic while reaching for the ignition key can cause damage to the input quill and main drive shaft.

APPENDIX A. REFERENCES

1. Letter, AVRADCOM, DRDAV-EQI, Project No. 78-03, 30 January 1978, subject: Preliminary Airworthiness Evaluation, Enhanced Cobra Armament System (ECAS), Modified AH-1S.

2. Test Plan, USAAEFA, Project No. 78-03, *Army Preliminary Airworthiness Evaluation, Enhanced Cobra Armament System Modified AH-1S,* June 1978.

3. Technical Manual, TM 55-1520-236-10, *Operator's Manual, Army Model AH-1S Helicopter,* 15 January 1977.

4. Letter, AVRADCOM, DRDAV-EQ, 13 July 1978, subject: Airworthiness Release of AH-1S Helicopter S/N 76-22567 for Enchanced Cobra Armament System (ECAS) Flight Testing, with Change 1.

5. Military Specification, MIL-H-8501A, *Helicopter Flying and Ground Handling Qualities; General Requirements For,* 7 September 1961, with Amendment 1, 3 April 1962.

6. Draft System Specification, Contract DAA-T01-76-C-086, "Model AH-1S Helicopter," 8 June 1977.

7. Final Report, US Army Aviation Test Activity (USAAVNTA), Project No. 67-26 (66-06), *Engineering Flight Test of the AH-1G (Hueycobra) Helicopter Equipped with the XM-28 Chin Turret with Twin XM-134 Miniguns, Phase B, Part 3,* March 1968.

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10. Final Report, USAAEFA, Project No. 74-33, *Army Preliminary Evaluation, YAH-1R Improved Cobra Agility and Maneuverability Helicopter,* May 1975.

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13. Textbook, *Mechanical Vibrations, Second Edition,* by W. T. Thompson, June 1954.

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APPENDIX B. DESCRIPTION

GENERAL

1. The Modernized Cobra/TOW entails the development, qualification, and production incorporation of a Universal Turret Subsystem (UTS), a Rocket Management Subsystem (RMS), a Fire Control Subsystem, and several other product improvements of the AH-1S helicopters. This will be accomplished in two major phases.

2. Phase 1, the Enhanced Cobra Armament Subsystem (ECAS), involved the design, development, and a qualification of a UTS RMS, and a second electrical generating system for the aircraft.

3. This appendix will be concerned with the UTS with the General Electric M-197 20mm gun installed, the electrical system, and the modified SCAS.

UNIVERSAL TURRET SUBSYSTEM

4. The UTS is to be a replacement turret for the current M-28 turret. The UTS will accommodate 7.62mm, 20mm, or 30mm, weapons. It is compatible with the M-97 turret and incorporates the M-197 gun.

a. *Turret Structure:* The turret structure is an azimuth-primary gimballed structure consisting of three basic components: the upper support, lower support, and saddle assemblies (fig. 1).

(1) Upper Support: The upper support provides the aircraft interface and mounting provisions. This mechanical interface is compatible with all AH-1 type aircraft. Mounted to the upper support is the azimuth drive, resolver assembly, mechanical stops, limit switches, and the azimuth resolver compensating amplifier.

(2) Lower Support: The lower support is mounted to the upper support through the azimuth bearing. The azimuth drive output pinion meshes with an external ring gear bolted to the lower support to provide azimuth coverage. The lower support contains an integral gear drive for the elevation axis. Also mounted on the lower support are the elevation electrical limit sensors, resolver, resolver compensating amplifier, rounds totalizer, saddle pivot pin bearing, emergency elevation stow switch, and the emergency stow control unit.

(3) Saddle: The saddle is a frame which will support the M-197 gun or the XM-134 weapons and is mounted through pivot pins and bearings to the lower support. The output pinion of the elevation gear drive meshes with the sector gear on the saddle to provide elevation coverage. Mounted on the saddle are the down-limit sensor actuator, emergency stow switch actuator cam, weapon rear ball mount, and weapon mounting pip pins.

(4) Recoil Adapters: Also included as part of the turret system is the low-force recoil absorbing device for the M-197 weapon. The low-force recoil adapter system was developed for turret application on the TOW equipped AH-1J helicopter.

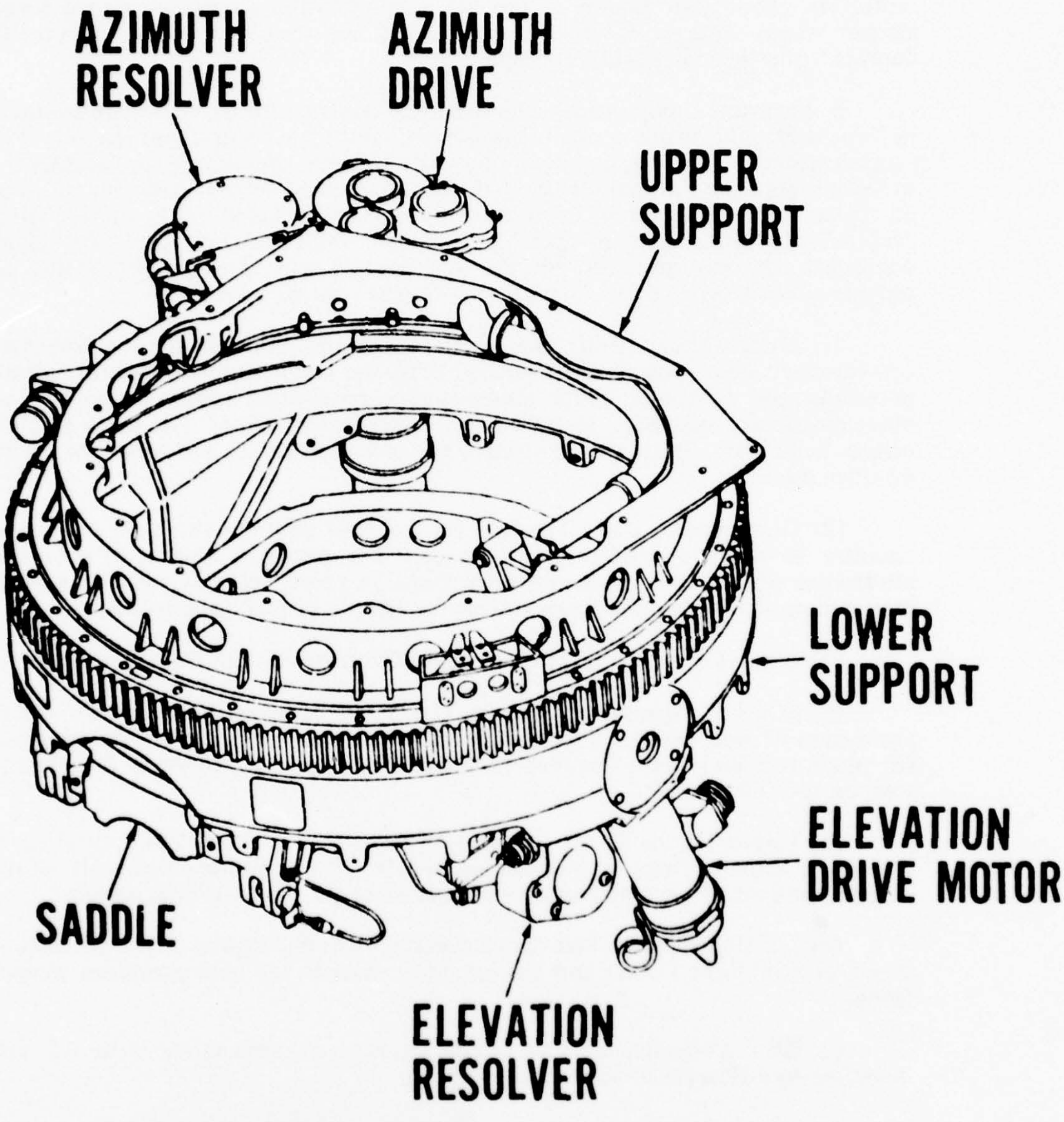


Figure 1. Turret Assembly.

(5) Gun Drive: The M-197 gun drive assembly consists of a shunt-wound DC motor and appropriate gearing to fire the weapon within a specified rate at normal aircraft supply voltages. Internal to the gearbox are shear pins which minimize the damage to the weapon should a stoppage occur.

b. Electrical Components: The electrical controls for the turret are contained in three units: the turret control, gun control, and logic control unit. Each unit has printed circuit boards using card edge connectors, simplifying replacement of subassemblies. The internal circuits have been separated so that basic functions are on replaceable printed circuit boards. Test points are included on the printed circuit cards of the turret control assembly to aid in fault isolation. An external test connector has been provided on the gun control unit. Test points on this unit provide access to system logic signals and weapon control circuits.

(1) Turret Control Unit: The turret control unit contains the low level servo control electronics, power amplifiers, EMI filters, error interlock circuits, elapsed time indicator, proximity switch power supply, over/under voltage protection, and other electronics necessary to power the turret drive motors. The servo amplifier utilizes solid state electronics to control the speed, direction, and torque of the turret drive motors.

(2) Gun Control Unit: The gun control unit contains the logic and control circuitry to safely and reliably fire the gun. The circuitry consists of solid state electronics which control the gun drive motor, a power relay declutching solenoid mounted on the feeder, and firing voltage for electric primed ammunition.

(3) Logic Control Unit (LCU): The LCU provides the following functions:

(a) SCAS Compensation Signals: The SCAS compensation provides for the conversion of weapons firing loads into scaled airframe attitude disturbance signals (*ie*, pitch, roll, and yaw). Channels for these signals are open to the SCAS when the weapon turret is activated.

(b) Torque Enable Signal: The enabling signal, which is present only when, the weapon is actually firing rounds, causes the SCAS to counteract aircraft attitude changes induced by weapon recoil by utilization of the three attitude signals.

(c) 1.5° Coincidence: This circuit detects when the angular difference between turret line of sight (LOS) and aiming LOS exceeds 1.5° and precludes weapons firing.

(d) 180° Coincidence: This circuit operates in conjunction with 1.5° error detection to differentiate between 0 and 180°.

(e) Ground Depression Limit: This circuit detects and limits the weapons depression to -5° when the switch is activated, and is used for landings and ground operations.

(f) Burst Length Limiting: This circuit limits the burst length to that peculiar weapon type installed.

(g) 2.5 Second Interlock Delay: This circuit provides the timing function for the firing interrupt during firing of fixed forward weapons, such as TOW or rockets.

(h) Rocket Firing Interlock: Upon firing any fixed forward wing stores, this circuit shall interrupt turret firing.

(i) Firing Interruption: This circuit provides firing interruption when the turret reaches the electrical limits in azimuth and elevation.

(j) Reticle Signal Inversion: This circuit precludes firing of the turret when the turret and the sight are 180° out of coincidence.

(k) 20mm Feed System: The 20mm feed system has three subassemblies: the storage box, cover/booster group, and feed chute (fig. 2).

(1) Storage Box: The storage box has three longitudinal storage bays for the full depth of the box. Ammunition is placed into these bays and folded back and forth in eight layers. Across the forward end of the box is a crossover bay. The ammunition from one bay hangs in a loop which enters the next bay. The loops are supported by guides which prevent the ammunition from jamming as it feeds out of one bay and transitions to the next. The box (and the main cover panel) are fabricated from sandwiches of aluminum sheet with Lexand inside.

(2) Cover/Booster Group: The cover/booster group moves the ammunition belt from the box to the feed chute. The cover has a roller at the forward end which supports the ammunition belt as it empties from the storage bays. The ammunition slides the length of the cover over a stainless steel wear plate and enters the booster. It also prevents the chute from sagging and fouling the ammunition belt which is moving under it. The booster assembly consists of a housing with ammunition feed guides, a sprocket shaft to drive the ammunition through the housing, and a torque motor to turn the sprocket shaft. There is a sensor attached to the booster which activates the ammunition totalizer on the turret. The booster assembly removes ammunition from the box and pushes it into the feed chute. This means the gun feeder only needs to delink entering rounds and feed them into the gun.

(3) Feed Chute: The feed chute is a multisegment, highly flexible duct through which the ammunition flows from the ammunition box to the gun. Chute flexibility provides for turret and gun movement and still allows firing without jamming.

d. M-197 20mm Gun: The M-197 gun (photo 1) is an air-cooled, three-barrel weapon which operates at a firing rate of 750 shots per minute and is a direct descendant of the Vulcan cannon. The gun utilizes a rotary action mechanism contained within a fixed housing and a rotating barrel cluster. The M-197 gun is driven by the gun drive which is mounted to the gun. A series of gears transmits power from the drive motor to the forward gear on the gun rotor to drive the gun. Power to operate the gun drive is provided by the aircraft electrical system and is controlled by the gun control assemble.

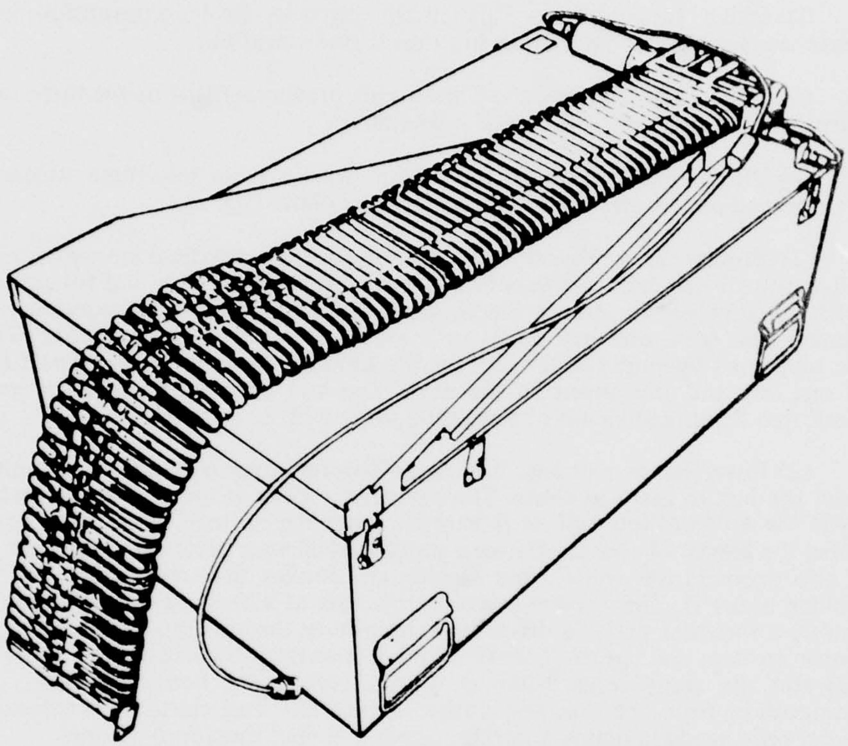


Figure 2. 20mm Feed System.

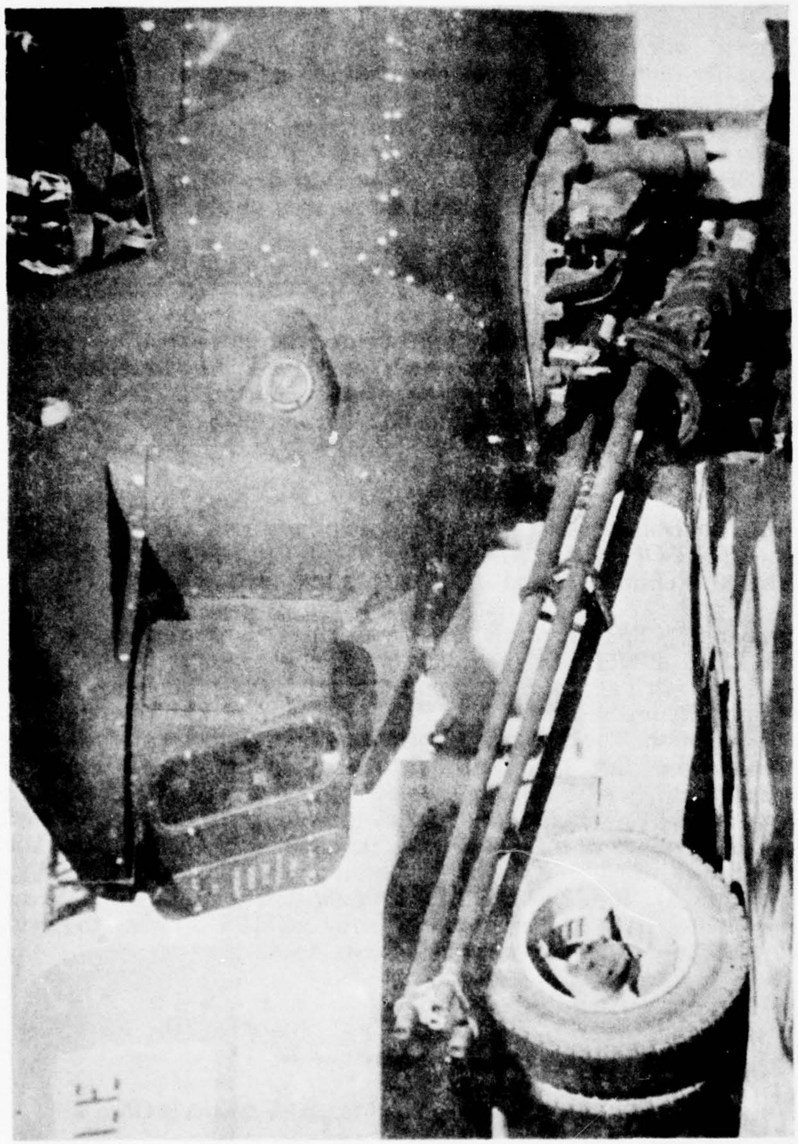


Photo 1. M-197 20mm Gun.

ECAS ELECTRICAL SYSTEM

General

5. The AH-1S/ECAS electrical subsystem consists of five power sources, three 28 VDC power distribution buses, two 28 VDC power transfer buses, a three phase 115 VAC 400 Hz power distribution bus system, interconnecting logic control relays, and crew control switches. The battery (BAT), starter-generator (S/G), and the transformer-rectifier unit (TRU) supply power to the essential (EES), nonessential (NON-ESS), and armament (ARMT) 28 VDC buses (BUS) through the power transfer (PWR XFR) and TRU buses, as required, depending on crew control switch settings and power source operation. The 115 VAC bus system is powered by either the inverter (INV) or the alternator (ALT) (photo 2) depending on crew control switch settings and aircraft rotor RPM. The TRU supplies power only when the ALT is in operation.

6. The bus interconnect logic system controls power transfer from the 28 VDC power source and the 28 VDC external power (EXT PWR) to the load distribution system. In various modes, any distribution bus may be powered from any source except that the BAT alone may never power the ARMT bus. Interlocks prevent incompatible power source interconnections while permitting BAT charging from any other source when the proper conditions for charging exist.

Controls

7. Pilot crew controls consist of BAT switch (positions OFF-START-RUN), S/G switch (RESET-OFF-ON), ALT switch (OFF-RESET-ON), NON-ESS bus switch (MANUAL-NORMAL), and MASTER ARM switch (OFF-STBY-ARM).

8. Copilot/gunner (CP/G) controls are the electrical power emergency switch (EMERG-OFF-ELEC PWR) and the pilot override armament switch (OFF-PLT OVRD). The BAT switch applies battery power to the ESS BUS in either START or RUN and additionally enables the INV in RUN position. The INV is inhibited when the ALT is in operation. The S/G switch energizes the S/G to supply power to the appropriate buses when ON. It resets the field control relay when in RESET. The ALT switch energizes the ALT to supply its power to the 115 VAC buses and TRU when in ON position. It resets the generator control unit when in the OFF RESET. The NON-ESS BUS switch when in MANUAL permits battery power to be applied to the NON-ESS BUS when only the battery is supplying VDC. In this condition, if the switch is NORMAL, the NON-ESS BUS is disabled. The MASTER ARM switch energizes appropriate relays to supply power to the ARMT BUS when the switch is in STBY or ARM if any of the following conditions are met:

a. EXT PWR is applied.

b. Both S/G and TRU are in operation.

c. Either S/G or TRU is in operation and the BAT switch is ON.

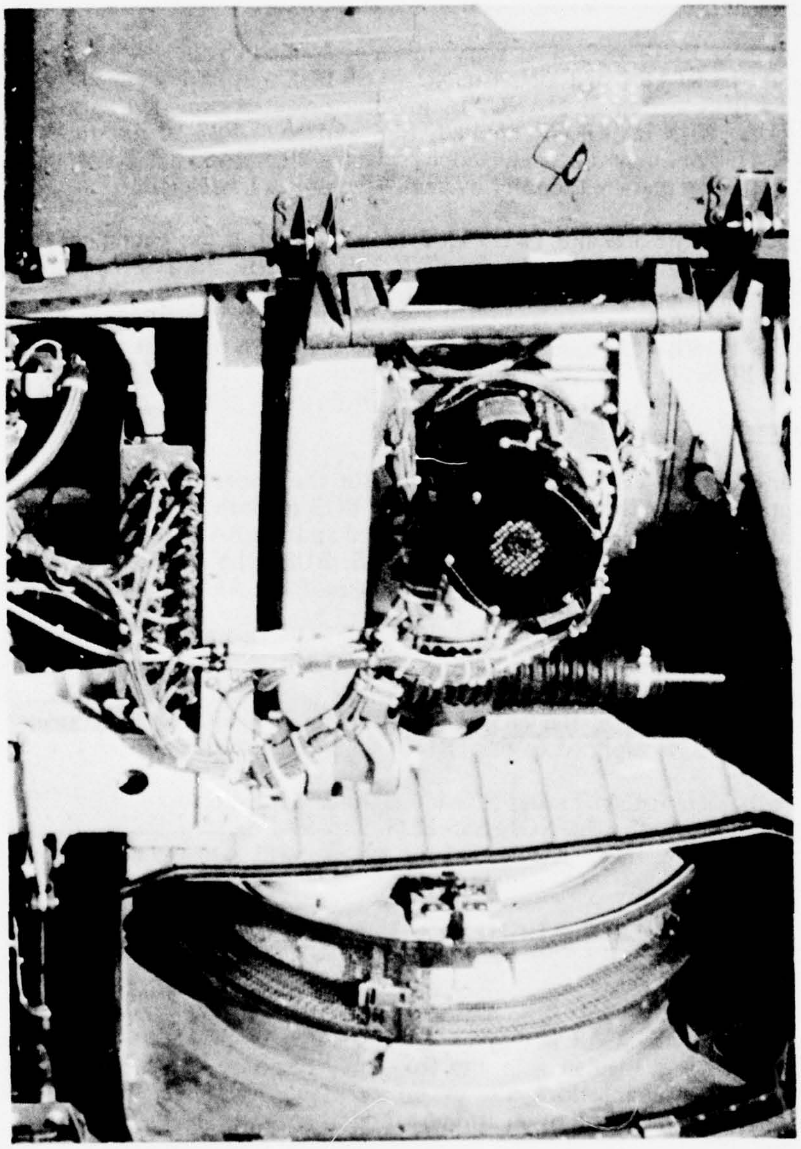


Photo 2. Left Side View AH-1S ECAS.

9. The electrical power emergency switch permits the CP/G to turn off all electrical power in an emergency by placing this switch in EMERG OFF. The pilot overrride armament switch permits the CP/G to energize the ARMT BUS and fire the weapons in case of pilot incapacitation. This is also dependent on the conditions specified for operation under MASTER ARM switch above.

Normal Operation

10. Without EST PWR applied, battery power is applied to the ESS BUS with the BAT switch in the START or RUN. The NON-ESS BUS may be energized by placing the NON-ESS BUS switch in MANUAL. Inverter power is provided with the BAT switch in RUN. With EXT PWR applied, ESS and NON-ESS buses are energized and the ARMT BUS may be energized by placing the MASTER ARM switch in STBY or ARM or by placing the pilot override switch in PLT OVRD.

11. In flight, both the S/G and TRU (ALT) are energized. If the armament system is OFF, S/G power is applied through the PWR XFR BUS to the ESS BUS and TRU power is applied through the TRU BUS to the NON-ESS BUS. When the armament system is energized, S/G power is applied through the PWR XFR BUS to the ARMT BUS and TRU POWER is applied through the TRU BUS to both the ESS BUSS and the NON-ESS BUS.

Failure Modes

12. With an ALT or TRU inoperable, and with the armament system unarmed, the S/G supplies power through the PWR XFR BUS to both the ESS BUS and the NON-ESS BUS. With the armament system armed and the BAT switch in START or RUN, the S/G and battery supply the ESS BUS, the NON-ESS BUS and ARMT BUS. The INV supplies the 115 VAC buses if the ALT is off or inoperable.

13. With the S/G OFF or inoperable and with the armament system unarmed, the TRU supplies the ESS BUS and NON-ESS BUS through the TRU BUS. With the armament system armed and the BAT switch in START or RUN, the battery and TRU supply ESS BUS, the NON-ESS BUS and the ARMT BUS through the TRU BUS. 115 VAC is supplied to the TRU and the AC buses by the ALT.

14. With both TRU (or ALT) and S/G inoperable, the BAT supplies the ESS BUS and at the pilot's option, the NON-ESS BUS. 115 VAC is suppiled by the ALT if operating, or by the INV. The armament system will not be powered in this condition.

STABILITY AND CONTROL AUGMENTATION SYSTEM

General

15. The AH-1S/ECAS SCAS is derived from the AH-1S SCAS. Major changes to the SCAS include a change in gain and frequency response, the introduction of a time delayed AC power interlock, the use of a pulse derivation technique for SCAS gain control, and the inclusion of an armament compensation signal.

Gain Response

16. BHT has reduced the gain of the SCAS system in order to improve the handling qualities of the AH-1S/ECAS. These reductions have also resulted in frequency response changes. The gain reductions from the original SCAS are: 30% in pitch, 20% in roll, and 20% in yaw.

Power Interlock

17. In the production AH-1S, an AC power loss or AC power transients would immediately disengage the SCAS. The AH-1S/ECAS is equipped with a power interlock system which allows the SCAS to continue to operate for a short period of time in the event of power loss or fluctuations. The time delay is maintenance adjustable up to 2 seconds. Power for the SCAS is supplied from the battery through the inverter when normal power is lost.

Demodulation System

18. The demodulation technique used on all BHT SCAS is a synchronous type since each signal contains both magnitude and direction information. The demodulation in the AH-1S SCAS is achieved by a pulse system derived from a fixed timing circuit tuned to 400 Hz. Any change in the AC frequency would change the gain of the SCAS. The AH-1S/ECAS SCAS employs a difference of pulse derivation technique for the demodulation. This demodulation is not sensitive to frequency variations; thus the SCAS gain will remain constant for all flight conditions.

Armament Compenstation Signals

17. The armament compensator circuit provides inputs to the SCAS when the weapon is fired. The compenstor signals depend solely on the position of the gun, and are designed to hold the attitude of the aircraft. Since they have no input from the attitude gyros or the airspeed system, the inputs will be exact for only one particular matrix of airspeed and gross weight. The maximum compensation occurs when the weapon's position most strongly affects the aircraft (*ie*, maximum yaw compensation with the gun 90° to the nose), while minimum compensation occurs when an axis is least affected (minimum yaw response with the weapon fixed forward). The ECAS SCAS has 25% control authority in all axes (±12.5% in pitch, roll, and yaw). The maximum compensations available from the armament compensator are:

Pitch - 55% SCAS authority (7% control authority)

Roll - 59% SCAS authority (7.4% control authority)

Yaw - 80% SCAS authority (10% control authority)

APPENDIX C. INSTRUMENTATION

An FM magnetic tape system was used to record data during all phases of the test program. Two installations of this system were utilized to cover gun firing tests and nonfiring handling qualities tests. The instrumentation system was located in pods mounted on the inboard stores stations for all firing tests (photo 1 & 2). During handling qualities testing, the instrumentation system was installed in the ammunition bay area. In addition to the FM system, limited test instrumentation was installed in the cockpit areas for both firing and nonfiring tests. Cockpit instrumentation installed during all firing tests consisted of flight control position indicators and a g meter mounted on the glare shield of the pilot instrument panel (photo 3), instrumentation activation controls located on the copilot instrument panel (photo 4) and pilot instrument panel and collective control (photo 5). During gun firing tests three high-speed 16mm movie cameras were mounted on the skids and right wing of the test aircraft (photos 6 and 7). A switch for operating the cameras was located on the pilot right side instrument panel. Additional cockpit test instrumentation installed for the handling qualities testing only consisted of (1) calibrated airspeed indicators in place of the standard ship airspeed indicators in both the pilot and gunner instrument panels, and (2) angle of attack and angle of sideslip indicators mounted on the pilot instrument panel glare shield (photo 3). A nose-mounted test instrumentation boom which provided sideslip information was installed for the handling qualities portion of the test program. All test instrumentation was installed, calibrated, and maintained by BHT. The following parameters were recorded on magnetic tape:

- Control position:
  - Longitudinal
  - Lateral
  - Directional
  - Collective
  - Throttle
- Control force:
  - Longitudinal
  - Lateral
  - Directional
- SCAS position:
  - Longitudinal
  - Lateral
  - Directional
- Aircraft attitude:
  - Pitch
  - Roll
  - Yaw
- Aircraft rate:
  - Pitch
  - Roll
  - Yaw
- Center-of-gravity normal acceleration

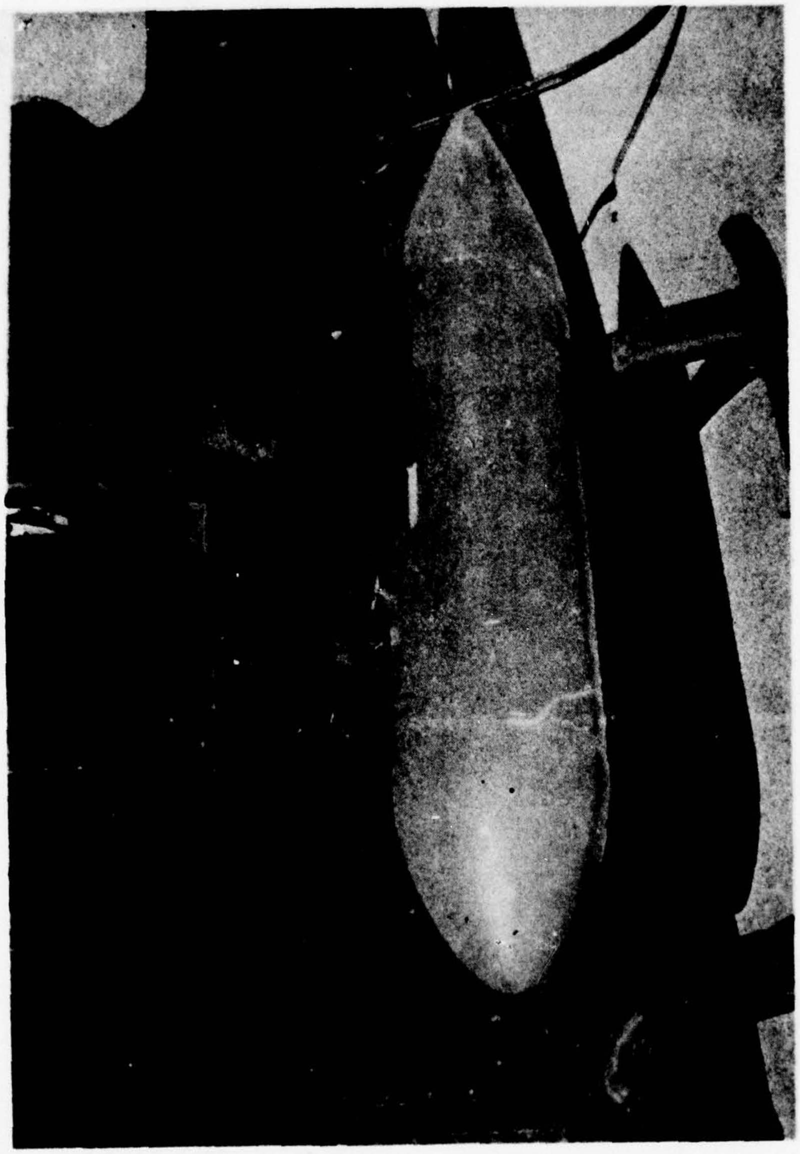


Photo 1. Left Instrumentation Pod.

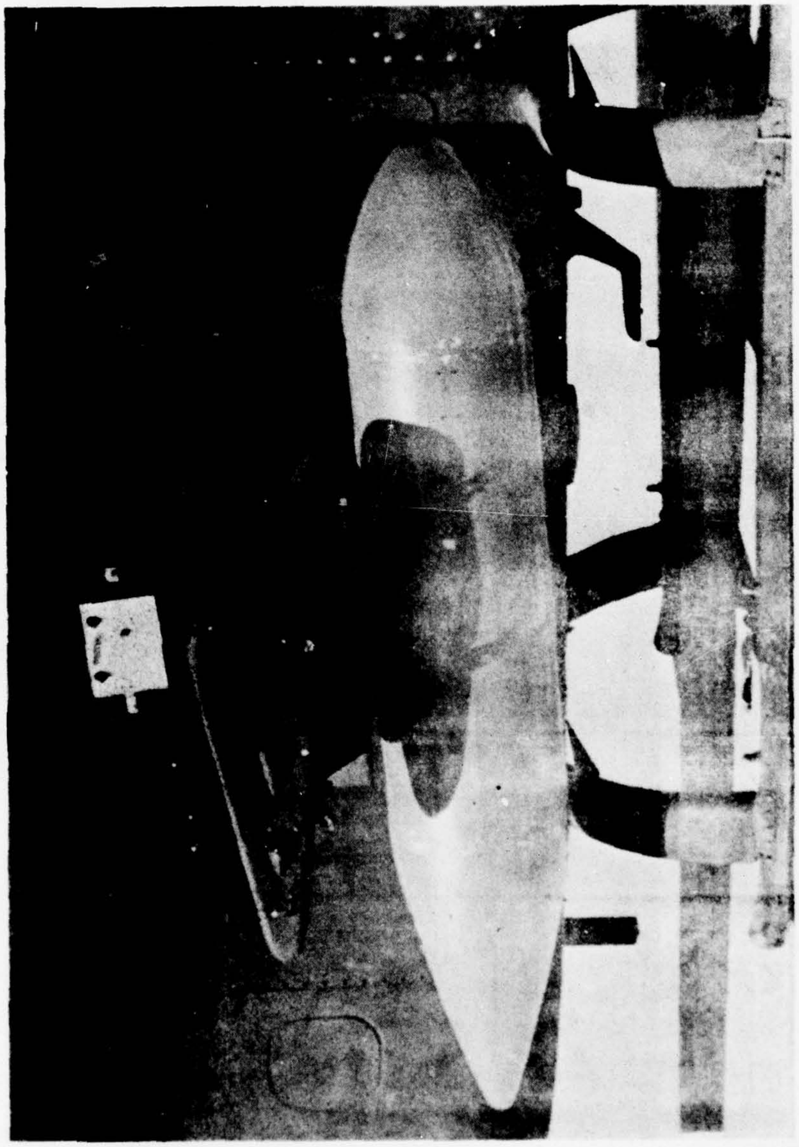


Photo 2. Right Instrumentation Pod.

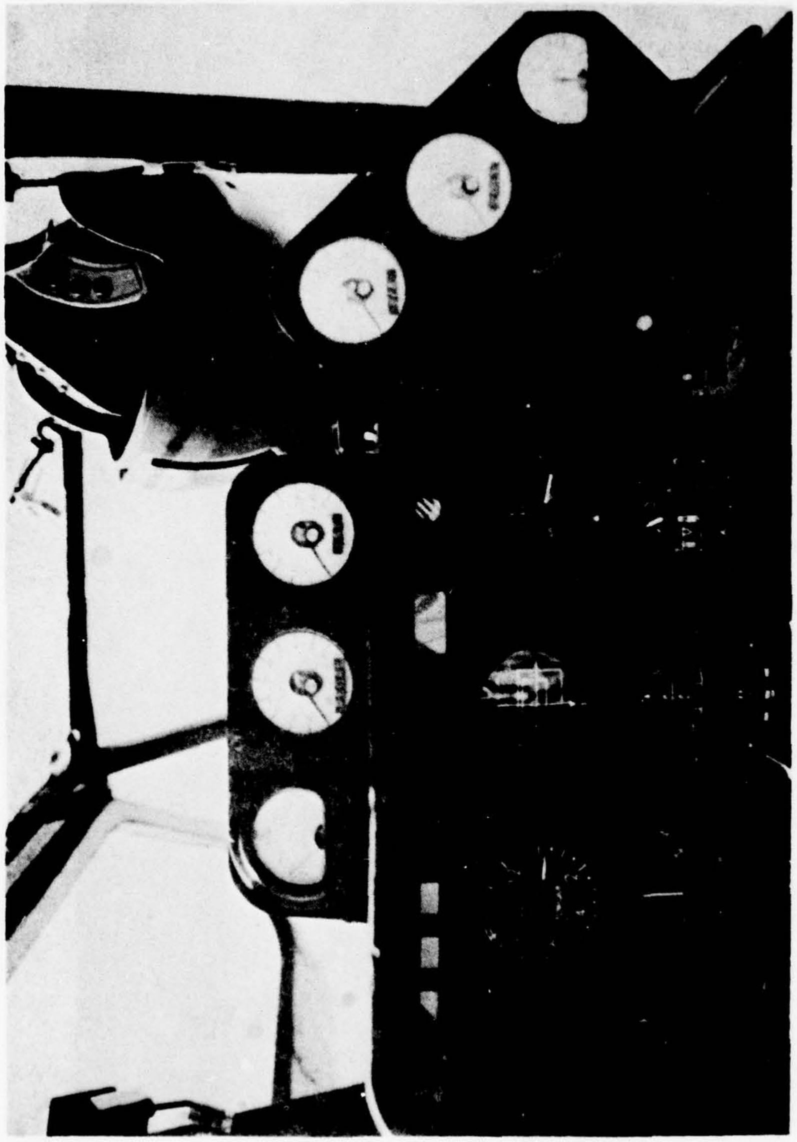


Photo 3. Special Instrumentation - Pilot's Station.

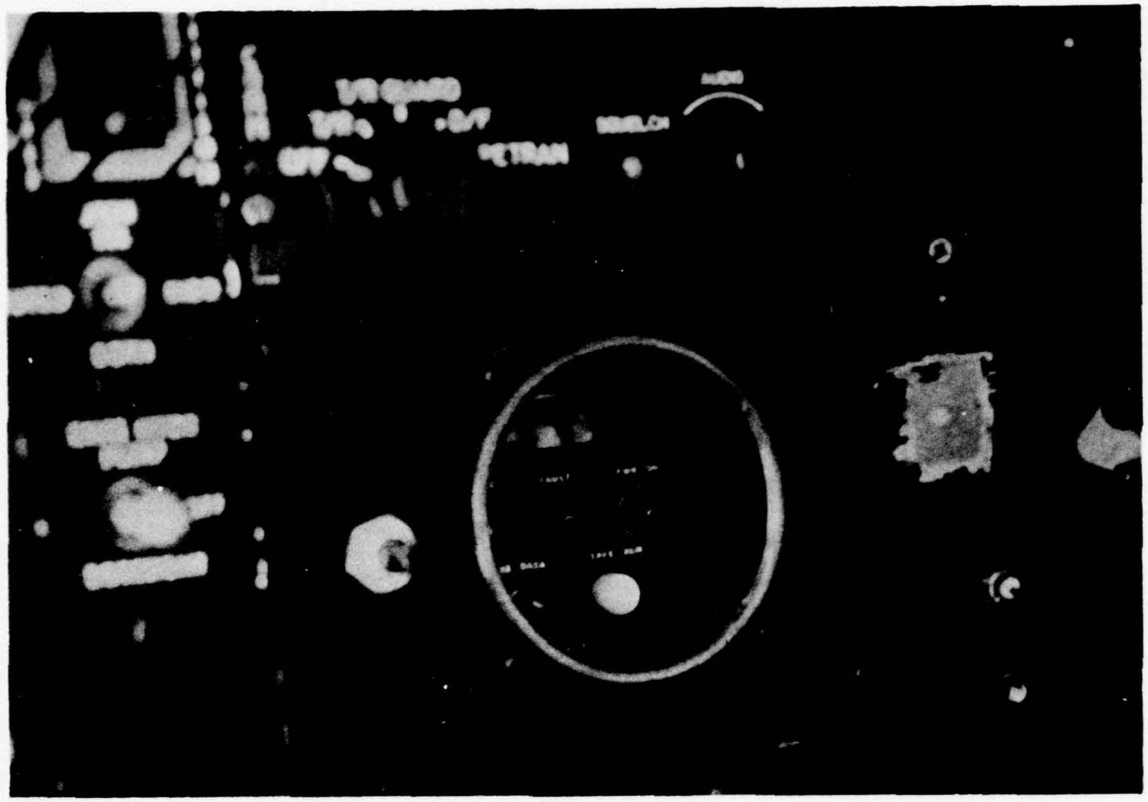


Photo 4. Special Instrumentation - Gunner's Station.

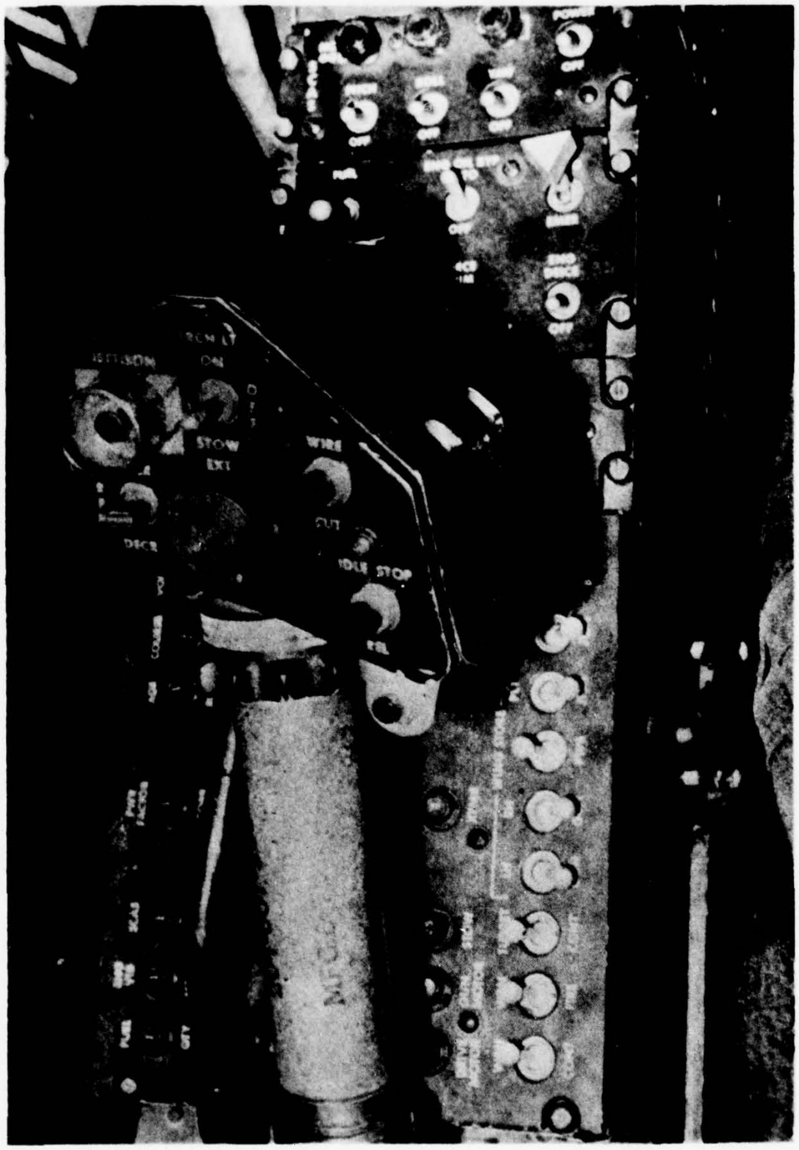


Photo 5. Collective Control.

Photo 6. Skid Camera Right Side.

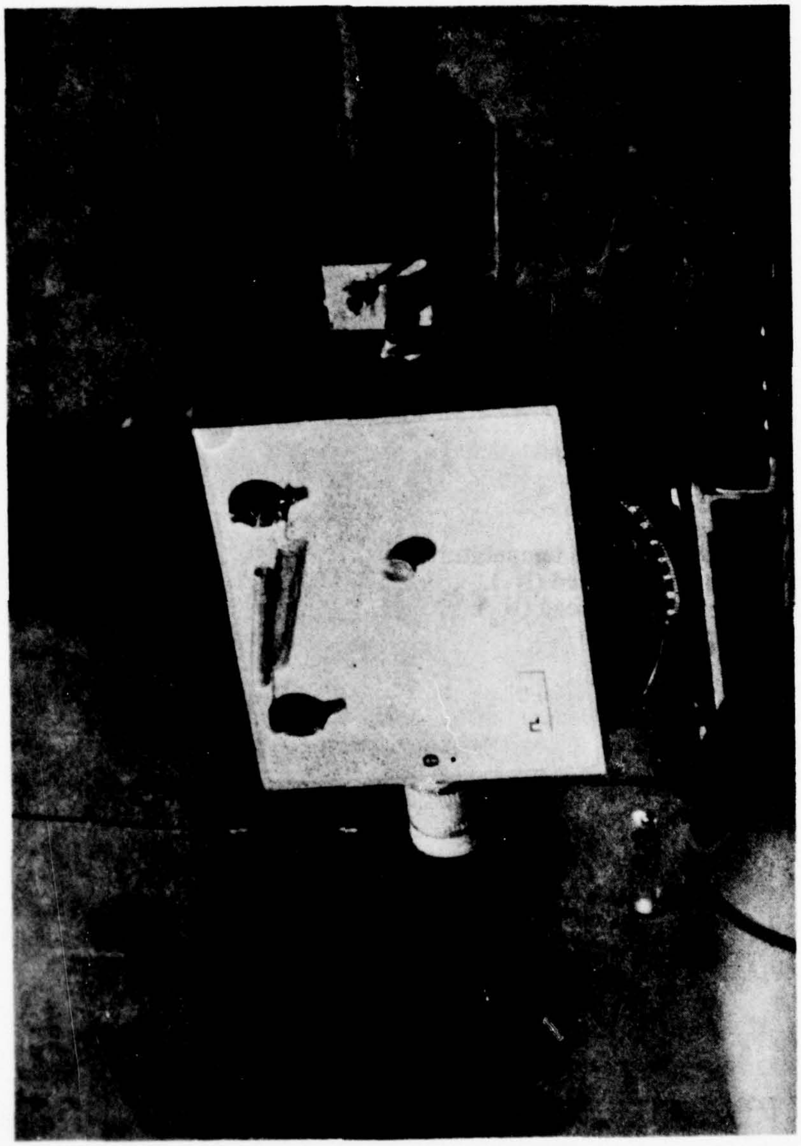


Photo 7. Wing Camera Right Side.

Center-of-gravity vibration:
- Lateral
- Vertical

Pilot seat vibration:
- Longitudinal
- Vertical

Gunner seat vibration:
- Longitudinal
- Lateral
- Vertical

TSU vibration:
- Longitudinal
- Lateral

Gunner side panel vibration:
- Lateral
- Vertical

Pilot side panel vibration:
- Lateral
- Vertical

Gun turret vibration:
- Longitudinal
- Lateral
- Vertical

Engine torque pressure
Engine interstage turbine temperature
Engine gas generator speed (N_1).
Engine power turbine speed (N_2).
Main rotor speed
Airspeed
Altitude
Angle of attack
Angle of sideslip
Pilot/copilot event
Gun azimuth
Gun elevation

APPENDIX D. DATA ANALYSIS METHODS

GENERAL

1. Stability and control data were collected and evaluated using standard test methods as described in reference 9, appendix A. The Handling Qualities Rating Scale presented in figure 1 was used to augment pilot comments relative to handling qualities and workload. Definitions of deficiencies and shortcomings are as stipulated in Army Regulation 310-25.

DYNAMIC RESPONSE

2. The dynamic response characteristics of the aircraft were evaluated to determine the damping ratios (ζ). Damping ratios were determined for all conditions tested using the logarithmic decrement method. The logarithmic decrement is defined as the natural logarithm of the ratio of any two successive peaks (fig. 2).

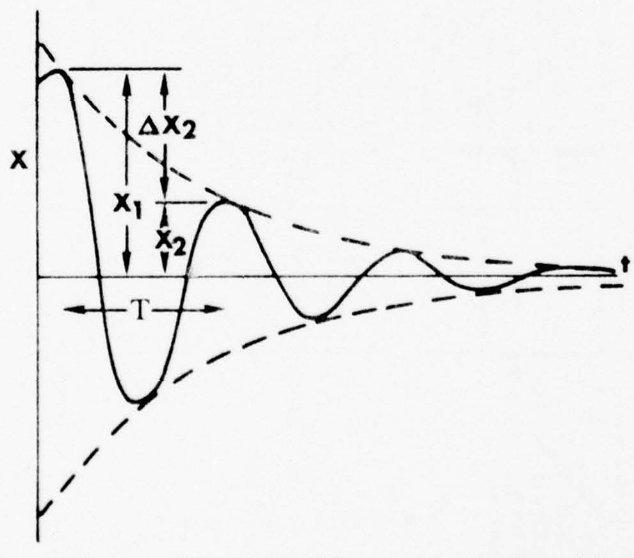
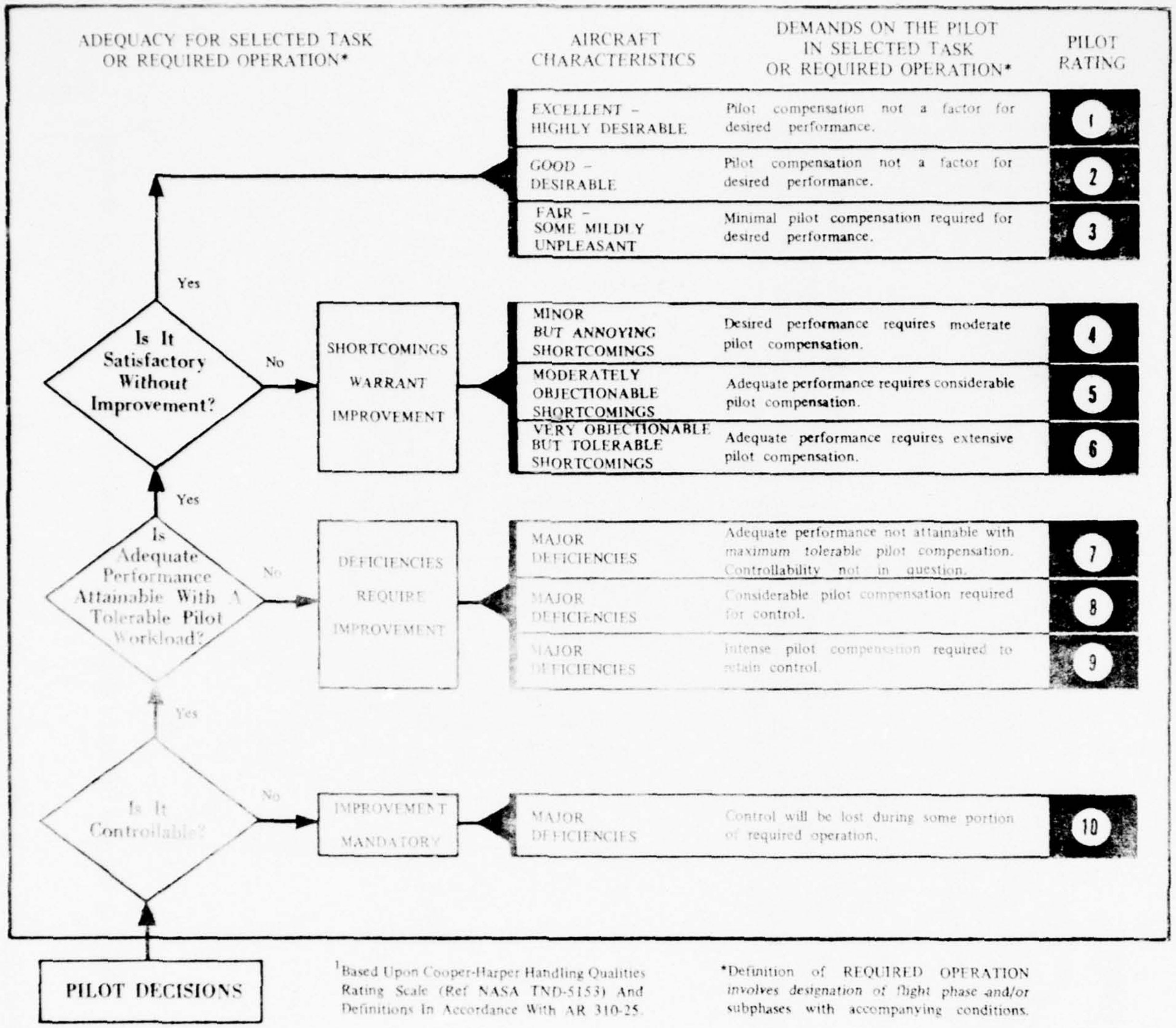


Figure 2. Rate of Decay of Oscillation Measured by the Logarithmic Decrement.

The logarithmic decrement δ is mathematically expressed as:

$$\delta = \ln \frac{x_1}{x_2} = \ln \frac{e^{-\zeta\omega n T_1}}{e^{-\zeta\omega n (T_1+\tau)}} = \ln e^{\zeta\omega_n \tau} = \zeta\omega_n \tau \qquad (1)$$



[1]Based Upon Cooper-Harper Handling Qualities Rating Scale (Ref NASA TND-5153) And Definitions In Accordance With AR 310-25.

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

Figure 1. Handling Qualities Rating Scale.

Since the period of the damped oscillation is equal to

$$\tau = 2\pi/\omega_n\sqrt{1-\zeta^2} \tag{2}$$

The decrement can be rewritten as:

$$\delta = \ln \frac{x_1}{x_2} = 2\pi\zeta^2/\sqrt{1-\zeta^2} \tag{3}$$

As seen in figure 3 for small values of ζ.

$$\delta<3, \ \zeta \simeq \ln \frac{x_1}{x_2} \ /2\pi \tag{4}$$

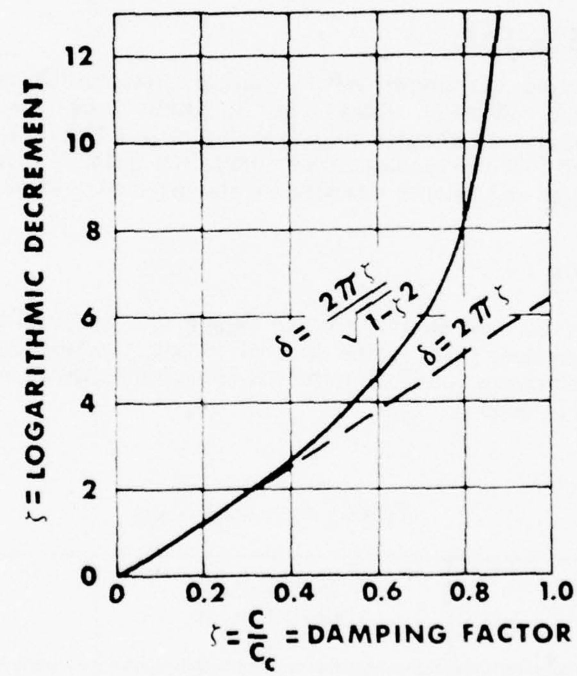


Figure 3. Logarithmic Decrements as Function of ζ.

The frequency is defined as $\omega = 2\pi/\zeta$ rad/sec; the natural frequency is defines as

$$\omega_n = 2\pi/\tau \ \sqrt{1-\zeta^2} \tag{5}$$

VIBRATION

3. The FM vibration data were reduced by means of a fast Fourier transform from the analog flight tape. Vibration levels, representing peak amplitudes, were extracted from this analysis at selected harmonics of the main rotor frequency. Gun firing vibration levels were quantified and presented in spectral plot format for analysis. The Vibration Rating Scale, presented in figure 4, was used to augment crew comments on aircraft vibration levels.

AIRSPEED CALIBRATION

4. A contractor supplied airspeed calibration (fig. 5) was utilized to determine airspeed.

WEIGHT AND BALANCE

5. Prior to testing, the aircraft gross weight and longitudinal and lateral cg were determined using calibrated scales. The longitudinal cg was calculated by a summation of moments about a reference datum line (FS 0.0). The aircraft was weighed with full fuel and included instrumentation installed in inboard wing pods. A calculated weight and balance was used for stability and control tests.

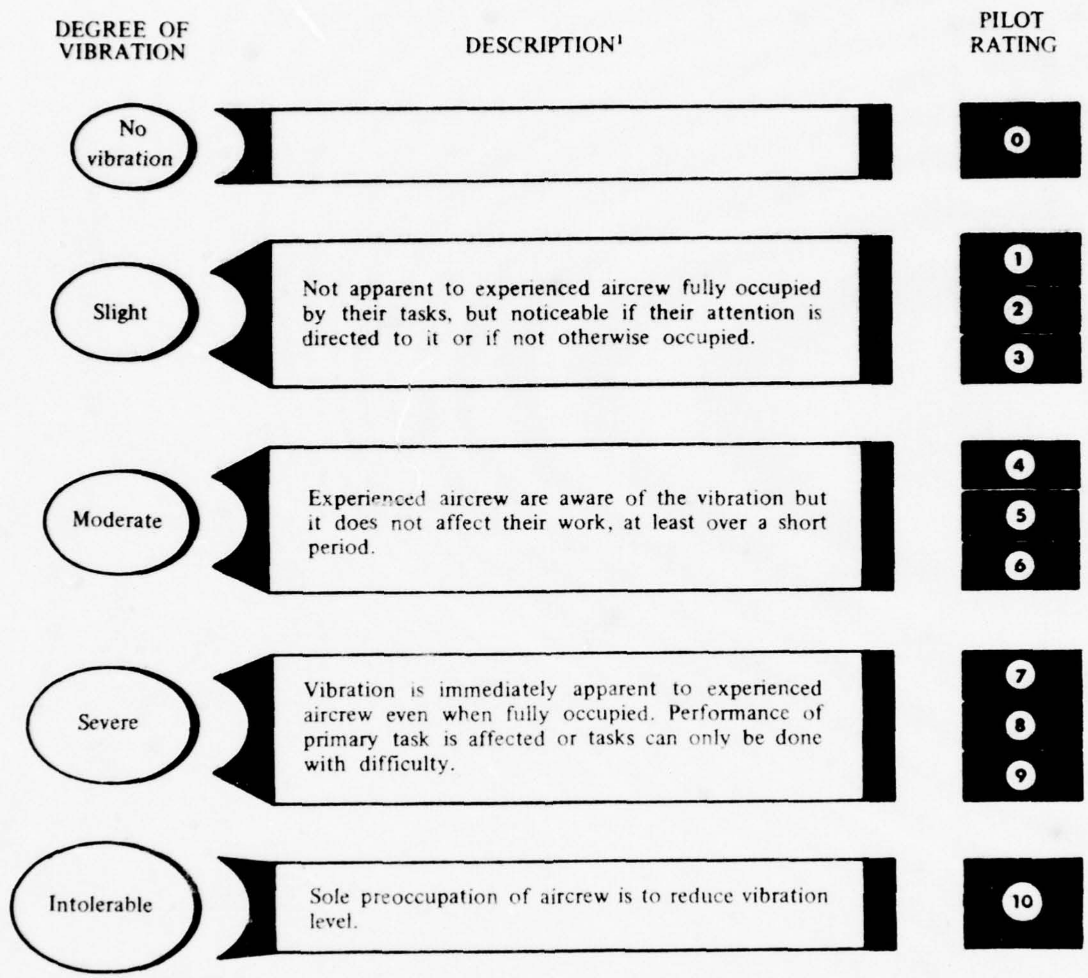
RIGGING CHECK

6. A check of the test aircraft control rigging was made on site by USAAEFA maintenance personnel prior to the start of testing. Control rigging was found to be within the tolerances specified in the AH-1S maintenance manual (ref 14, app A) and is presented in table 1.

Table 1. Control Rigging

Control	Specification Measurement (in.)	USAAEFA Measurement (in.)
Longitudinal[1]	12.82 ±0.06	12.88
Lateral[1]	12.52 ±0.06	12.58
Collective[2]	3.84 to 3.90	3.90
Directional[3]	4.07 ±0.03	4.09

[1] Cyclic control locked with fixture.
[2] Collective control full down.
[3] Full left pedal.



[1] Based upon the Subjective Vibration Assessment Scale developed by the Aeroplane and Armament Experimental Establishment, Boscombe Down, England.

Figure 4. Vibration Rating Scale.

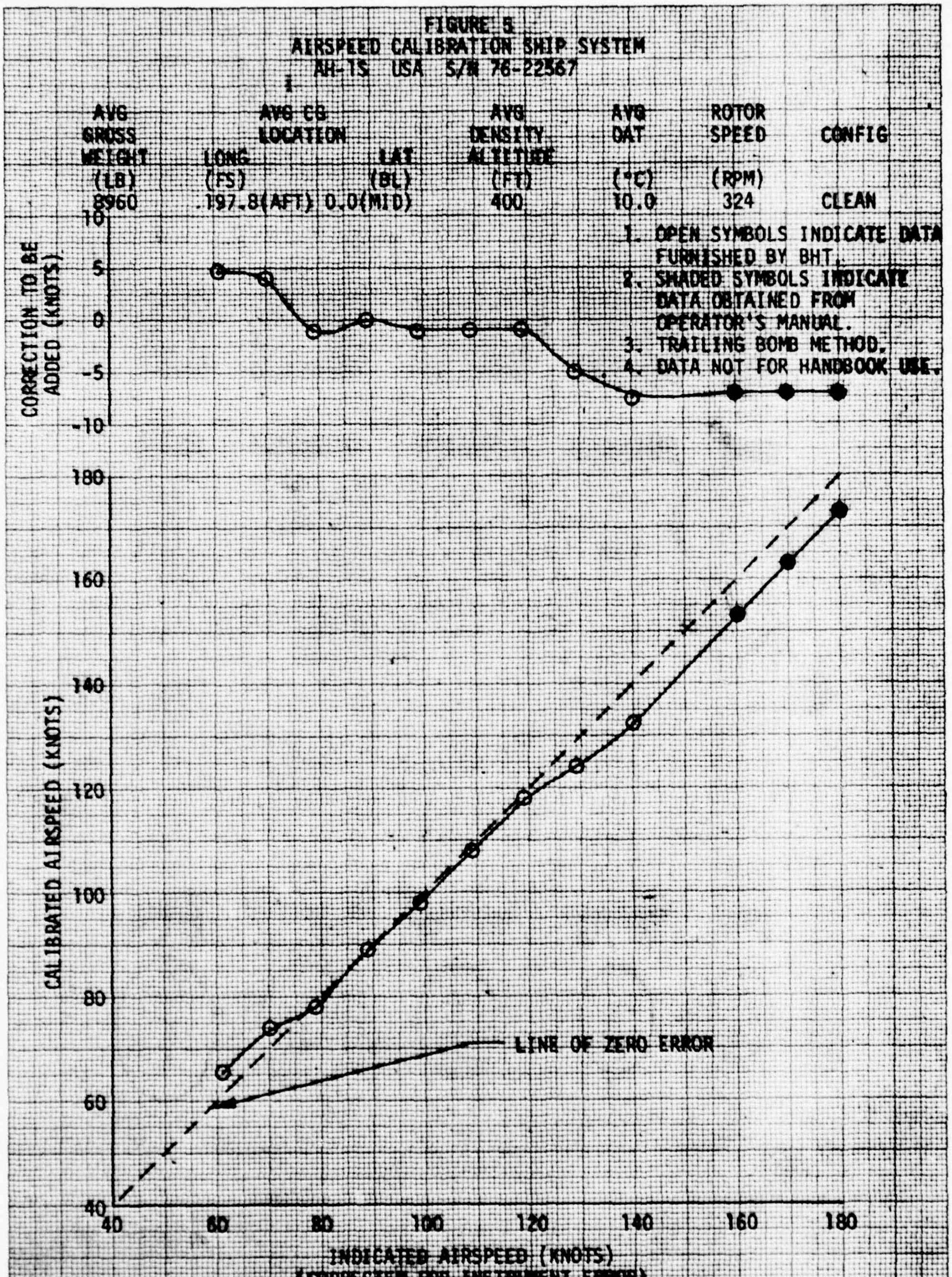


FIGURE 5
AIRSPEED CALIBRATION SHIP SYSTEM
AH-1S USA S/N 76-22567
AVG GROSS WEIGHT (LB) 8960
AVG CG LOCATION LONG (FS) 197.8(AFT) LAT (BL) 0.0(MID)
AVG DENSITY ALTITUDE (FT) 400
AVG OAT (°C) 10.0
ROTOR SPEED (RPM) 324
CONFIG CLEAN
1. OPEN SYMBOLS INDICATE DATA FURNISHED BY BHT.
2. SHADED SYMBOLS INDICATE DATA OBTAINED FROM OPERATOR'S MANUAL.
3. TRAILING BOMB METHOD.
4. DATA NOT FOR HANDBOOK USE.
CORRECTION TO BE ADDED (KNOTS)
10
5
0
-5
-10
CALIBRATED AIRSPEED (KNOTS)
180
160
140
120
100
80
60
40
LINE OF ZERO ERROR
40 60 80 100 120 140 160 180
INDICATED AIRSPEED (KNOTS)
(CORRECTED FOR INSTRUMENT ERROR)

7. Swashplate angles measured with the cyclic control fixture in place and the collective control full down were as follows:

Longitudinal - Degrees tilt at right horn = 1° down.
Lateral - Degrees tilt at left horn = 1.9° left.
Collective - Minimum blade angle = 8.25°.

8. Swashplate angles with controls at full throws were as follows:

Longitudinal control full aft = 13.5° up.
Longitudinal control full forward = 14.0° down.
Lateral control full left = 10.0° down.
Lateral control full right = 7.0° up.

9. Tail rotor blade angles measured with the pedals at full throws were as follows:

Full left pedal = 19.22°.
Full right pedal = 11.00°.

APPENDIX E. TEST DATA

INDEX

FIGURE 1
GUN FIRING IN LEVEL FLIGHT
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
9560	192.8 (FWD)	0.4 RT	6200	27.0	324	81	ON

NOTES: 1. GUN AZIMUTH = +90 DEG
2. GUN ELEVATION = 0 DEG

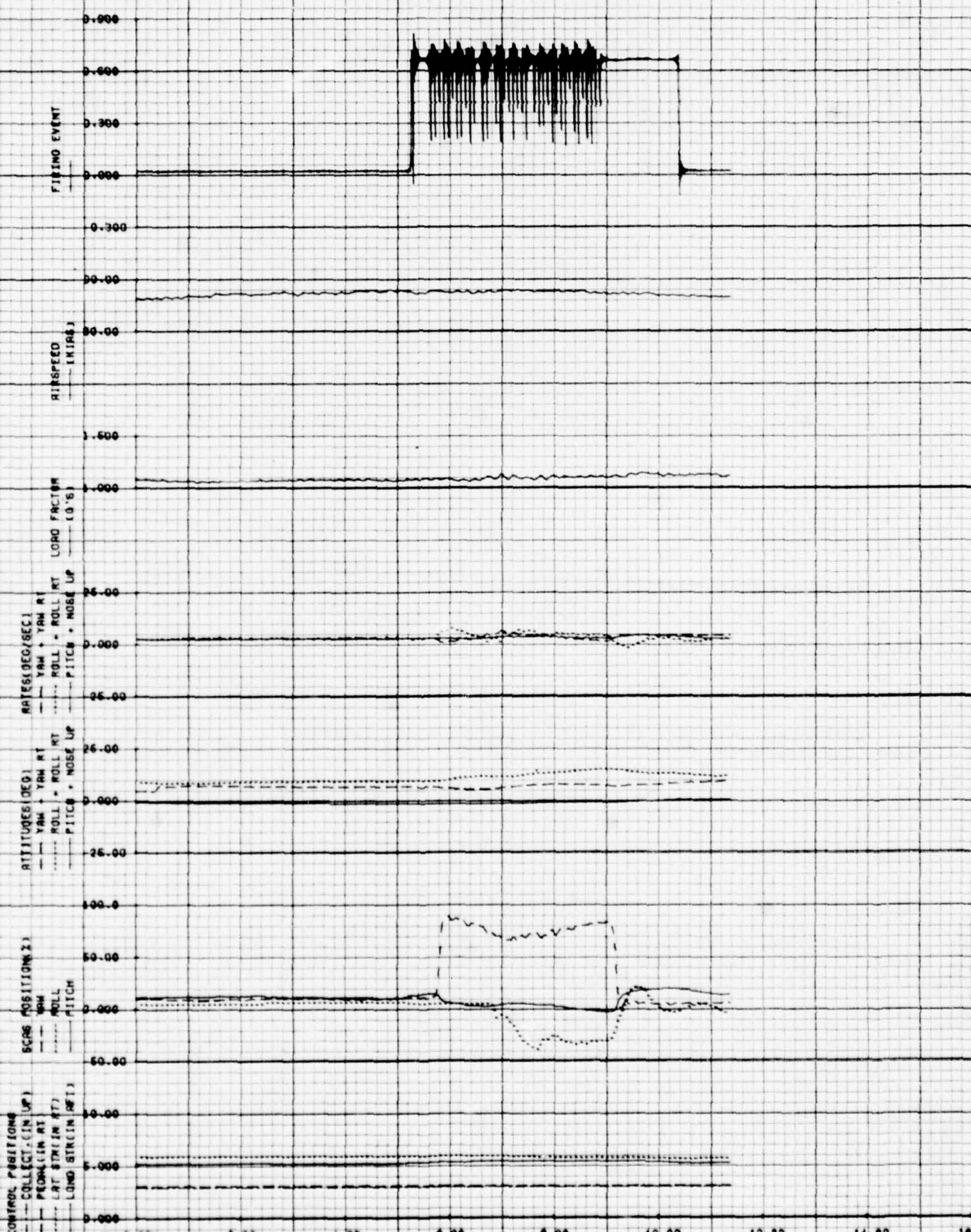


FIGURE 2
GUN FIRING IN LEVEL FLIGHT
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
9520	192.9 (FWD)	0.4 RT	6400	26.0	324	118	ON

NOTES: 1. GUN AZIMUTH = -90 DEG
2. GUN ELEVATION = 0 DEG

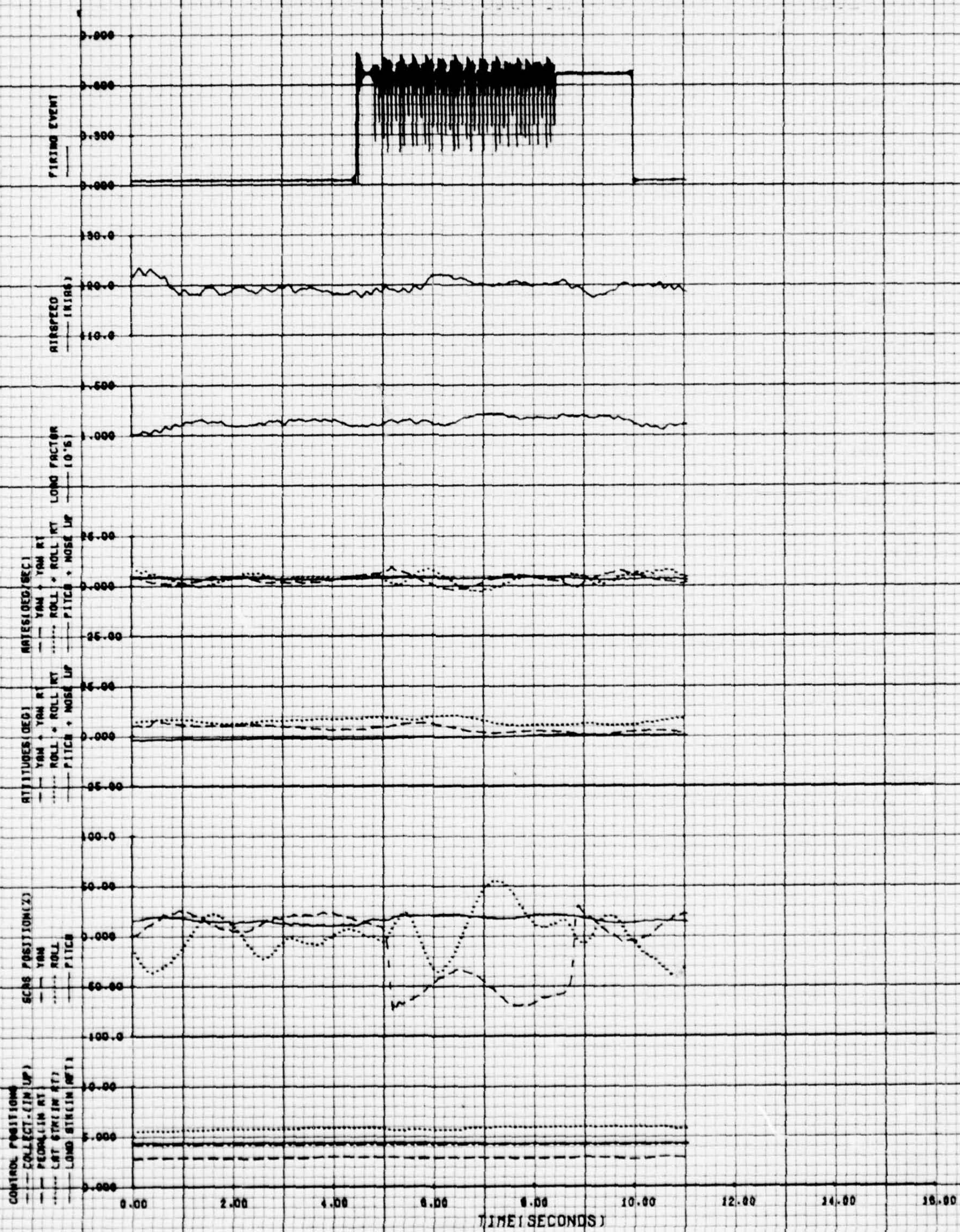


FIGURE 3
GUN FIRING DURING HOVERING FLIGHT
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
9700	192.7 (FWD)	0.4 RT	2600	32.0	324	HOVER	ON

NOTES: 1. GUN AZIMUTH = +90 DEG
2. GUN ELEVATION = 0 DEG

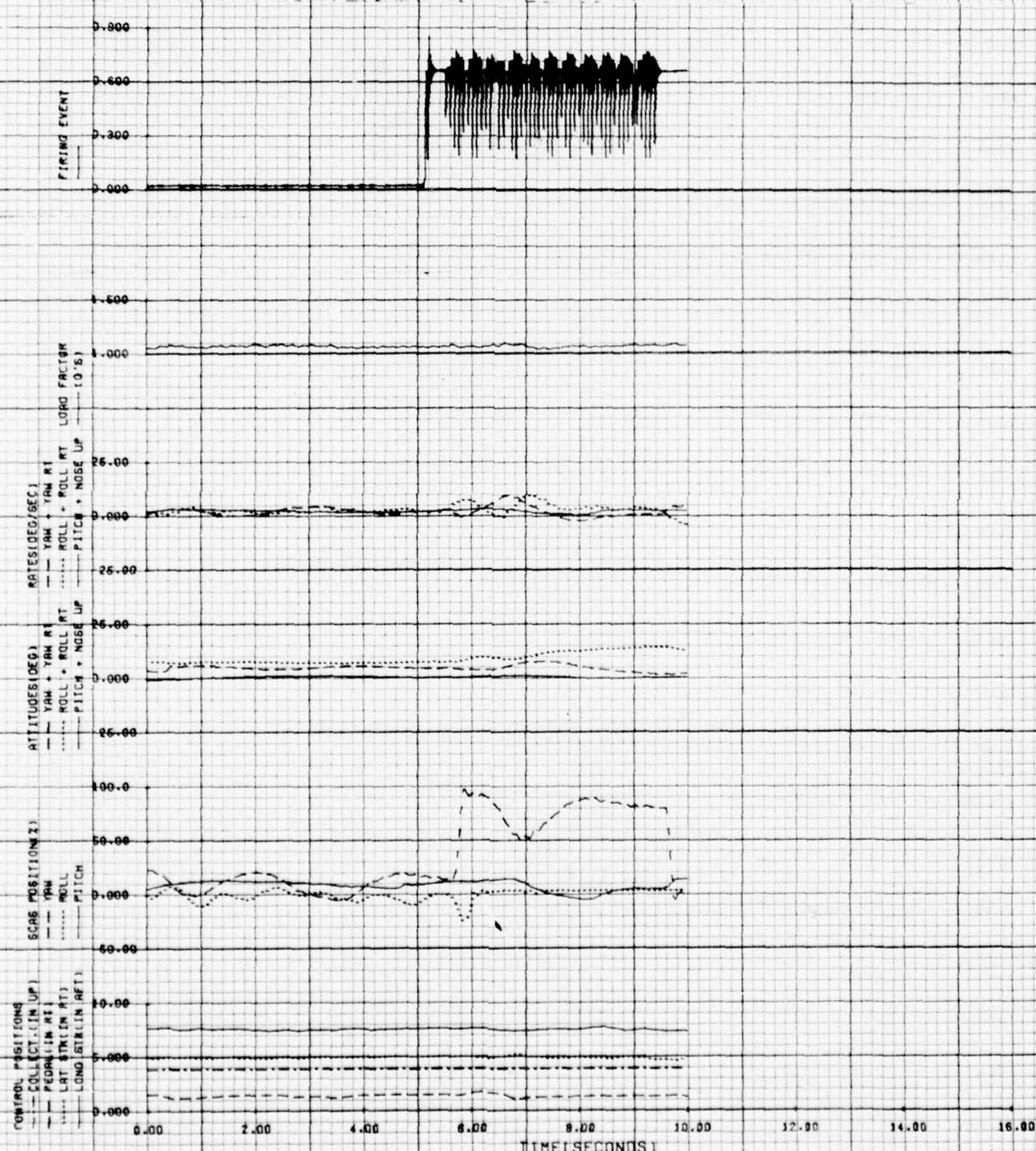


FIGURE 4
GUN FIRING DURING HOVERING FLIGHT
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
9680	192.9 (FWD)	0.4 RT	2600	32.0	324	HOVER	ON

NOTES: 1. GUN AZIMUTH = -90 DEG
2. GUN ELEVATION = 0 DEG

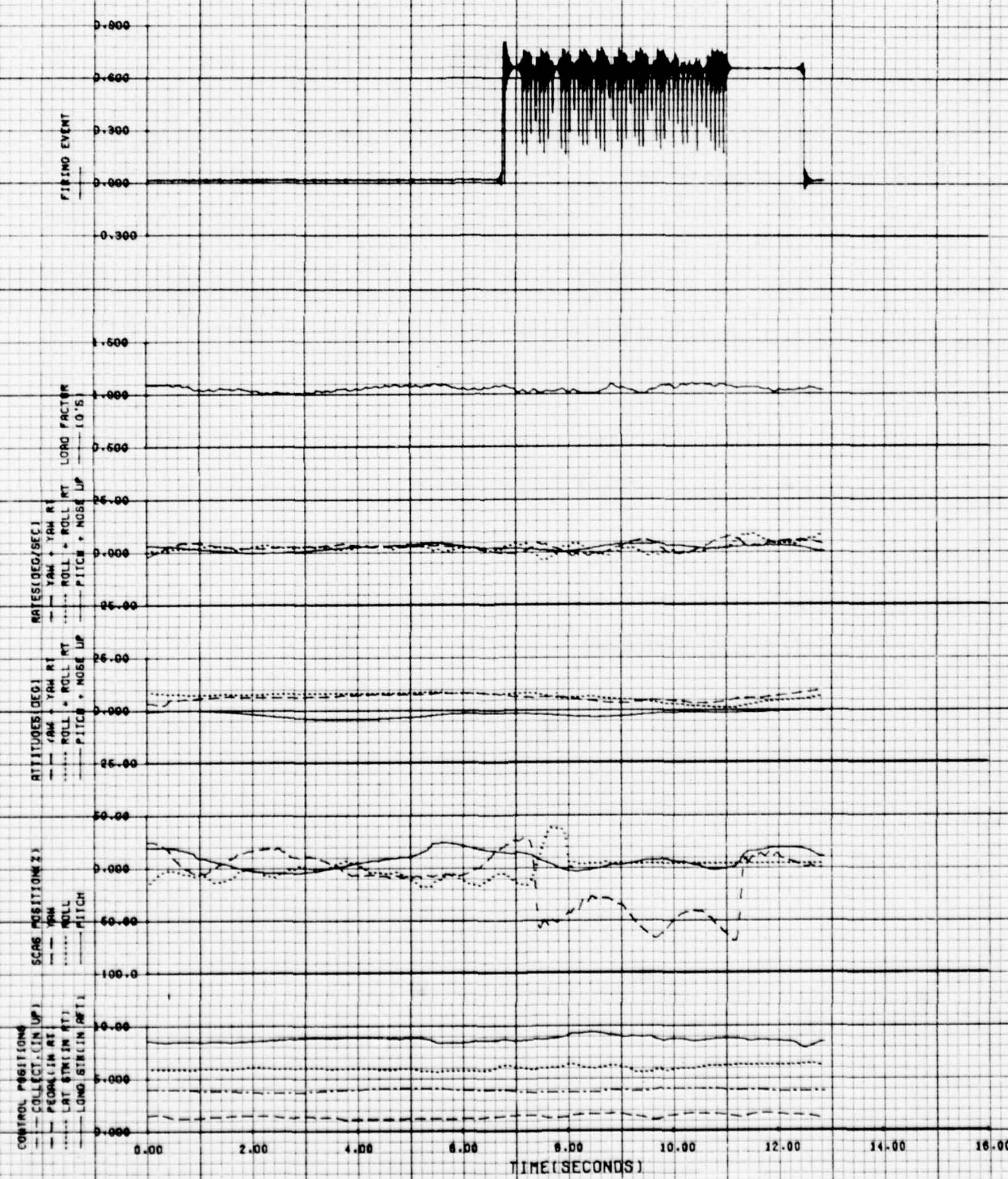


FIGURE 5
GUN FIRING IN REARWARD FLIGHT
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRUE AIRSPEED (KT)	SCAS CONDITION
9640	192.9 (FWD)	0.4 RT	2600	32.0	324	30	ON

NOTES: 1. GUN AZIMUTH = 0 DEG
2. GUN ELEVATION = 0 DEG

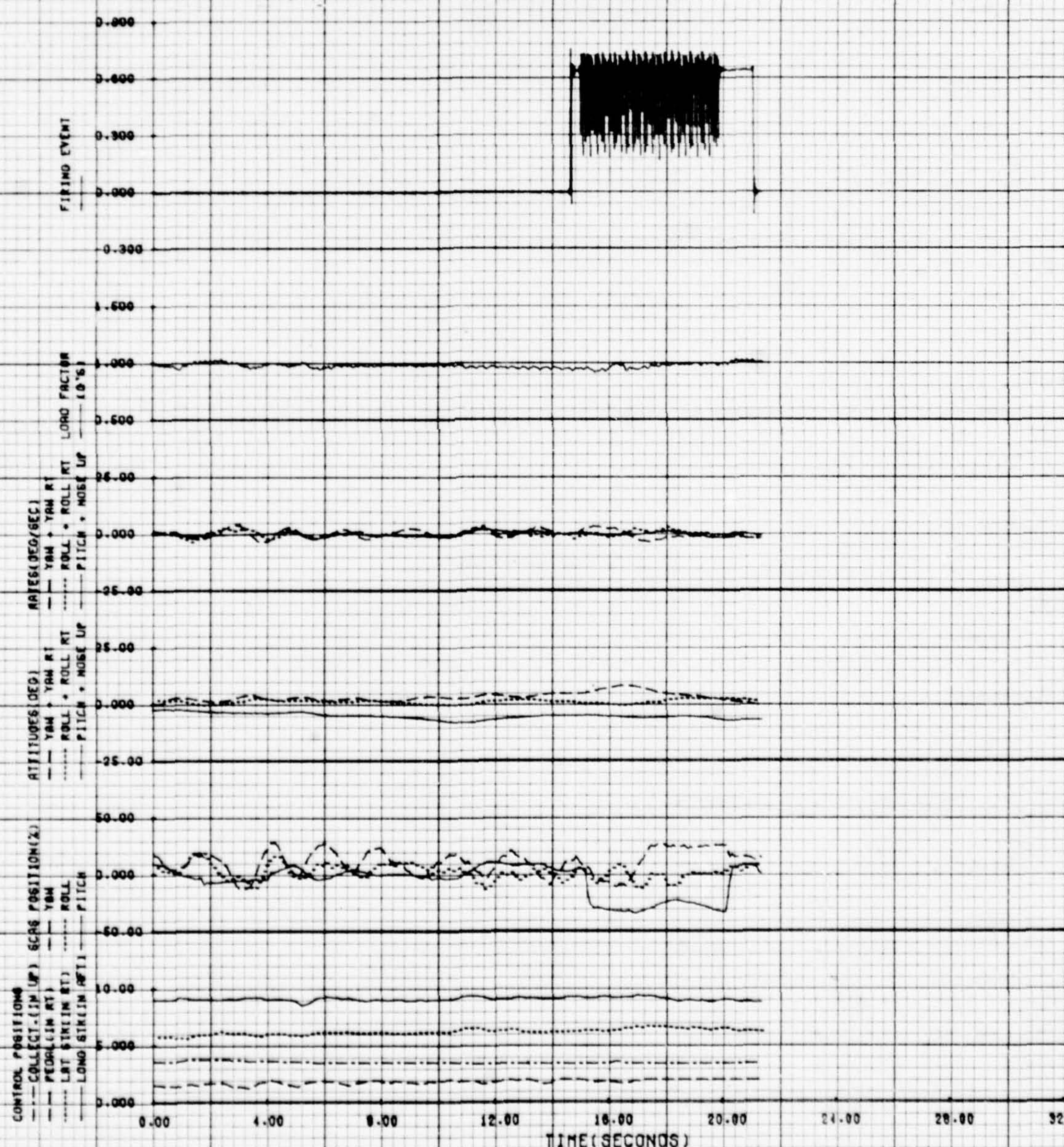


FIGURE 6
GUN FIRING IN RIGHT SIDEWARD FLIGHT
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	AIRSPEED (KT)	SCAS CONDITION
9600	192.9 (FWD)	0.4 RT	2600	32.0	324	30	ON

NOTES: 1. GUN AZIMUTH = +90 DEG
2. GUN ELEVATION = 0 DEG

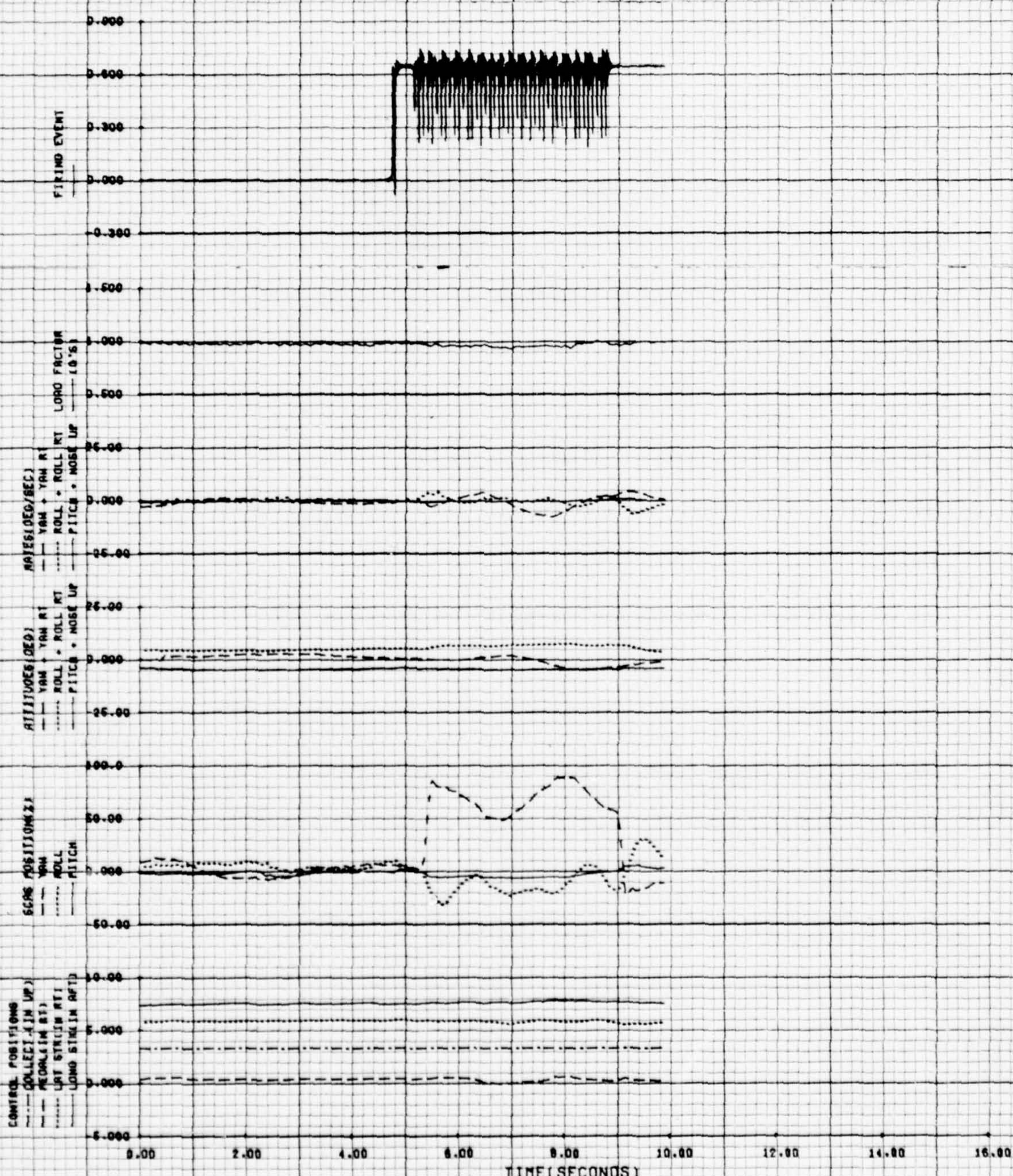
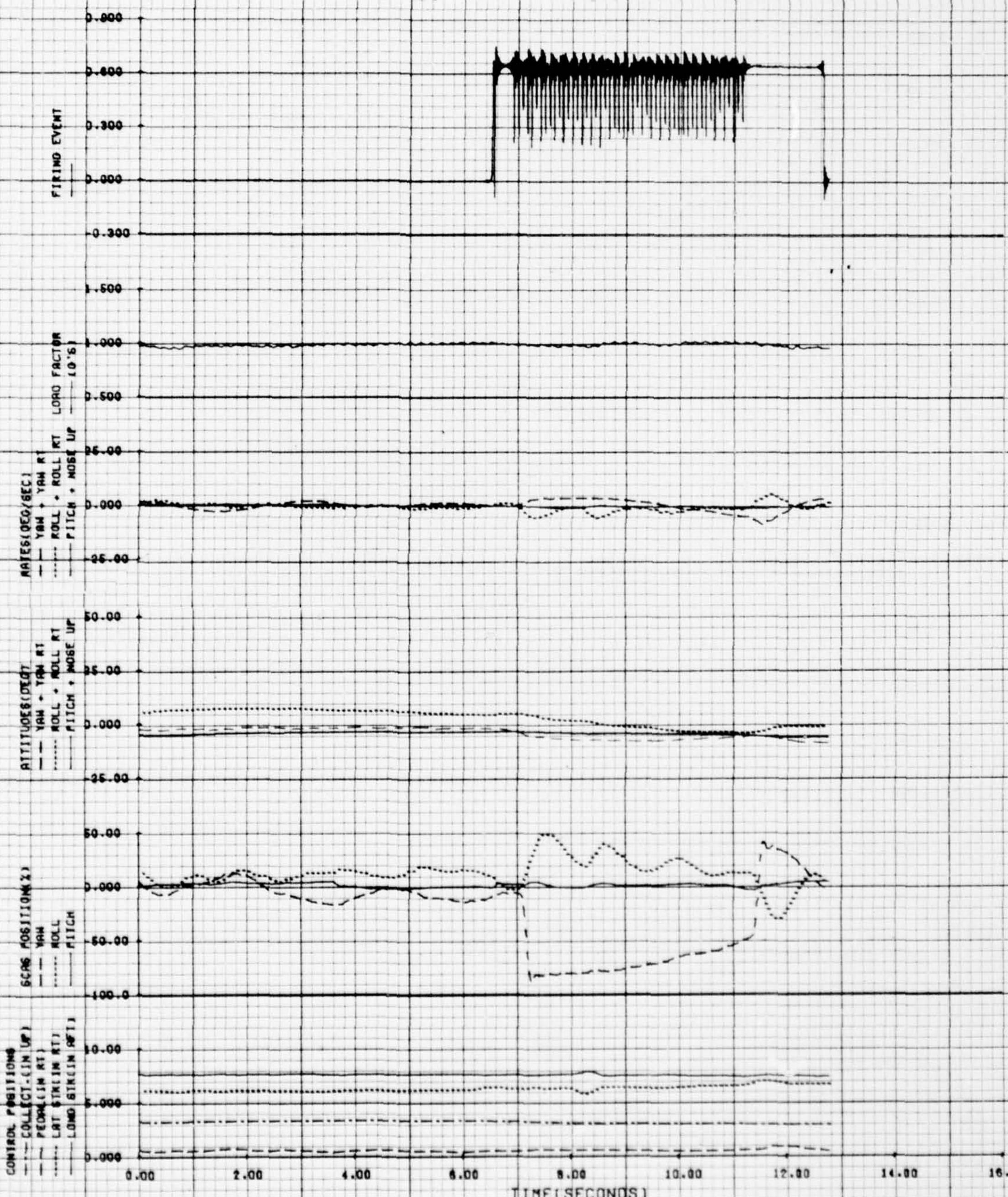


FIGURE 7
GUN FIRING IN RIGHT SIDEWARD FLIGHT
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRUE AIRSPEED (KT)	SCAS CONDITION
9580	192.9 (FWD)	0.4 RT	2600	32.0	324	15	ON

NOTES: 1. GUN AZIMUTH = -90 DEG
2. GUN ELEVATION = 0 DEG



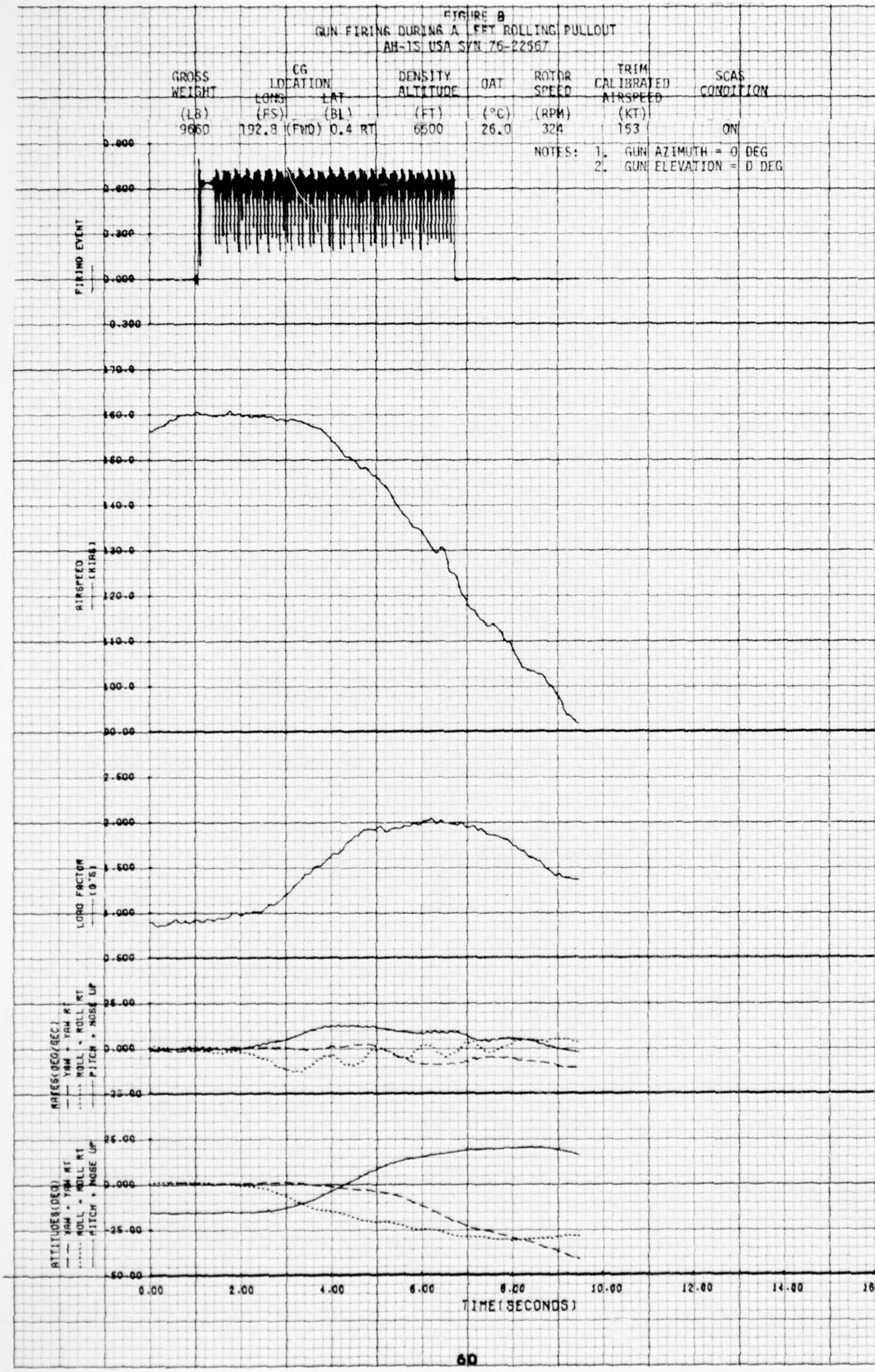


FIGURE 8
GUN FIRING DURING A LEFT ROLLING PULLOUT
AH-1S USA S/N 76-22567
GROSS WEIGHT (LB) 9660
CG LOCATION LONG (FS) 192.8 (FWD) LAT (BL) 0.4 RT
DENSITY ALTITUDE (FT) 6500
OAT (°C) 26.0
ROTOR SPEED (RPM) 324
TRIM CALIBRATED AIRSPEED (KT) 153
SCAS CONDITION ON
NOTES: 1. GUN AZIMUTH = 0 DEG
2. GUN ELEVATION = 0 DEG
FIRING EVENT
AIRSPEED (KIAS)
LOAD FACTOR (G'S)
RATES(DEG/SEC) YAW + YAW RT, ROLL + ROLL RT, PITCH + NOSE UP
ATTITUDES(DEG) YAW + YAW RT, ROLL + ROLL RT, PITCH + NOSE UP
TIME(SECONDS)

FIGURE 8 (CONTINUED)
GUN FIRING DURING A LEFT ROLLING PULLOUT
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
9660	192.8 (FWD)	0.4 RT	6500	26.0	324	153	ON

NOTES:
1. GUN AZIMUTH = 0 DEG
2. GUN ELEVATION = 0 DEG

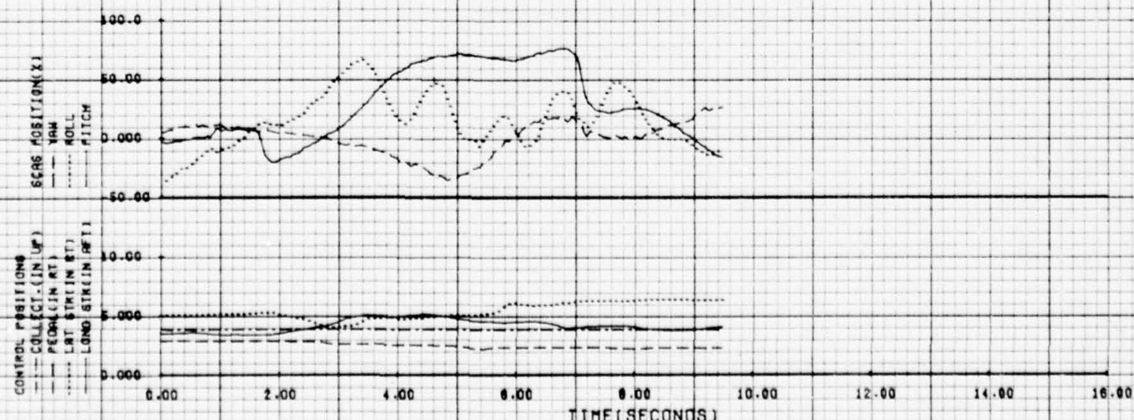


FIGURE 9
GUN FIRING DURING A STRAIGHT PULLOUT
AH-1S USA S/N 76-22567

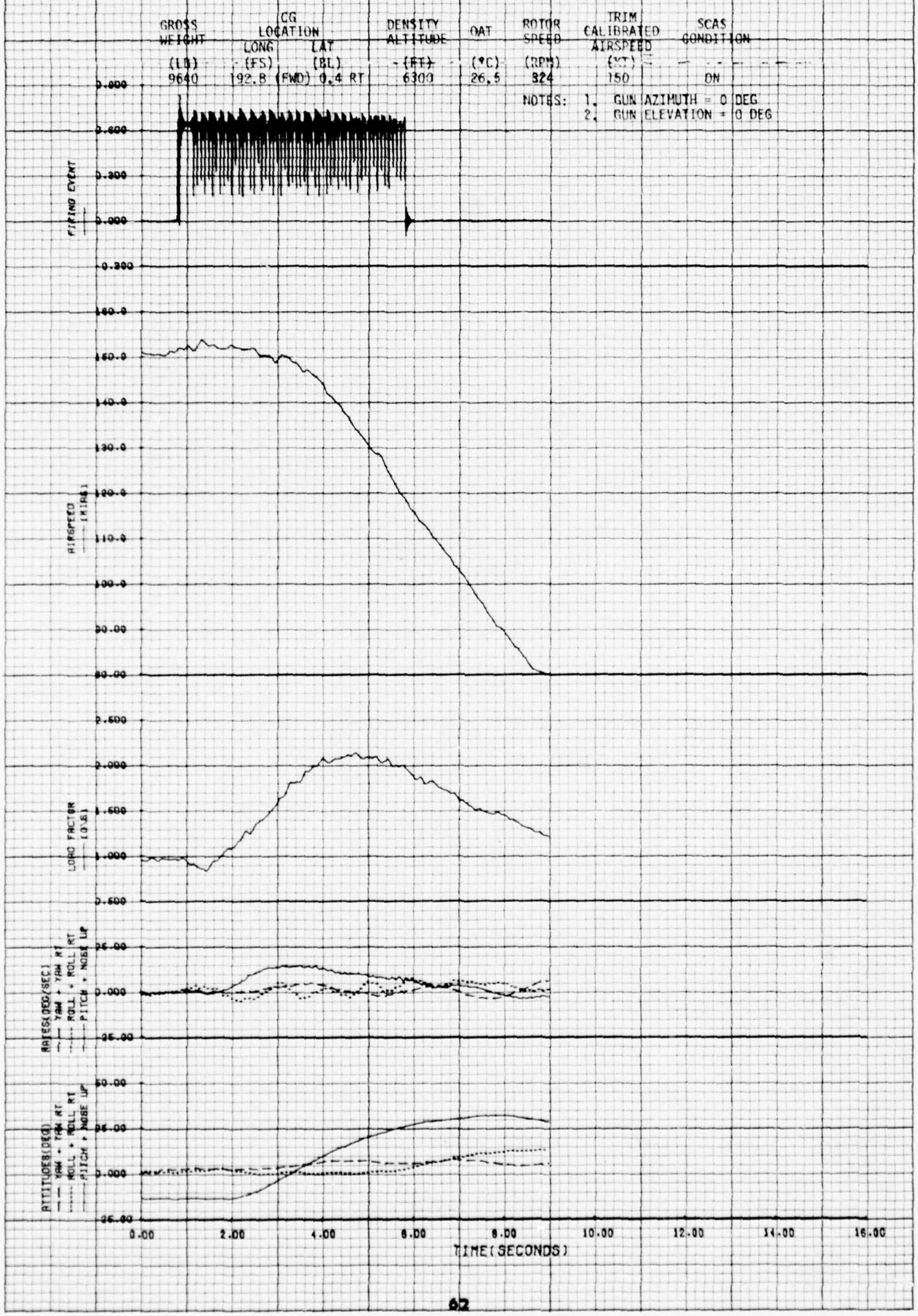
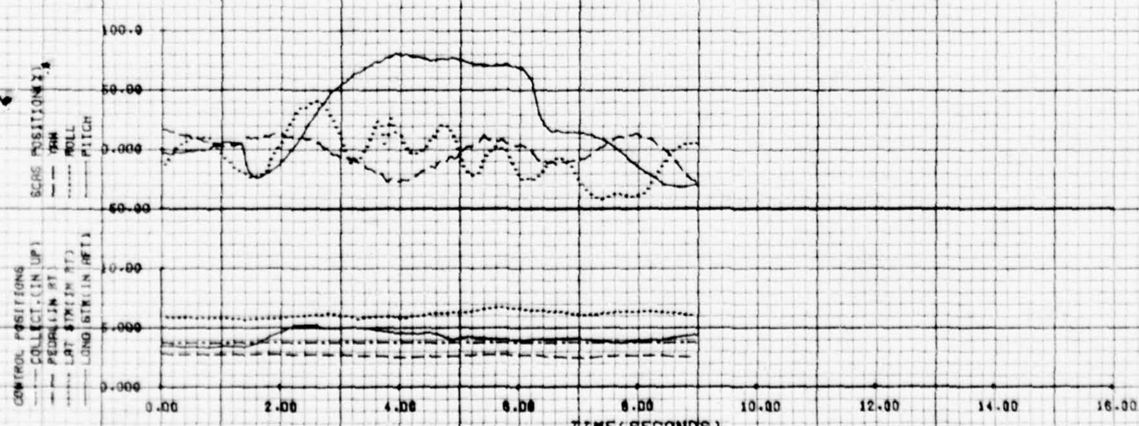


FIGURE 9 (CONTINUED)
GUN FIRING DURING A STRAIGHT PULLOUT
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
9640	192.8 (FWD)	0.4 RT	6300	26.5	324	150	ON

NOTES: 1. GUN AZIMUTH = 0 DEG
2. GUN ELEVATION = 0 DEG



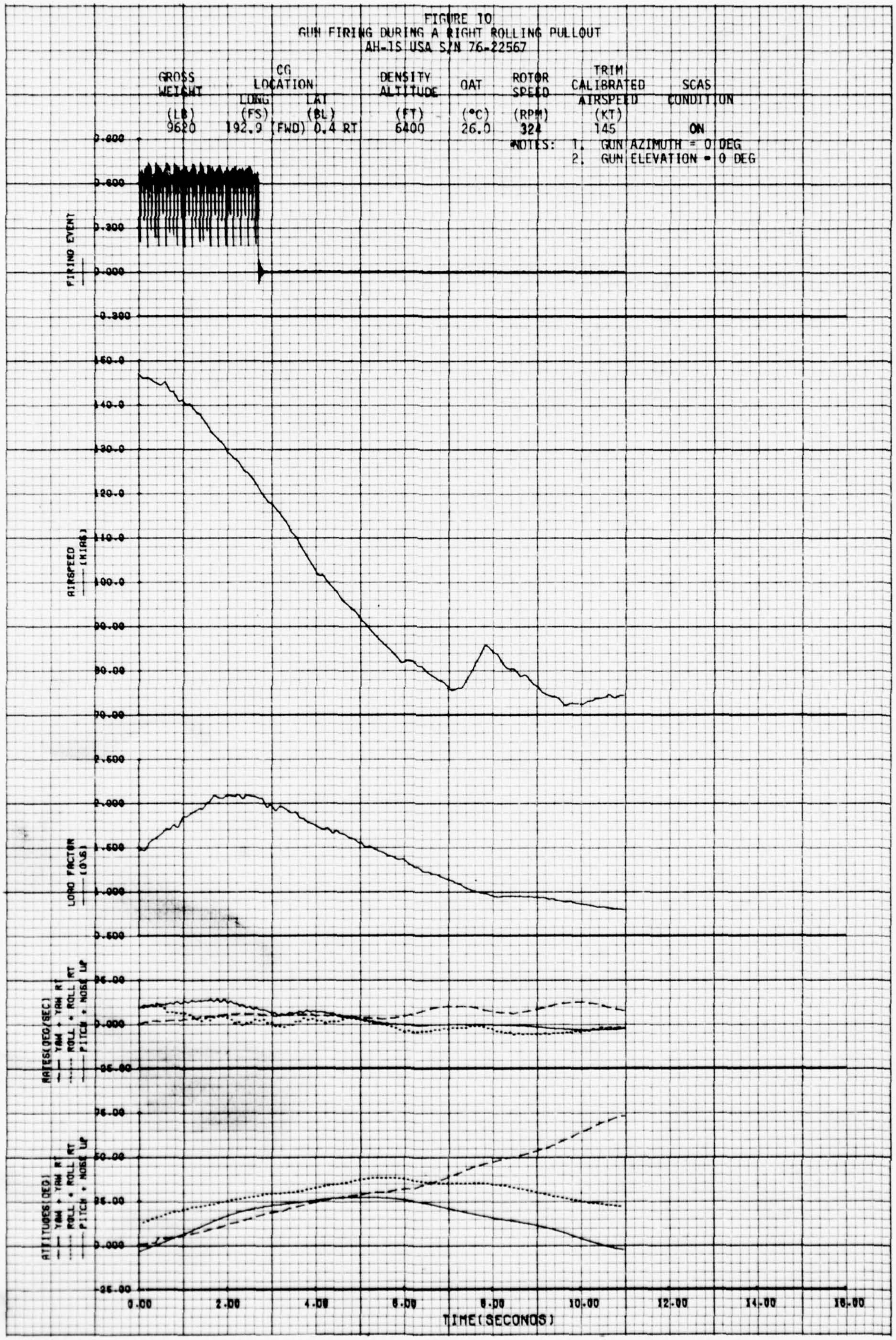


FIGURE 10
GUN FIRING DURING A RIGHT ROLLING PULLOUT
AH-1S USA S/N 76-22567
GROSS WEIGHT (LB) 9620
CG LOCATION LONG (FS) 192.9 (FWD)
LAT (BL) 0.4 RT
DENSITY ALTITUDE (FT) 6400
OAT (°C) 26.0
ROTOR SPEED (RPM) 324
TRIM CALIBRATED AIRSPEED (KT) 145
SCAS CONDITION ON
NOTES: 1. GUN AZIMUTH = 0 DEG
2. GUN ELEVATION = 0 DEG
FIRING EVENT
AIRSPEED (KIAS)
LOAD FACTOR (G'S)
RATES (DEG/SEC) YAW + YAW RT, ROLL + ROLL RT, PITCH + NOSE UP
ATTITUDES (DEG) YAW + YAW RT, ROLL + ROLL RT, PITCH + NOSE UP
TIME (SECONDS)

FIGURE 10 (CONTINUED)
GUN FIRING DURING A RIGHT ROLLING PULLOUT
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
9620	192.9 (FWD)	0.4 RT	6400	26.0	324	145	ON

NOTES: 1. GUN AZIMUTH = 0 DEG
2. GUN ELEVATION = 0 DEG

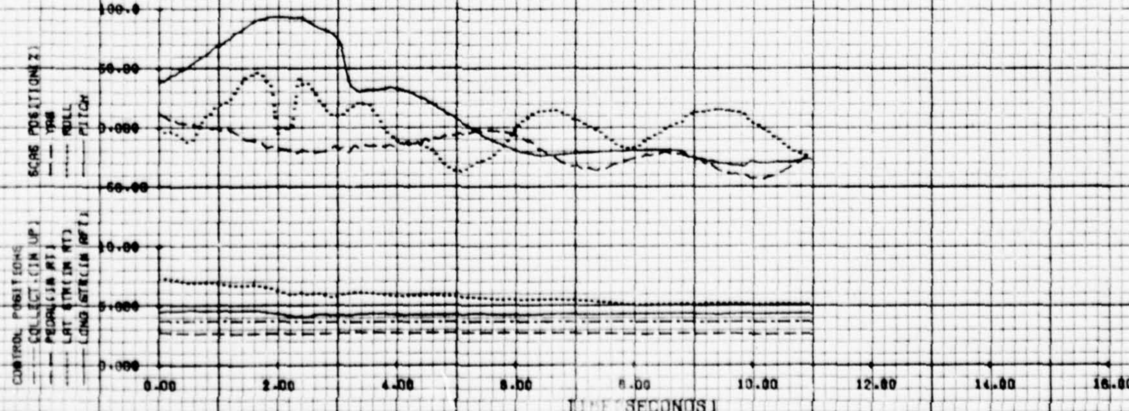


FIGURE 11
GUN FIRING DURING A LEFT ROLLING PULLOUT
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
9600	192.9 (FWD)	0.4 RT	6400	26.0	324	153	ON

NOTES: 1. GUN AZIMUTH = 0 DEG
2. GUN ELEVATION = 0 DEG

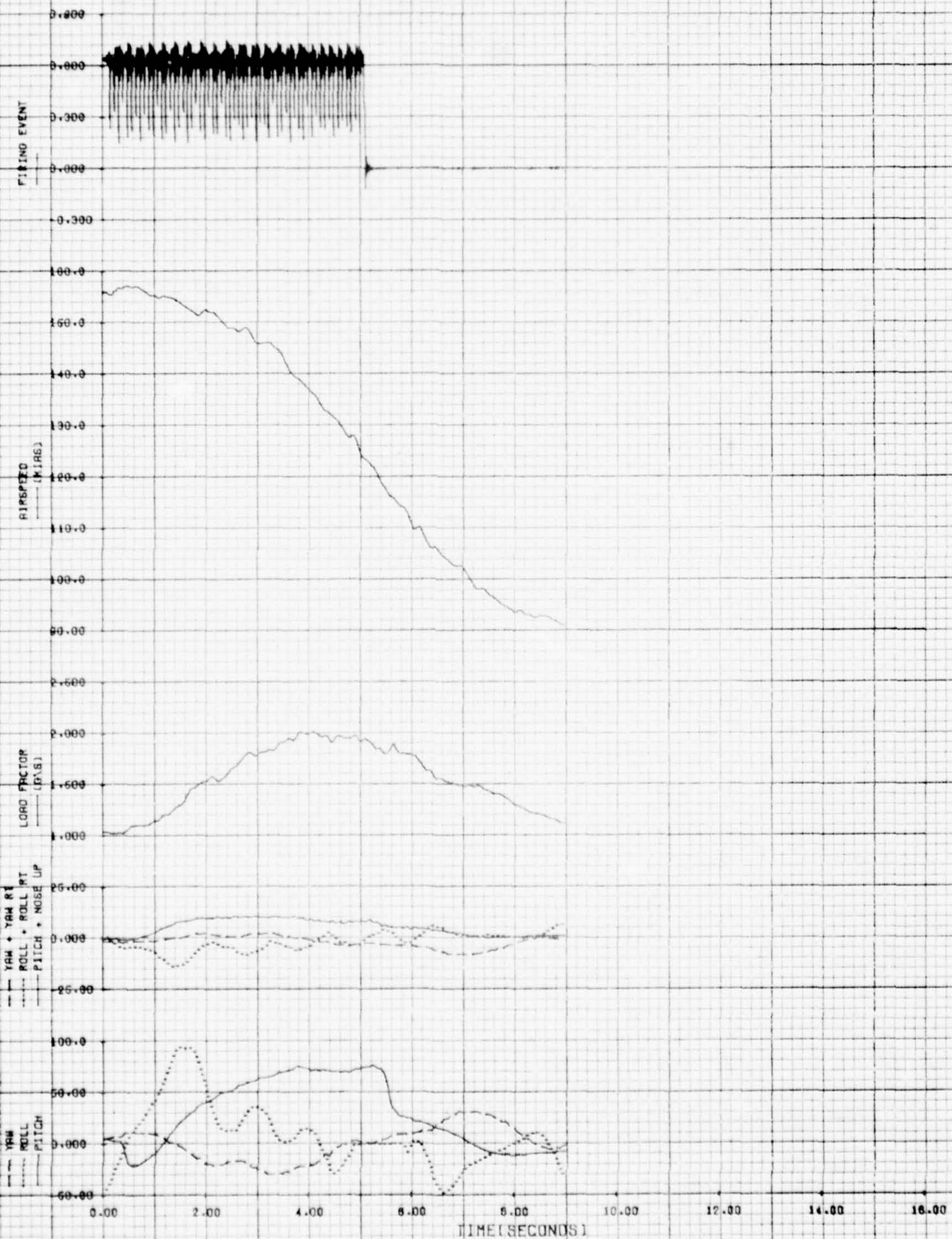


FIGURE 11 (CONTINUED)
GUN FIRING DURING A LEFT ROLLING PULLOUT
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
9600	192.9 (FWD)	0.4 RT	6400	26.0	324	153	ON

NOTES: 1. GUN AZIMUTH = 0 DEG
2. GUN ELEVATION = 0 DEG

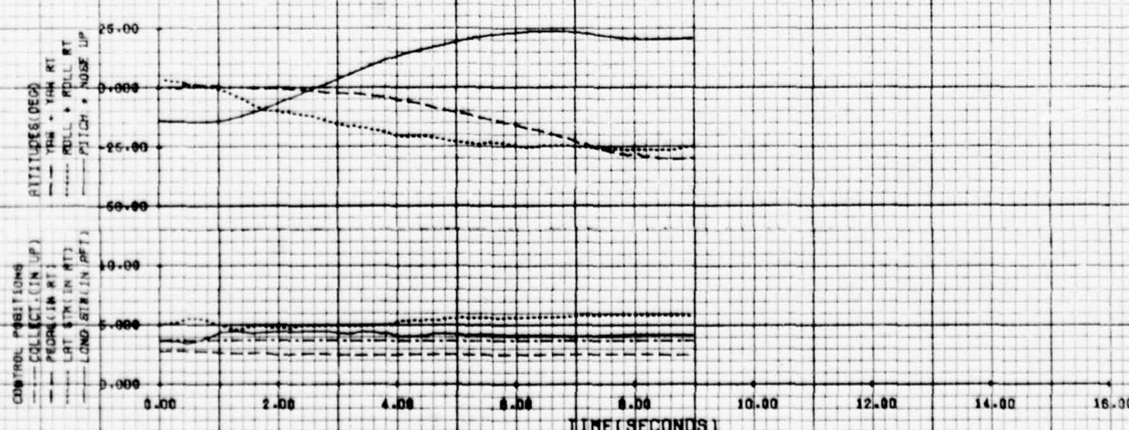


FIGURE 12
LONGITUDINAL CONTROL SYSTEM CHARACTERISTICS
AH-1S USA S/N 76-22567

NOTES:
1. ROTORS STATIC.
2. FORCES AND POSITIONS MEASURED AT CENTER OF GRIP.
3. HYDRAULIC AND ELECTRICAL POWER PROVIDED BY GROUND POWER UNITS.
4. TOTAL LONGITUDINAL CONTROL TRAVEL = 9.85 INCHES.
5. LATERAL CONTROL POSITION = 4.9 INCHES FROM FULL LEFT.

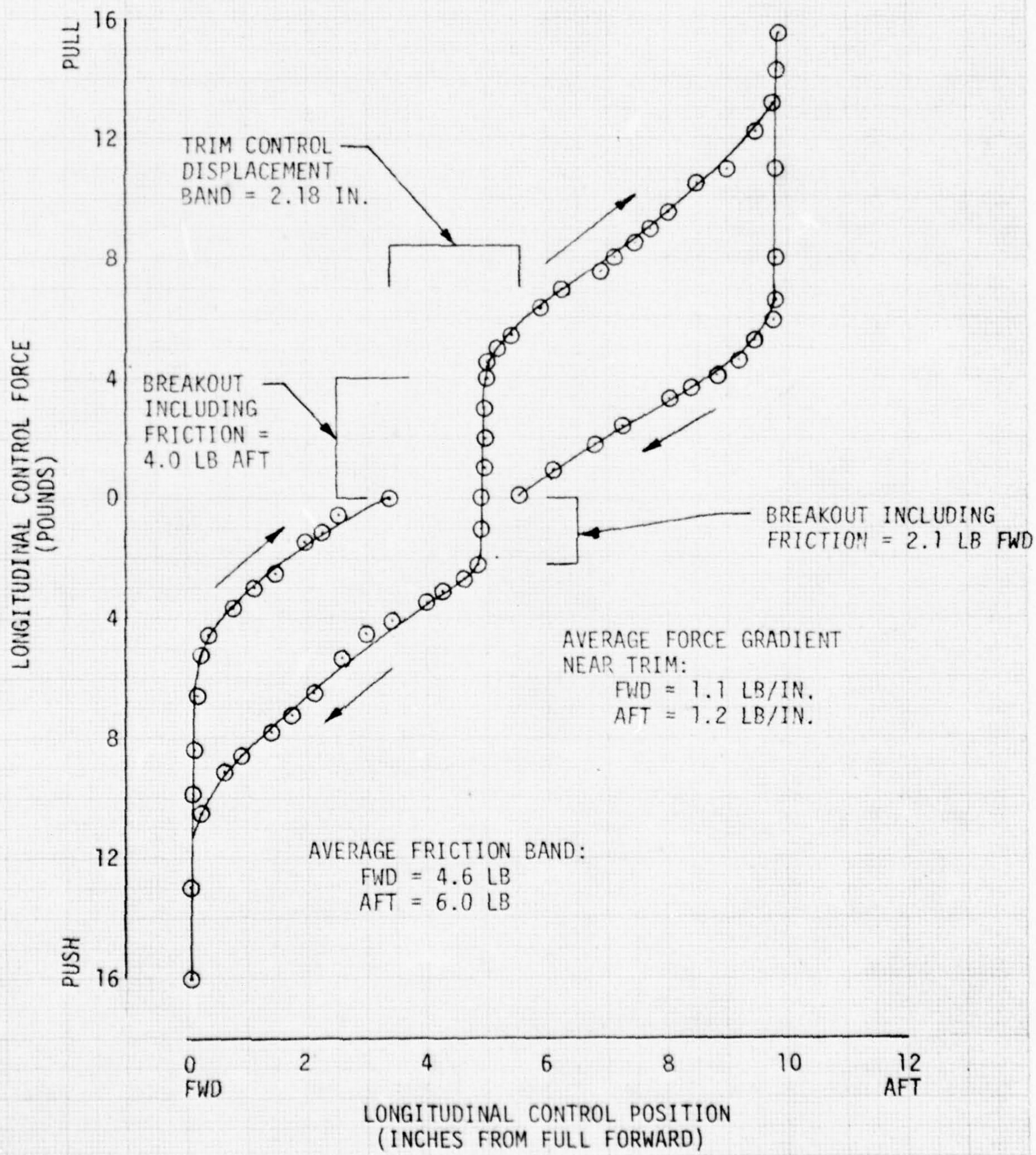


FIGURE 13
LATERAL CONTROL SYSTEM CHARACTERISTICS
AH-1S USA S/N 76-22567

NOTES:
1. ROTORS STATIC.
2. FORCES AND POSITIONS MEASURED AT CENTER OF GRIP.
3. HYDRAULIC AND ELECTRICAL POWER PROVIDED BY GROUND POWER UNITS.
4. TOTAL LATERAL CONTROL TRAVEL = 9.75 INCHES.
5. LONGITUDINAL CONTROL POSITION = 4.9 INCHES FROM FULL FORWARD.

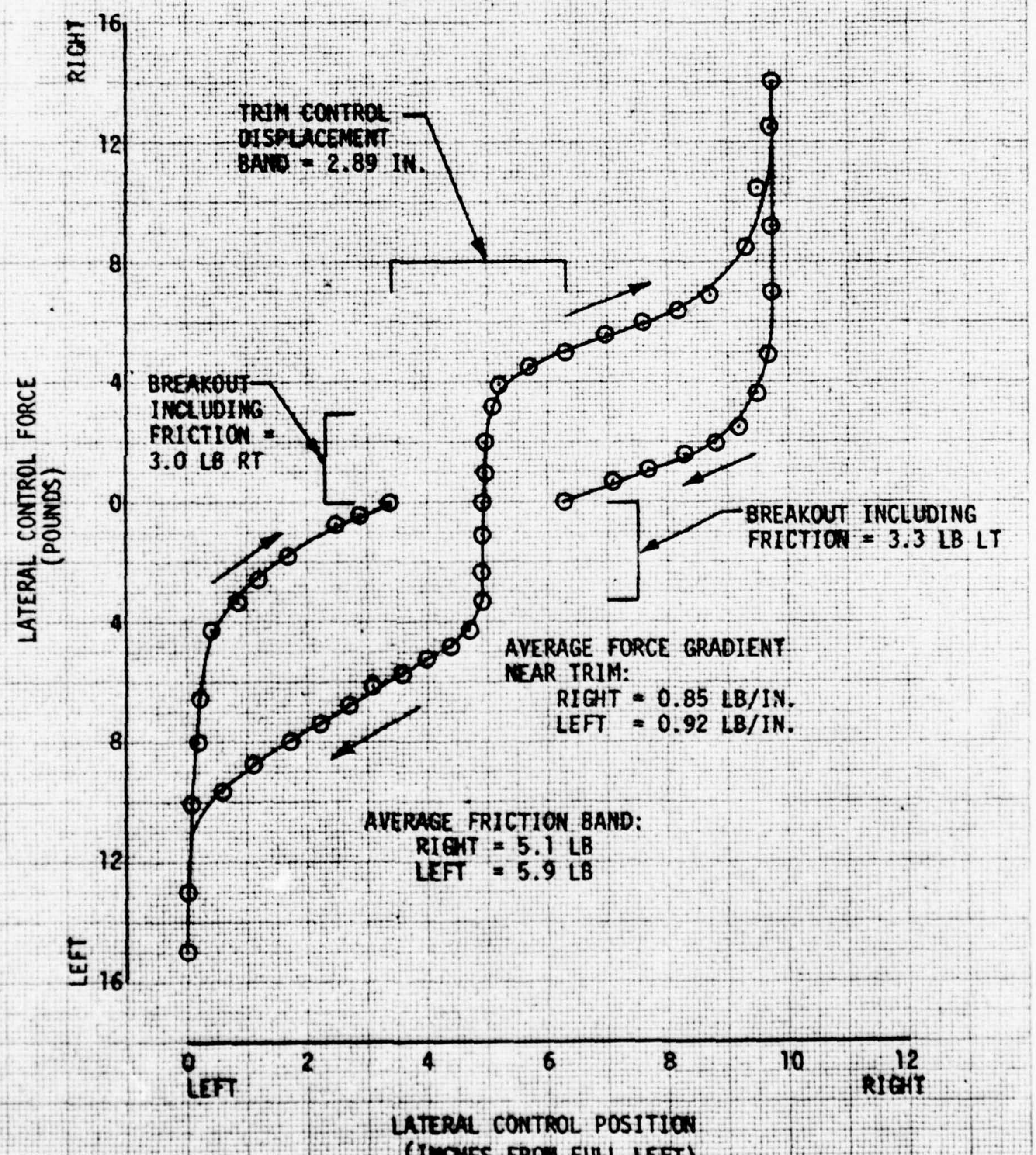


FIGURE 14
DIRECTIONAL CONTROL SYSTEM CHARACTERISTICS
AH-1S USA S/N 76-22567

NOTES:
1. ROTORS STATIC.
2. FORCES MEASURED AT THE DIRECTIONAL CONTROL.
3. HYDRAULIC AND ELECTRICAL POWER PROVIDED BY GROUND POWER UNITS.
4. TOTAL DIRECTIONAL CONTROL TRAVEL = 5.50 INCHES.

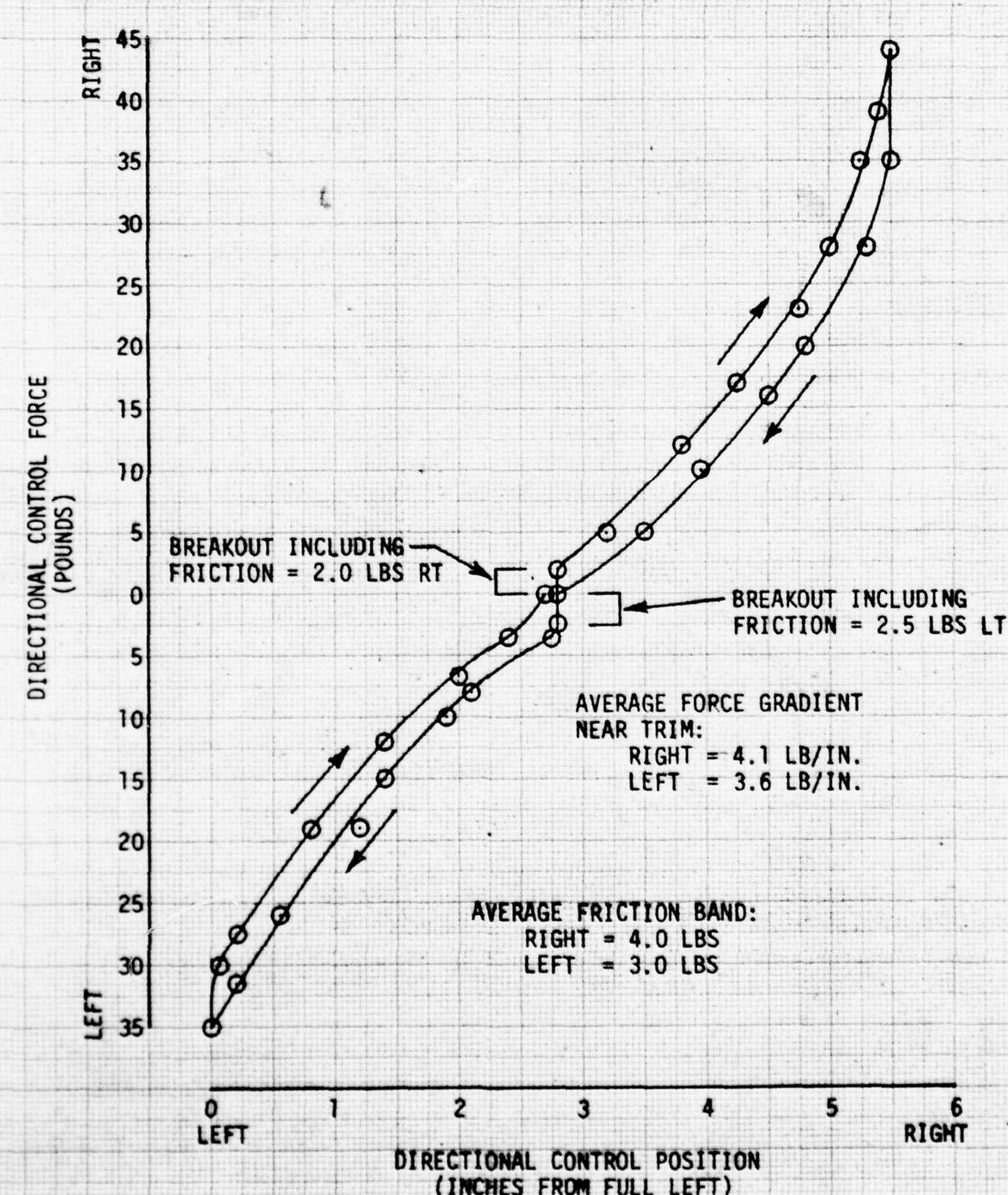


FIGURE 15
COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY
AH-1S USA S/N 76-22567

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG. DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	SCAS CONDITION
9060	194.1(FWD)	0.1 RT	5500	26.0	324	LEVEL	ON

NOTES: 1. SHADED SYMBOLS DENOTE TRIM.
2. CLEAN CONFIGURATION.

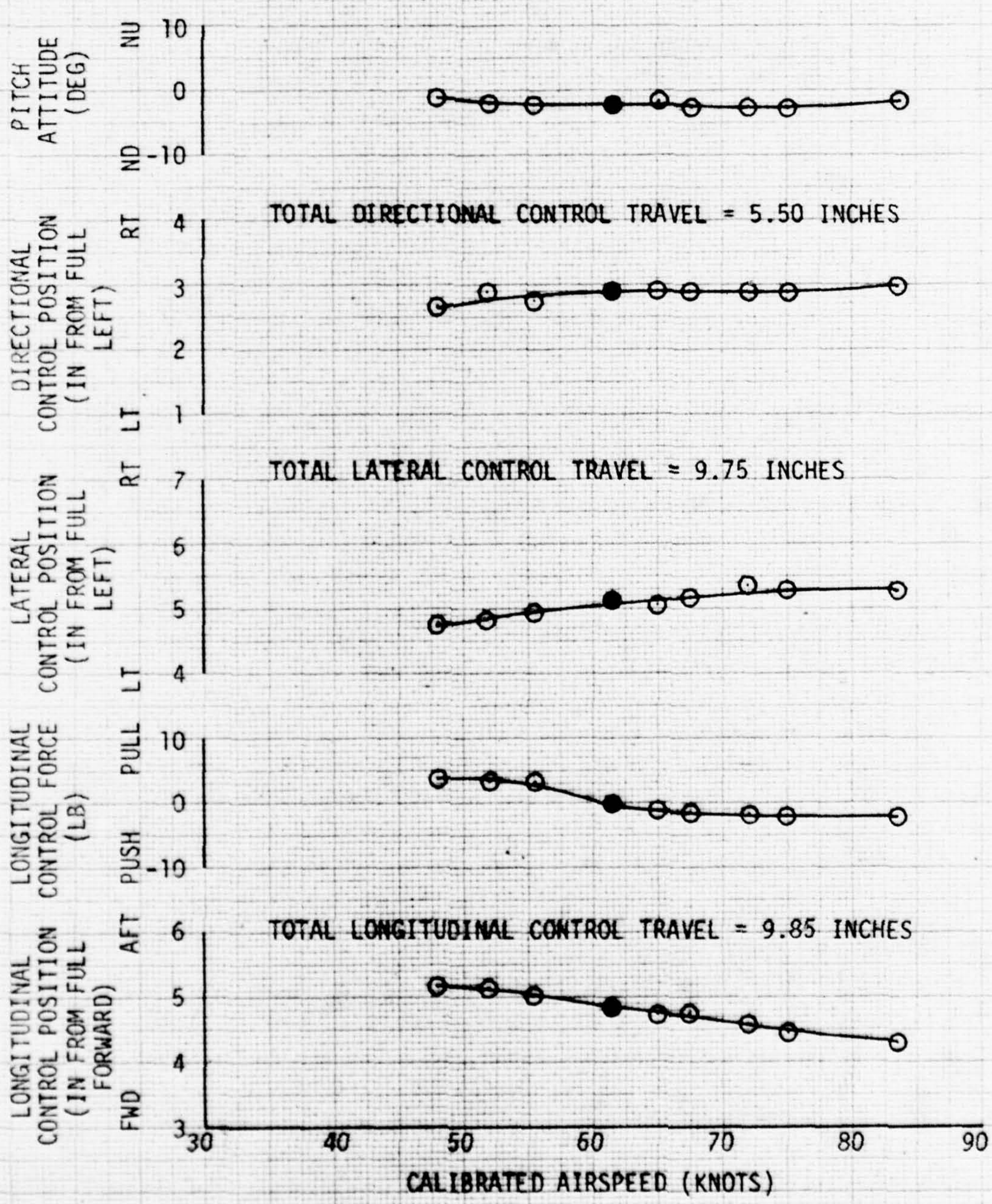


FIGURE 16
COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY
AH-1S USA S/N 76-22567

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	SCAS CONDITION
8860	194.2(FWD)	0.1 RT	6000	27.0	324	LEVEL	ON

NOTES: 1. SHADED SYMBOLS DENOTE TRIM.
2. CLEAN CONFIGURATION.

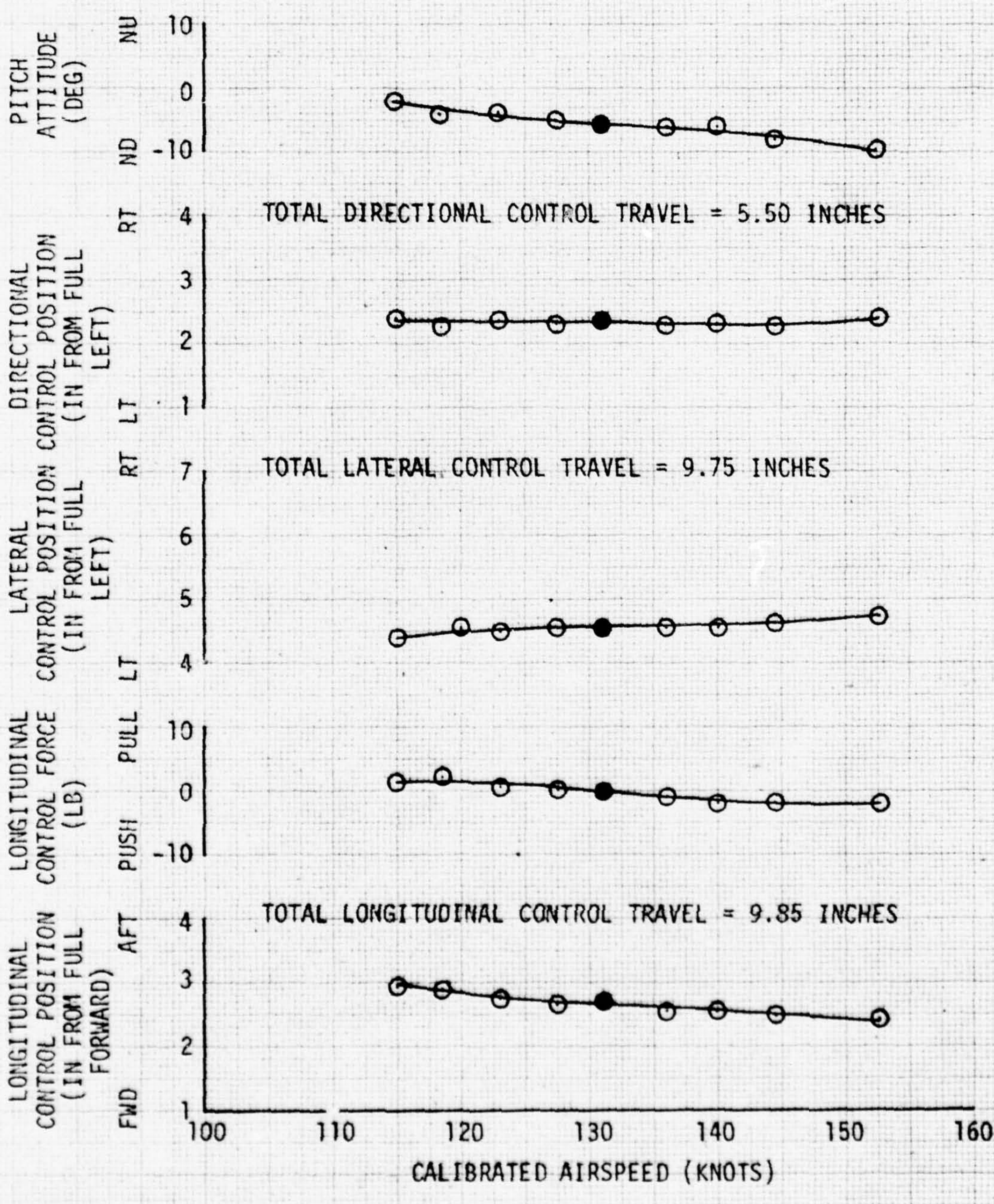


FIGURE 17
STATIC LATERAL-DIRECTIONAL STABILITY
AH-1S USA S/N 76-22567

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SCAS CONDITION
9100	194.0(FWD)	0.1 RT	5800	27.5	324	65	ON

NOTES: 1. SHADED SYMBOLS DENOTE TRIM.
2. CLEAN CONFIGURATION.

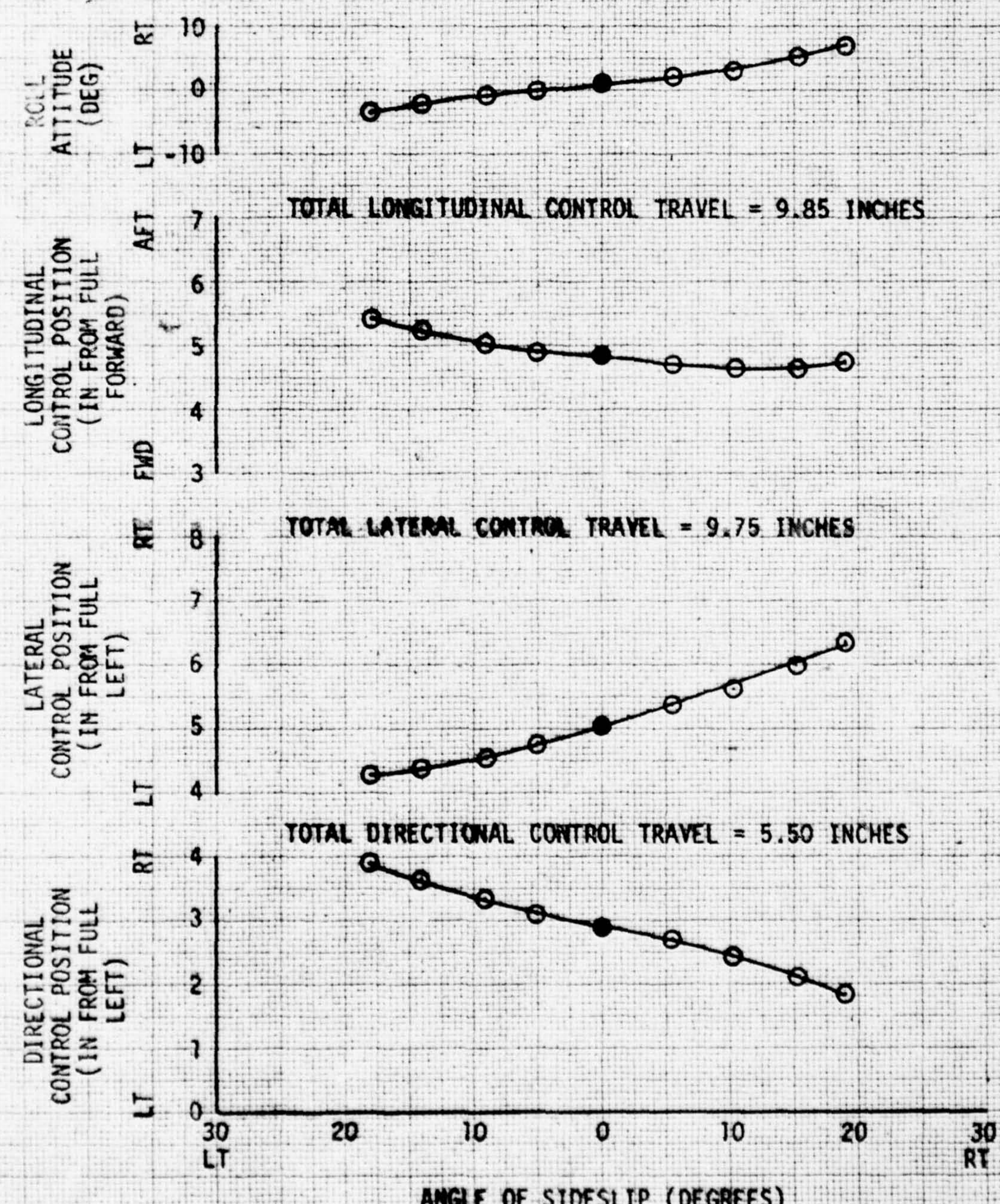


FIGURE 18
STATIC LATERAL-DIRECTIONAL STABILITY
AH-1S USA S/N 76-22567

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SCAS CONDITION
8920	194.1(FWD)	0.1 RT	6200	27.0	324	116	ON

NOTES: 1. SHADED SYMBOLS DENOTE TRIM.
2. CLEAN CONFIGURATION.

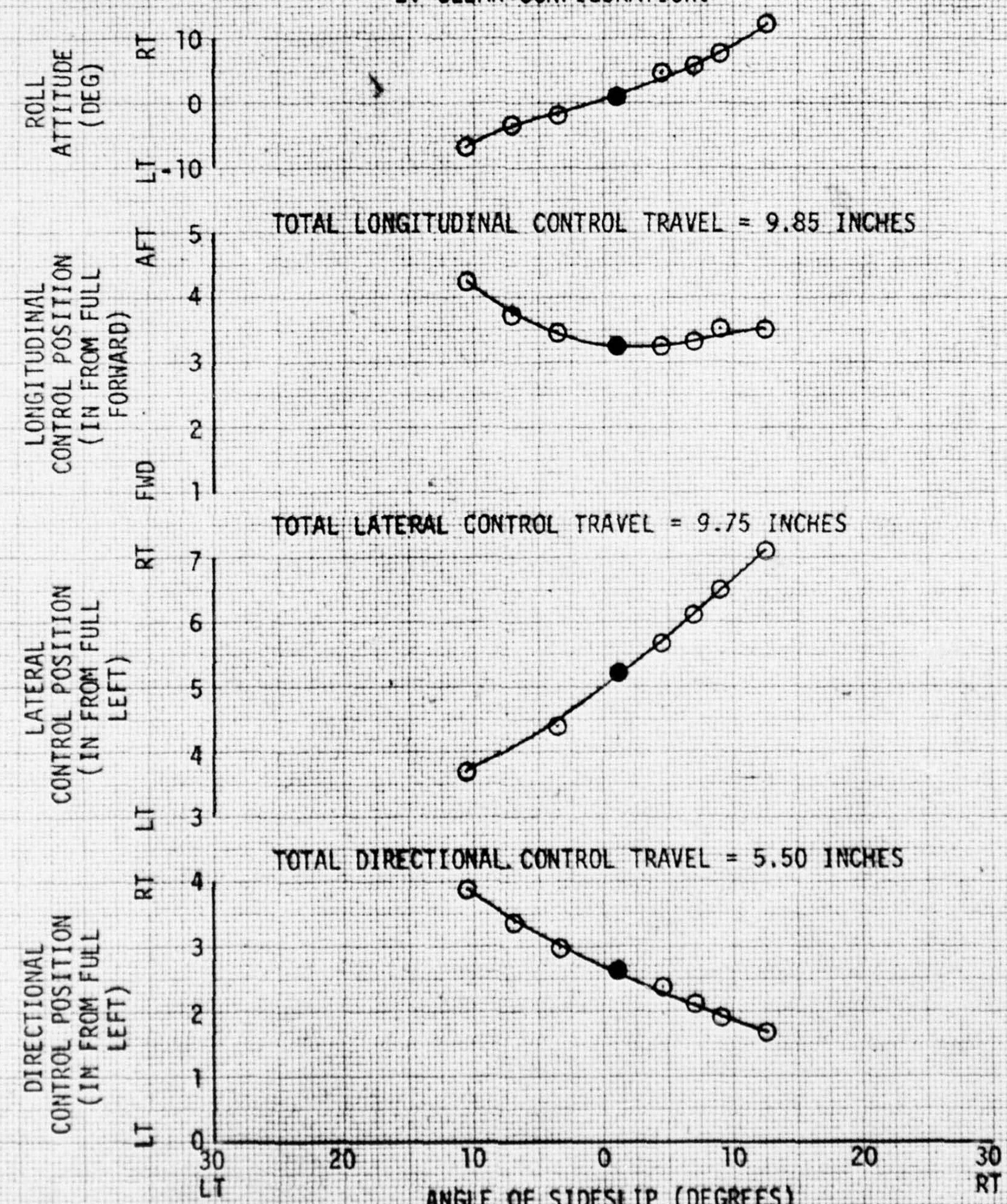


FIGURE 19

MANEUVERING STABILITY

AH-1S USA S/N 76-22567

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION	SCAS CONDITION
○	8560	194.2(FWD)	0.1 RT	6800	28.0	324	RT TURN	ON
□	8520	194.3(FWD)	0.1 RT	6800	28.0	324	LT TURN	ON

NOTES: 1. CLEAN CONFIGURATION.
2. 116 KCAS.
3. NORMAL RATED POWER.

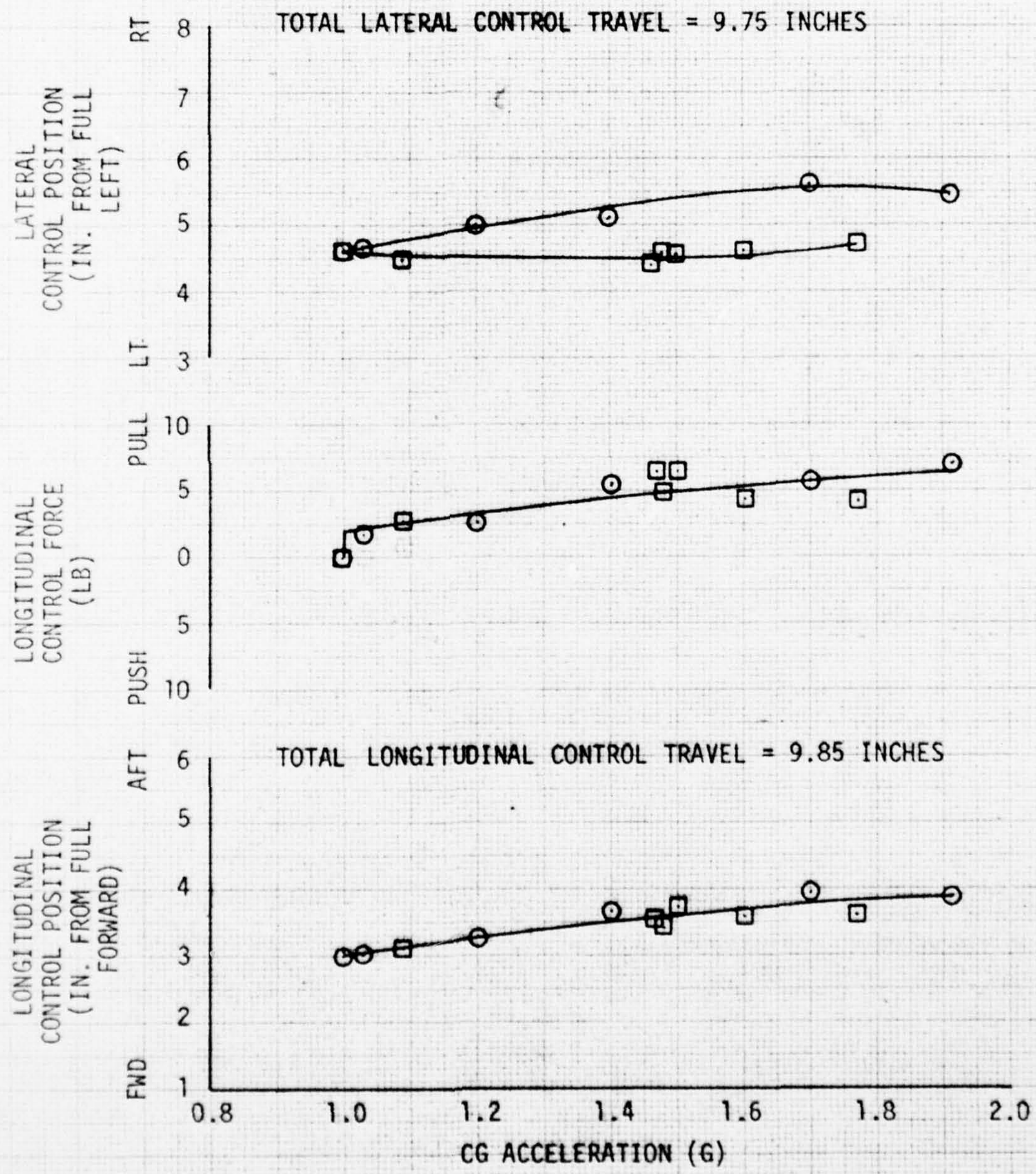


FIGURE 20
MANEUVERING STABILITY
AH-1S USA S/N 76-22567

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION	SCAS CONDITION
○	8360	194.2(FWD)	0.1 RT	6500	27.0	324	RT TURN	ON
□	8300	194.3(FWD)	0.1 RT	6500	27.0	324	LT TURN	ON

NOTES:
1. CLEAN CONFIGURATION.
2. 116 KCAS.
3. POWER FOR LEVEL FLIGHT.

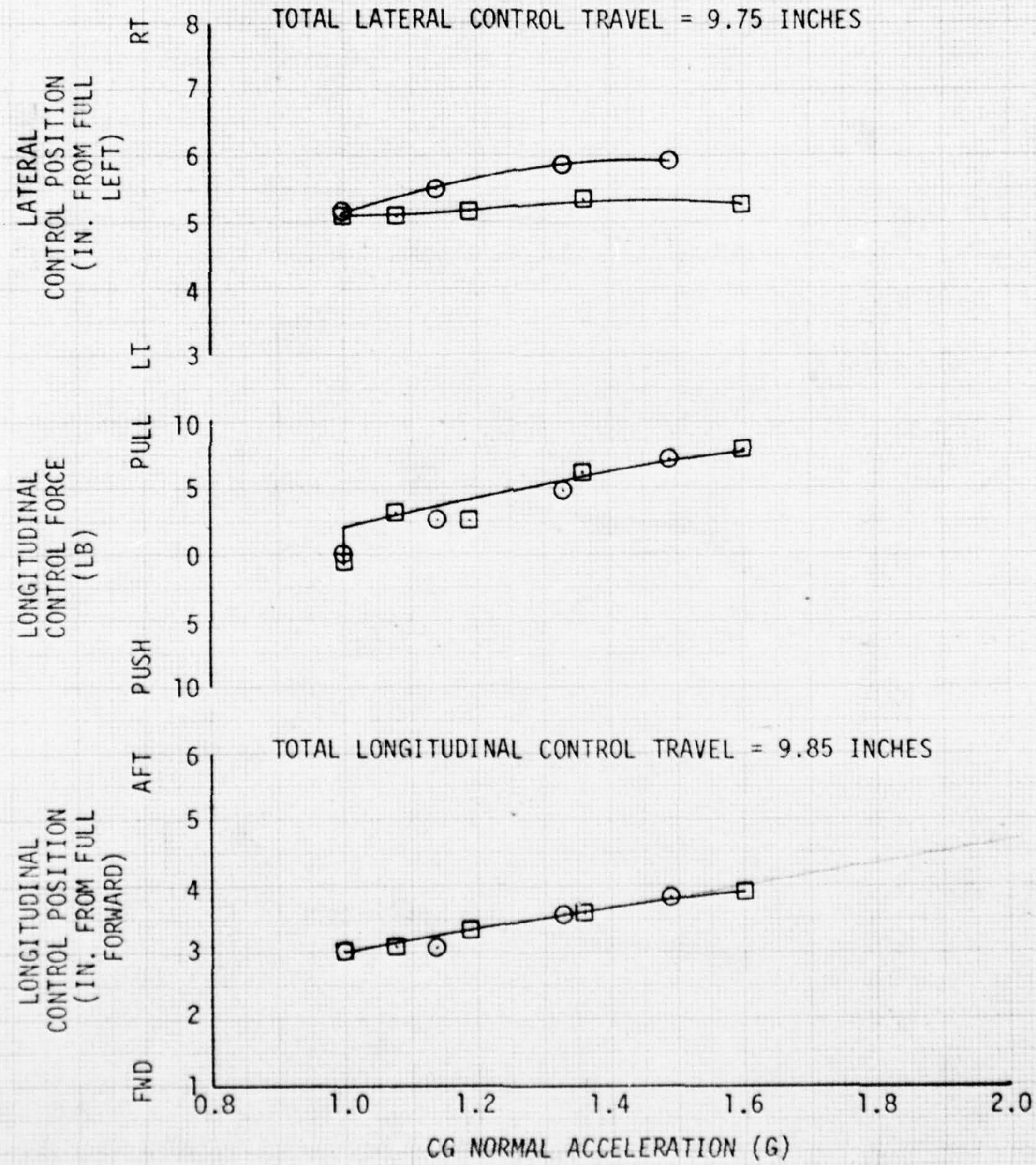


FIGURE 21
RIGHT DIRECTIONAL PULSE
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
8450	194.3 (MID)	0.1 RT	6500	25.0	324	64	ON

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION

FIGURE 22
RIGHT DIRECTIONAL PULSE
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
8520	194.3 (MID)	0.4 RT	6600	27.0	324	116	ON

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION

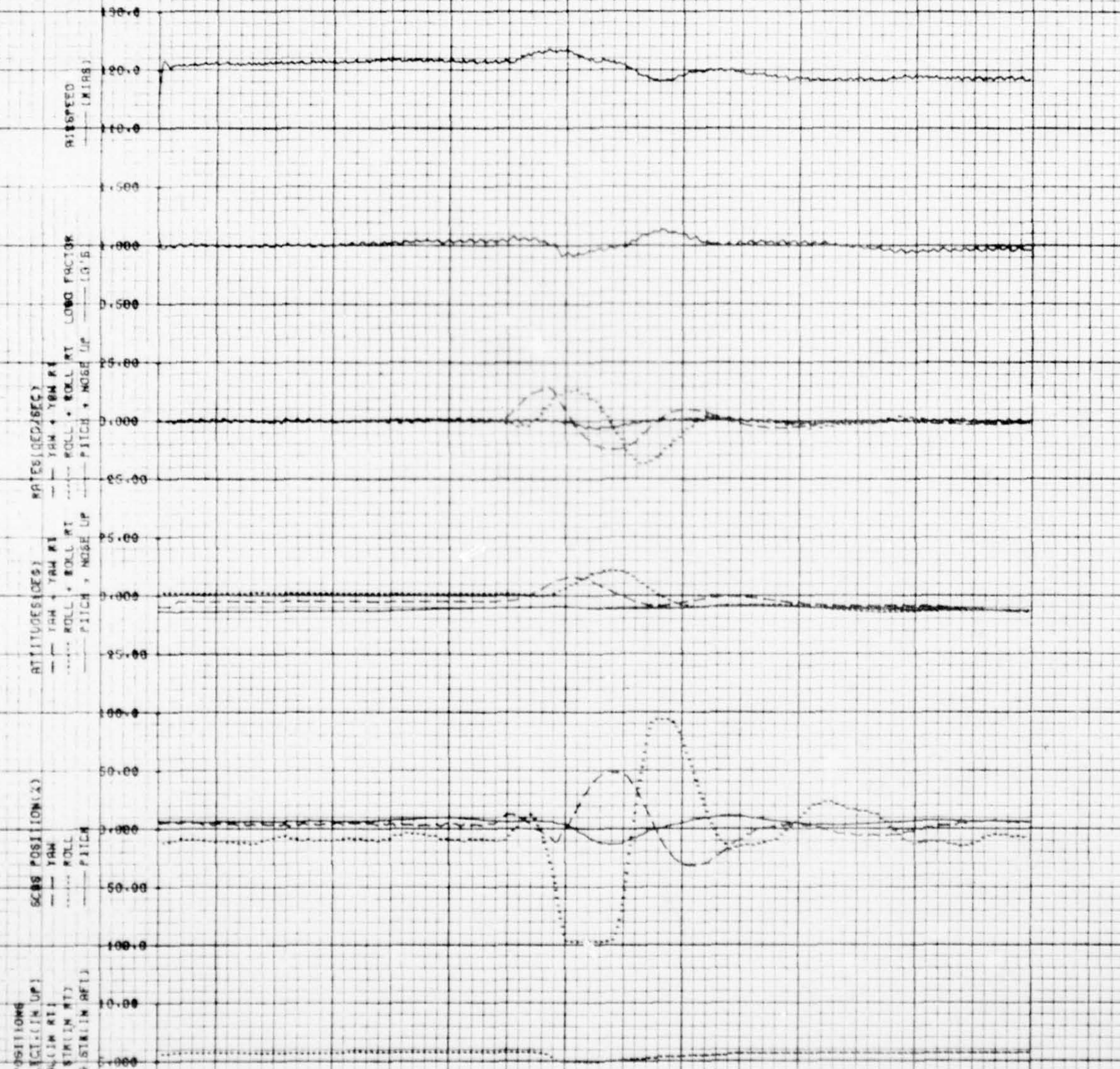


FIGURE 23
FORWARD LONGITUDINAL PULSE
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
8920	194.1 (MID)	0.1 RT	6460	27.0	324	64	ON

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION

FIGURE 24
FORWARD LONGITUDINAL PULSE
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
8800	194.1 (MID)	0.1 RT	6500	27.5	324	116	ON

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION

FIGURE 25
RIGHT LATERAL PULSE
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
8540	194.3 (MID)	0.1 RT	6400	26.5	324	64	ON

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION

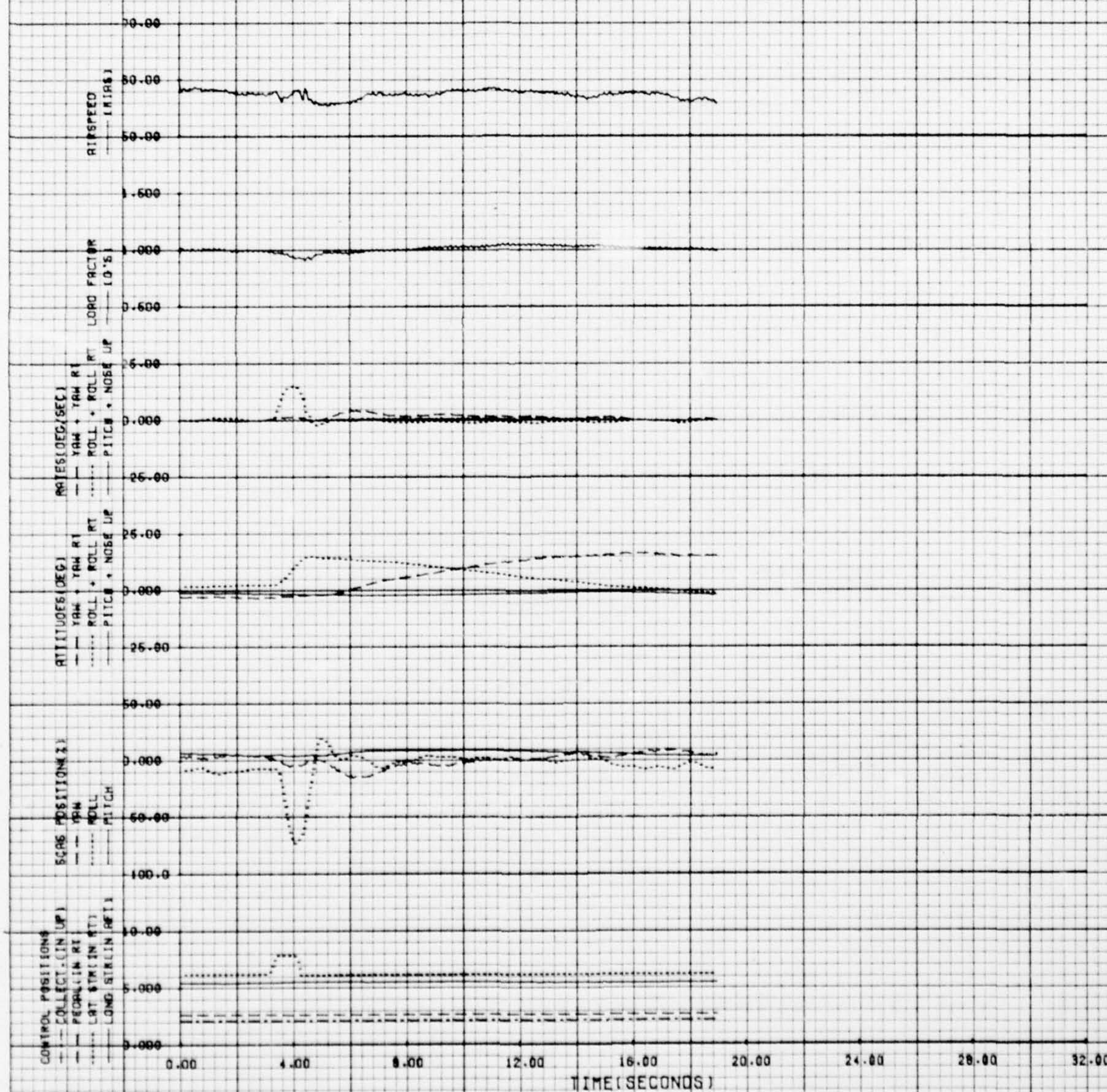


FIGURE 26
RIGHT LATERAL PULSE
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
9040	194.0 (MID)	0.1 RT	6000	25.5	324	108	ON

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION

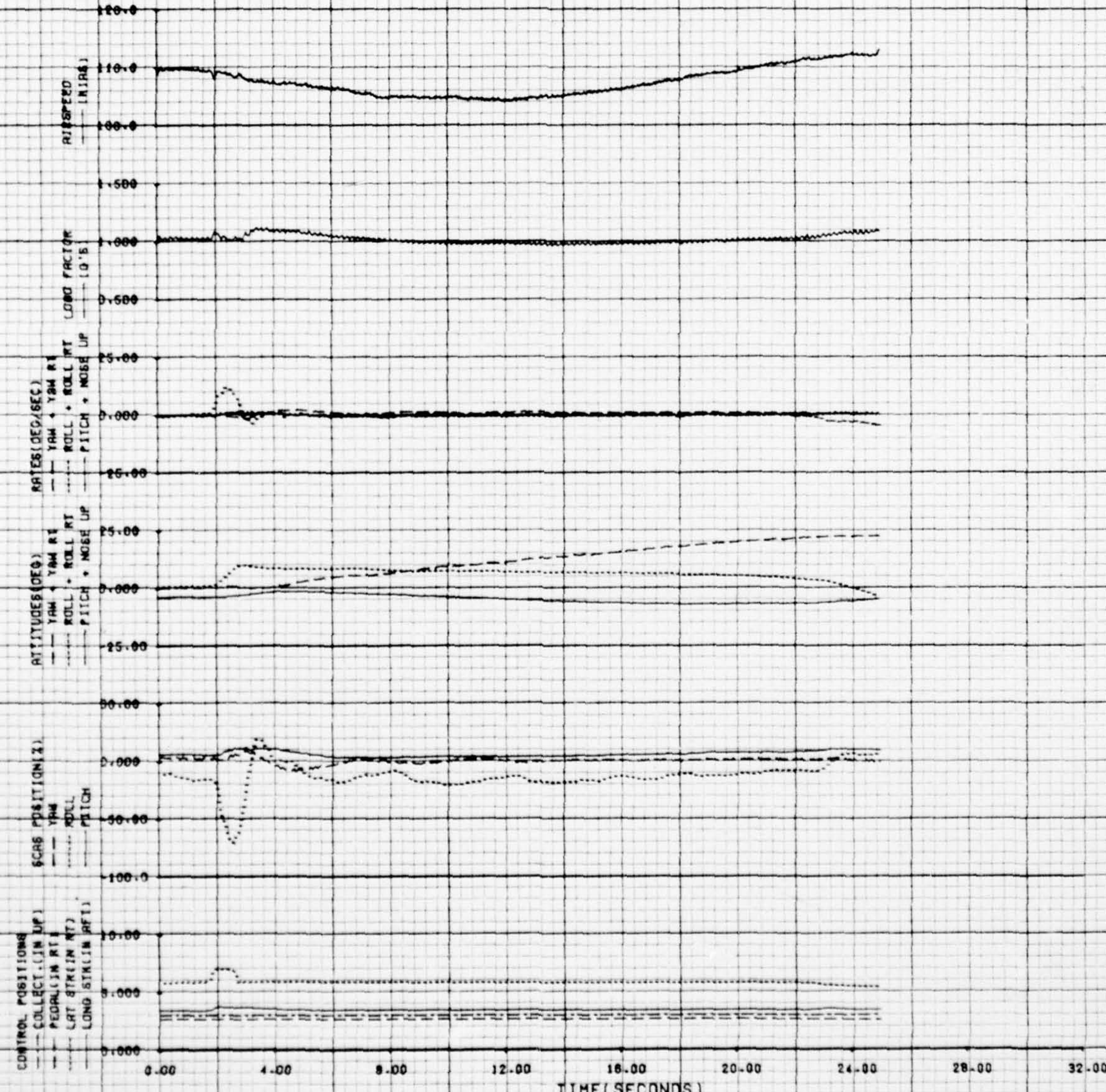


FIGURE 27
RIGHT LATERAL PULSE
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
9020	194.1 (MID)	0.1 RT	6240	26.0	324	115	ON

NOTES: 1. GUN STOWED
2. GUN ELEVATION

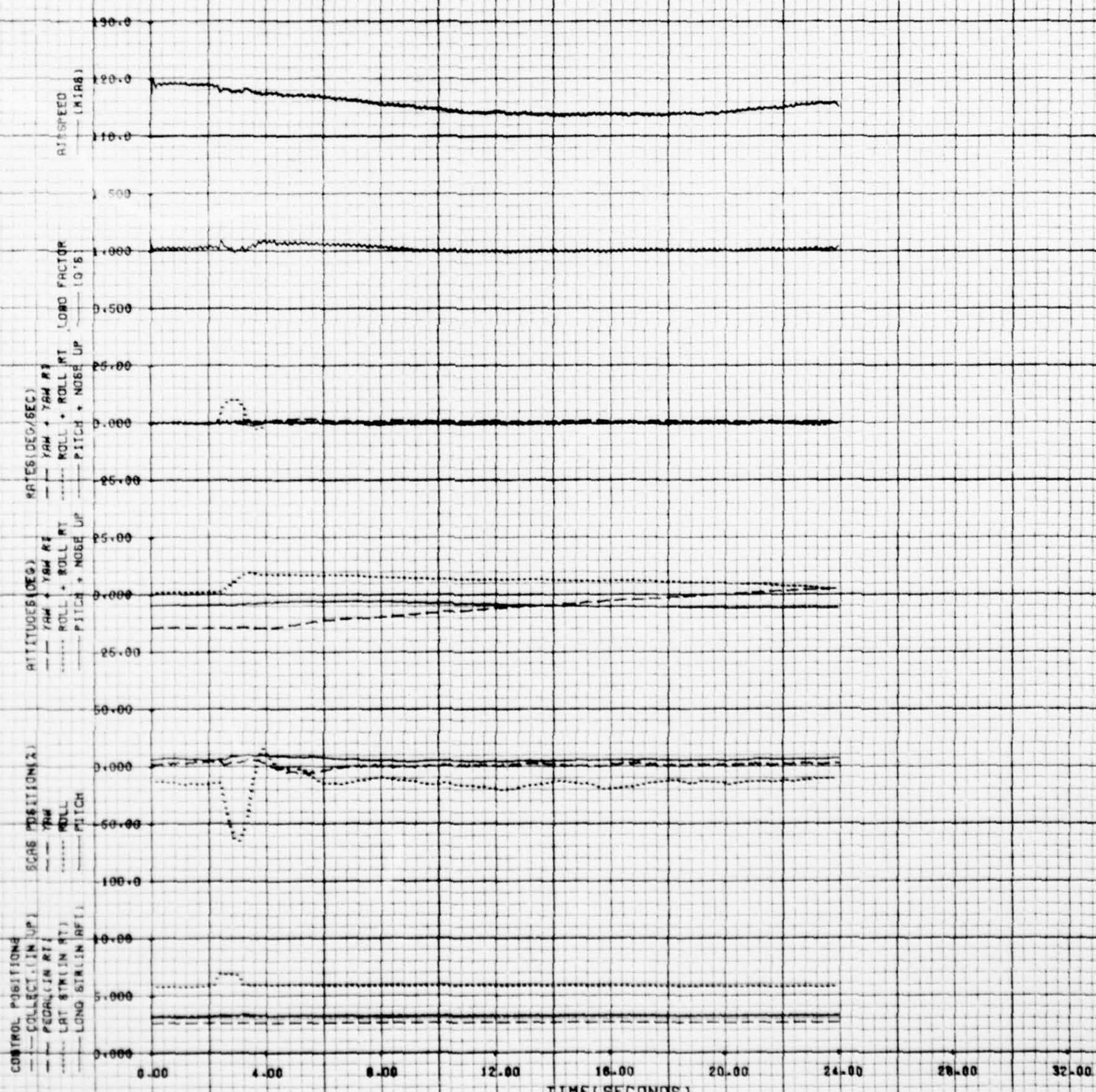


FIGURE 28
RIGHT LATERAL PULSE
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
9000	194.1 (MID)	0.1 RT	6400	26.5	324	127	ON

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION

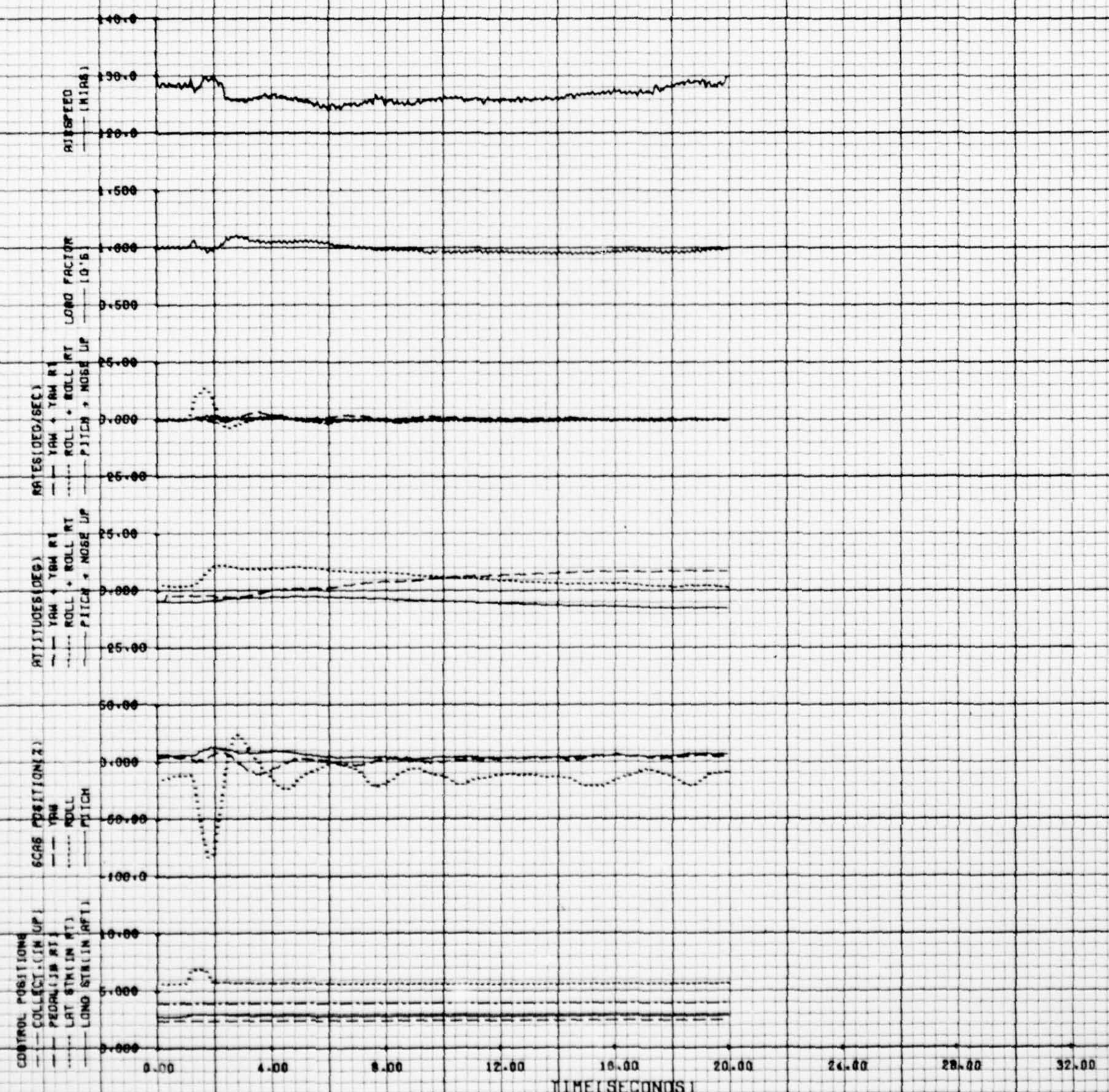


FIGURE 29
RIGHT LATERAL PULSE
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
8980	194.1 (MID)	0.1 RT	6400	26.0	324	137	ON

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION

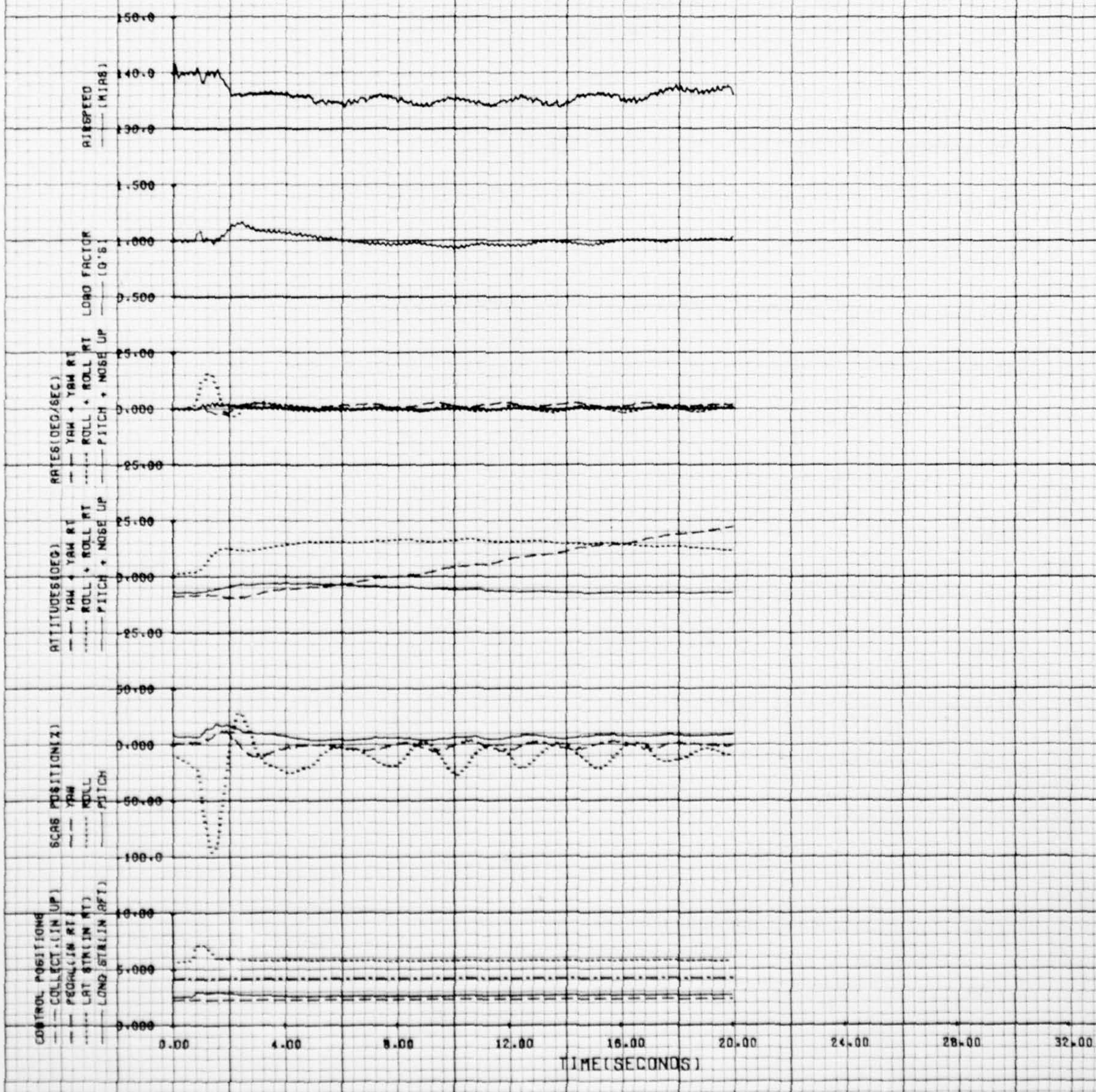


FIGURE 30
DUTCH ROLL
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
8900	194.1 (MID)	0.1 RT	6600	27.0	324	64	OFF

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION

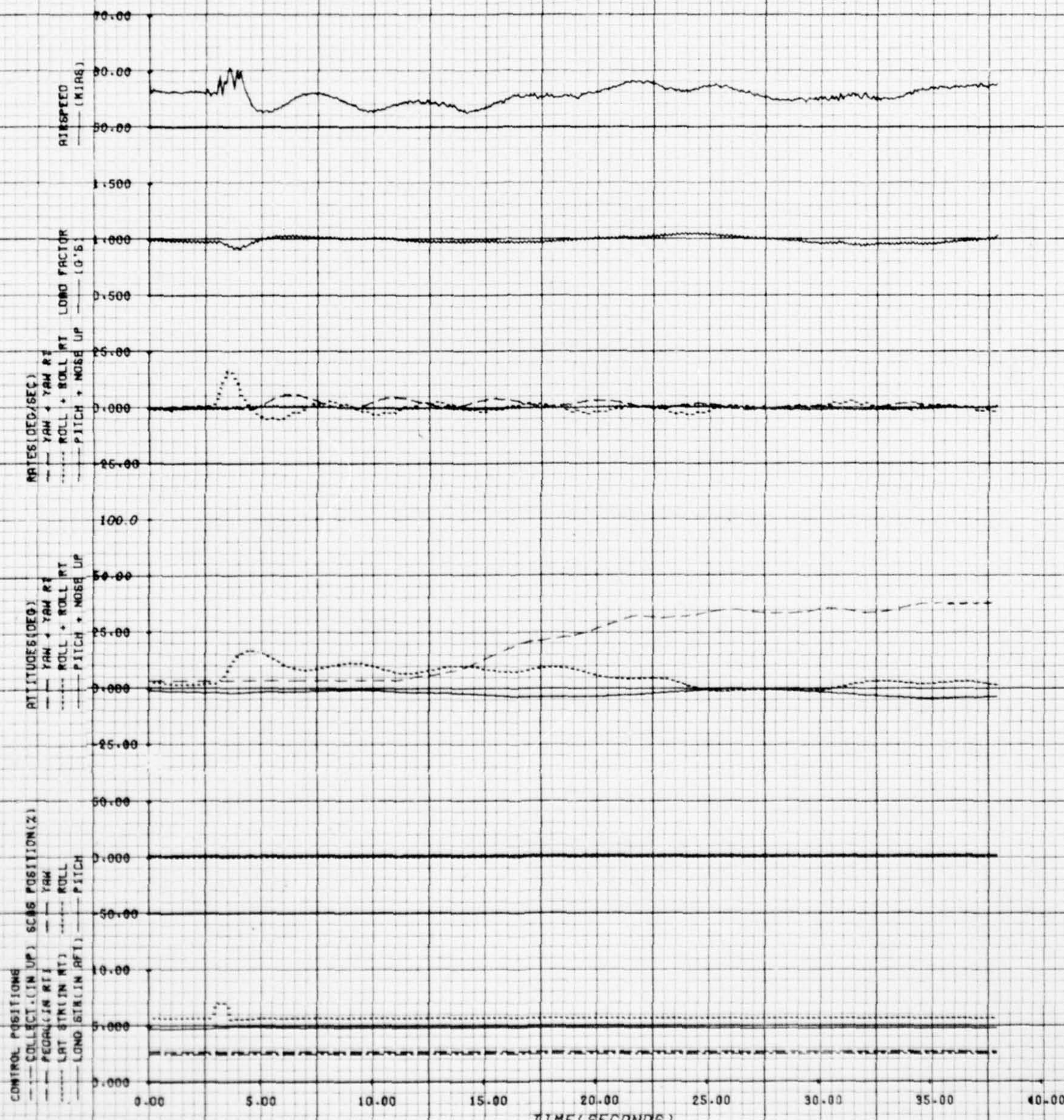


FIGURE 31
DUTCH ROLL
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
8880	194.1 (MID)	0.1 RT	6800	28.0	324	80	OFF

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION

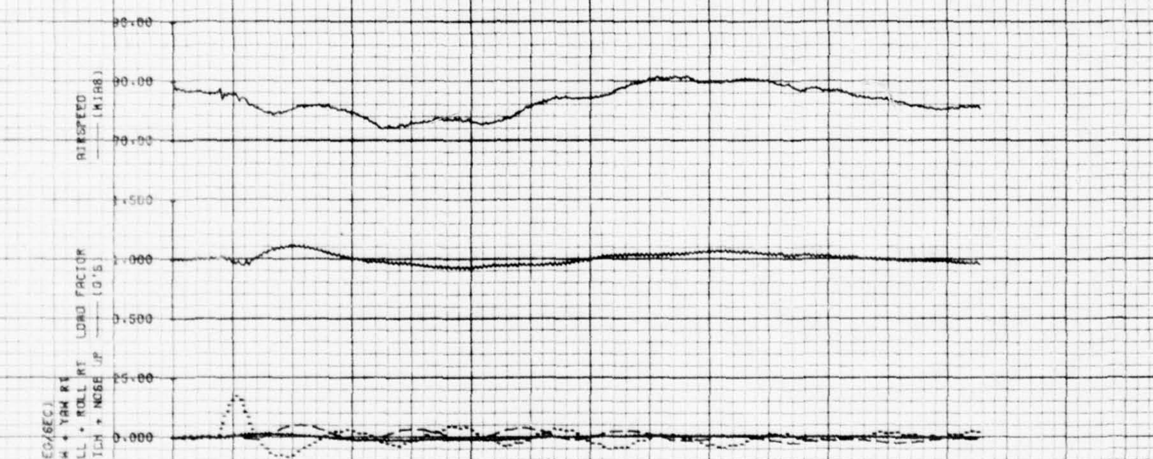


FIGURE 32
DUTCH ROLL
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
8860	194.1 (MID)	0.1 RT	6200	28.0	324	97	OFF

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION

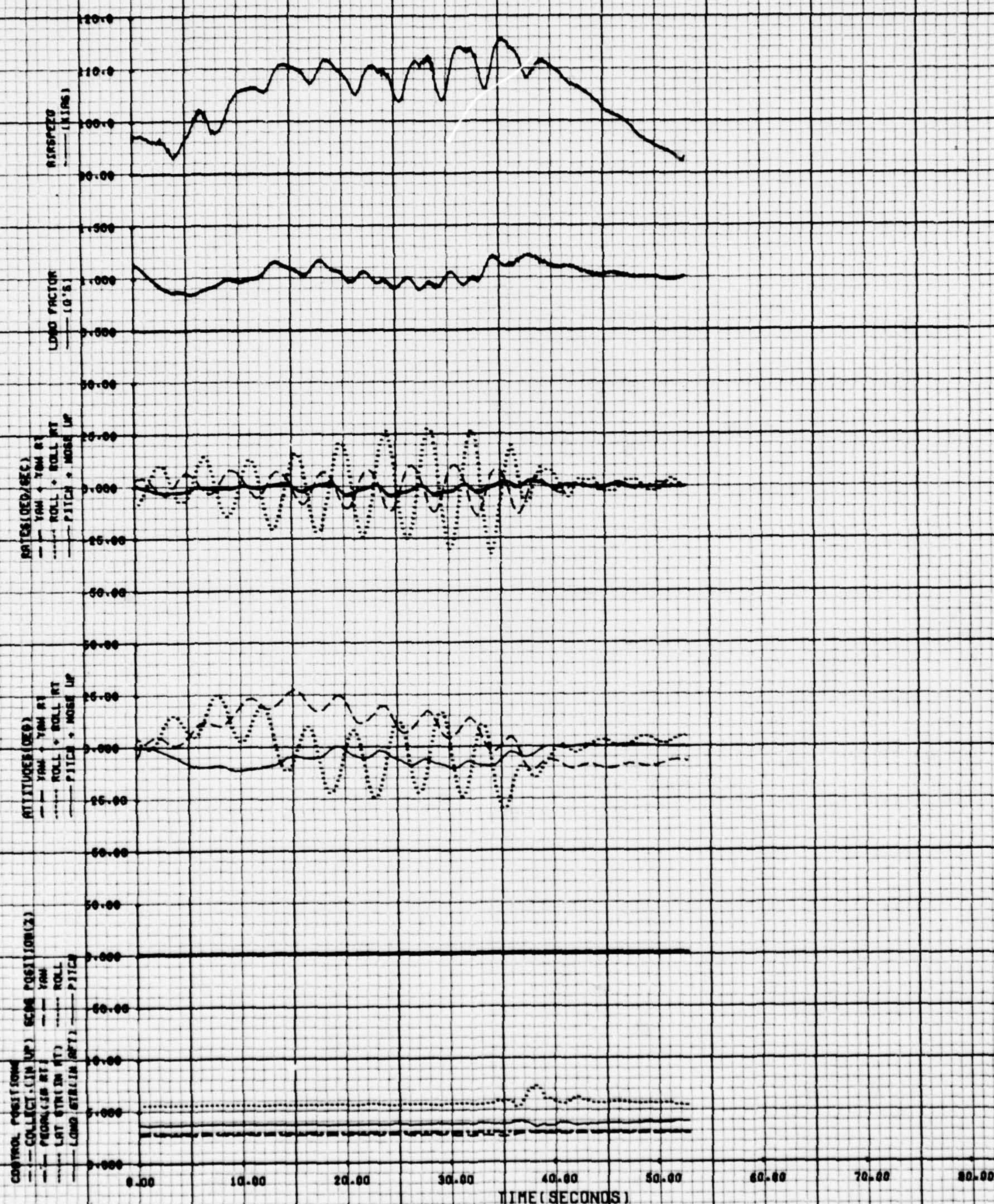


FIGURE 33
DUTCH ROLL
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
8860	194.1 (MID)	0.1 RT	6300	27.5	324	98	OFF

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION

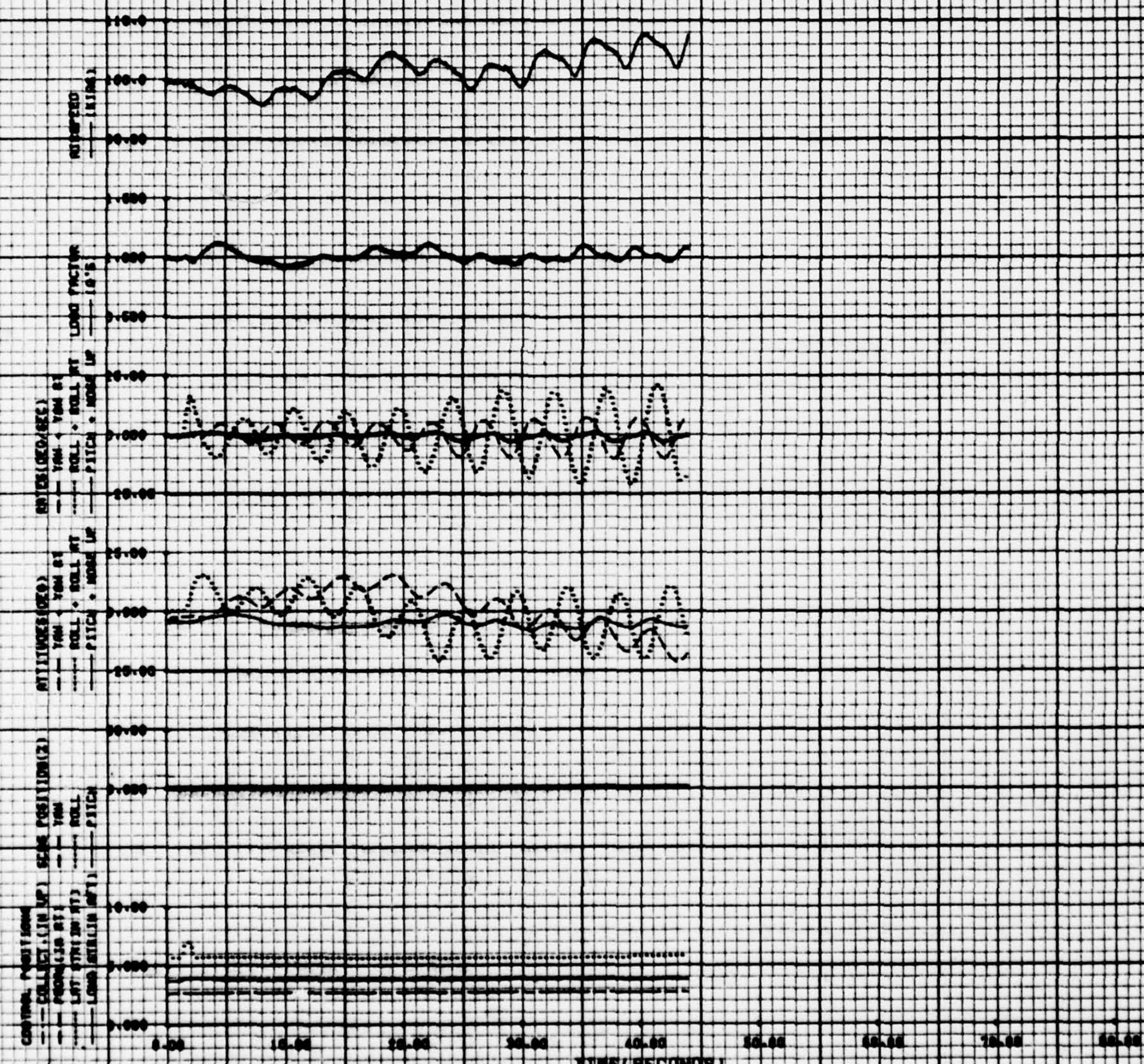


FIGURE 34
DUTCH ROLL RATE DAMPING
AH-1S USA S/N 76-22567

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	SCAS CONDITION
8800	194.2(FWD)	0.1 RT	6240	28.0	324	OFF

NOTES: 1. CLEAN CONFIGURATION.
2. DAMPING RATIO OBTAINED USING LOGARITHMIC DECREMENT.

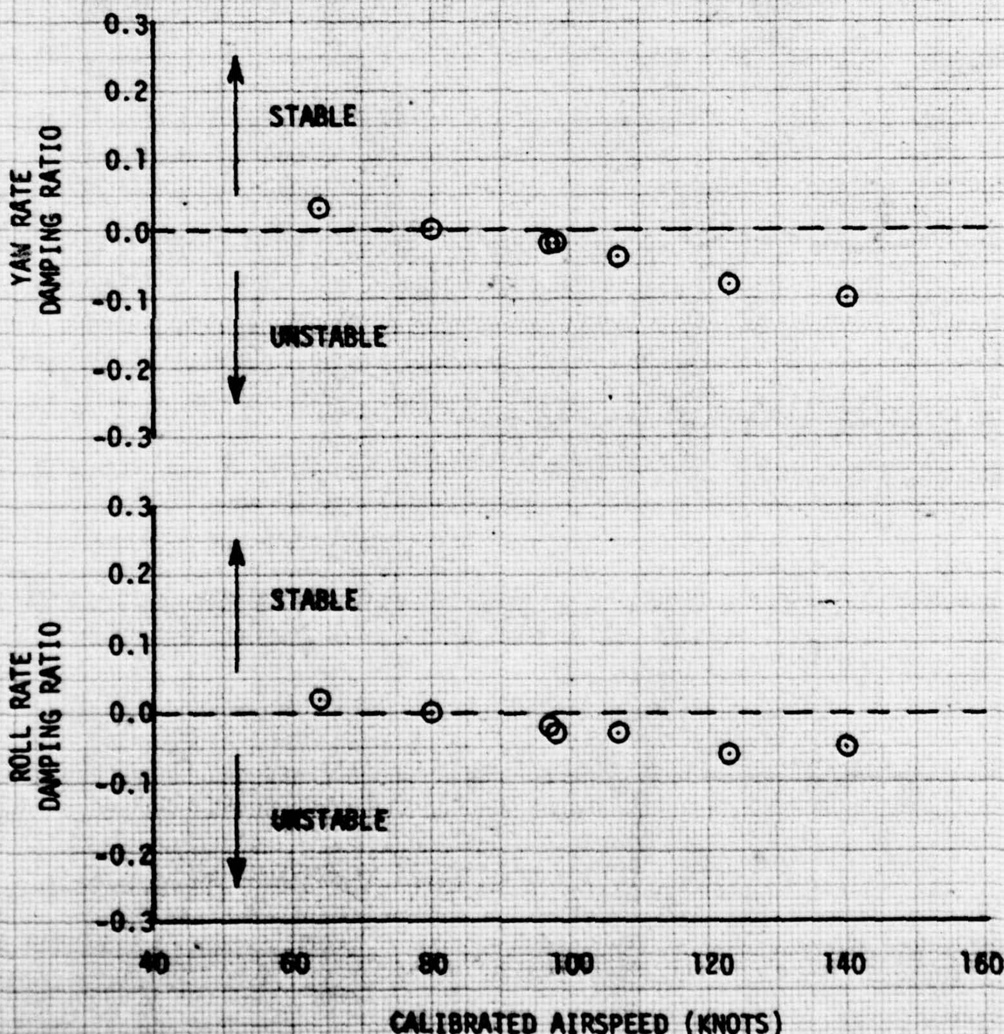
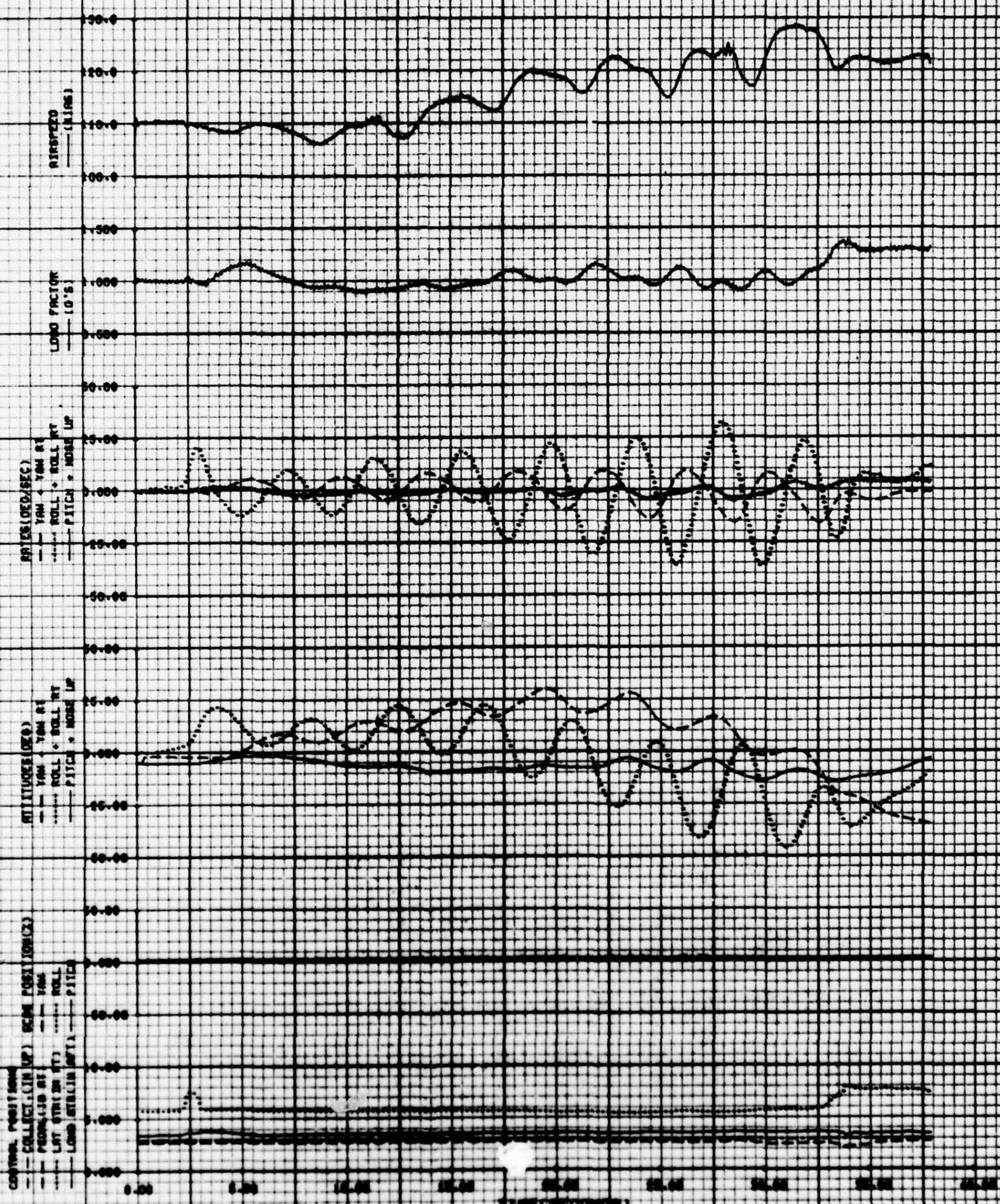


FIGURE 35
DUTCH ROLL
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
8840	194.1 (MID)	0.1 RT	6200	27.0	324	107	OFF

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION



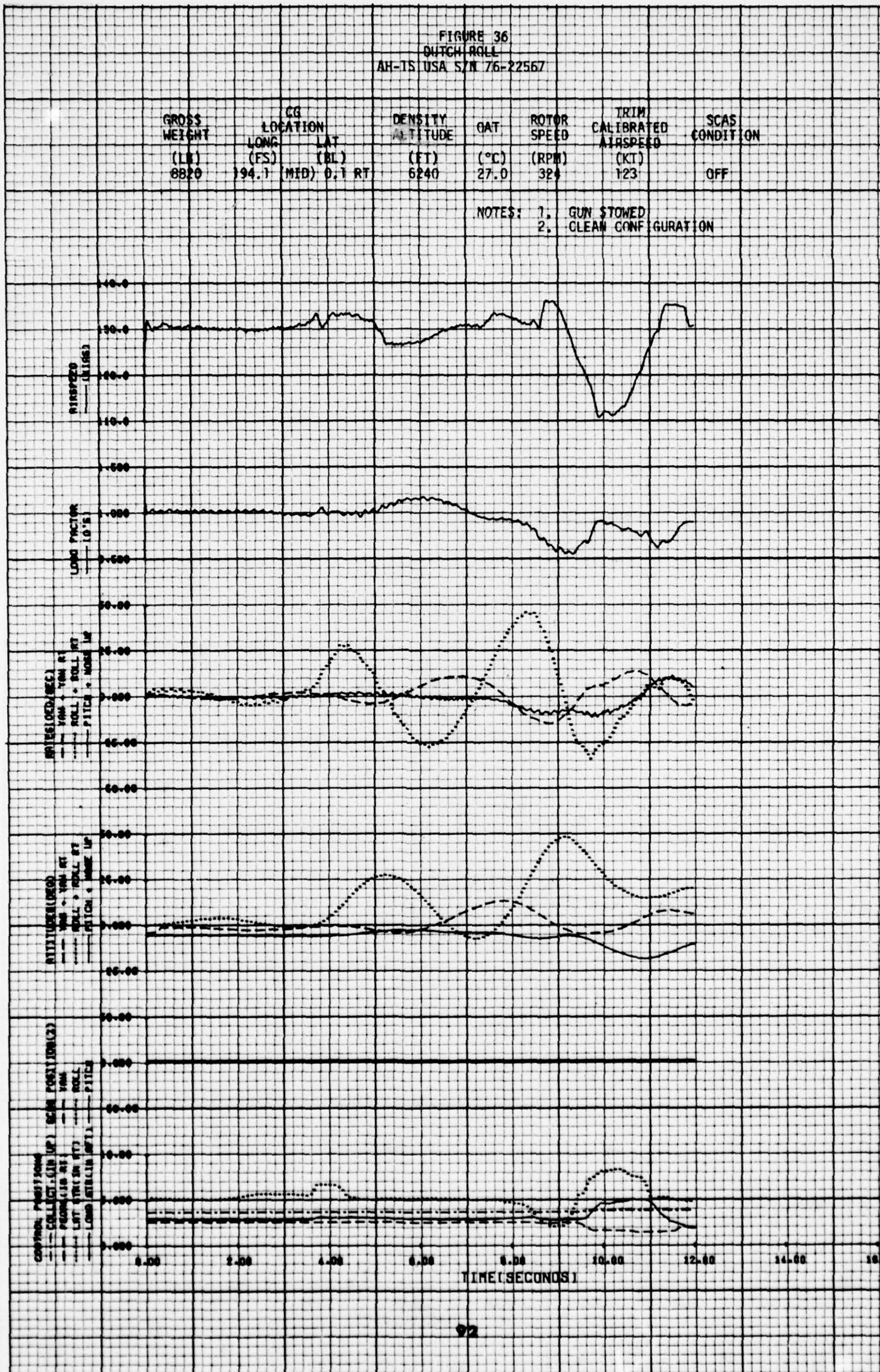


FIGURE 36
DUTCH ROLL
AH-1S USA S/N 76-22567
GROSS WEIGHT (LB) 8820
CG LOCATION LONG (FS) 194.1 (MID) LAT (BL) 0.1 RT
DENSITY ALTITUDE (FT) 6240
OAT (°C) 27.0
ROTOR SPEED (RPM) 324
TRIM CALIBRATED AIRSPEED (KT) 123
SCAS CONDITION OFF
NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION
AIRSPEED
LOAD FACTOR
RATES(DEG/SEC)
ATTITUDES(DEG)
SCAS POSITION(%)
CONTROL POSITIONS
TIME(SECONDS)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00

FIGURE 37
DUTCH ROLL
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
8800	194.1 (MID)	0.1 RT	6400	27.0	324	140	OFF

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION

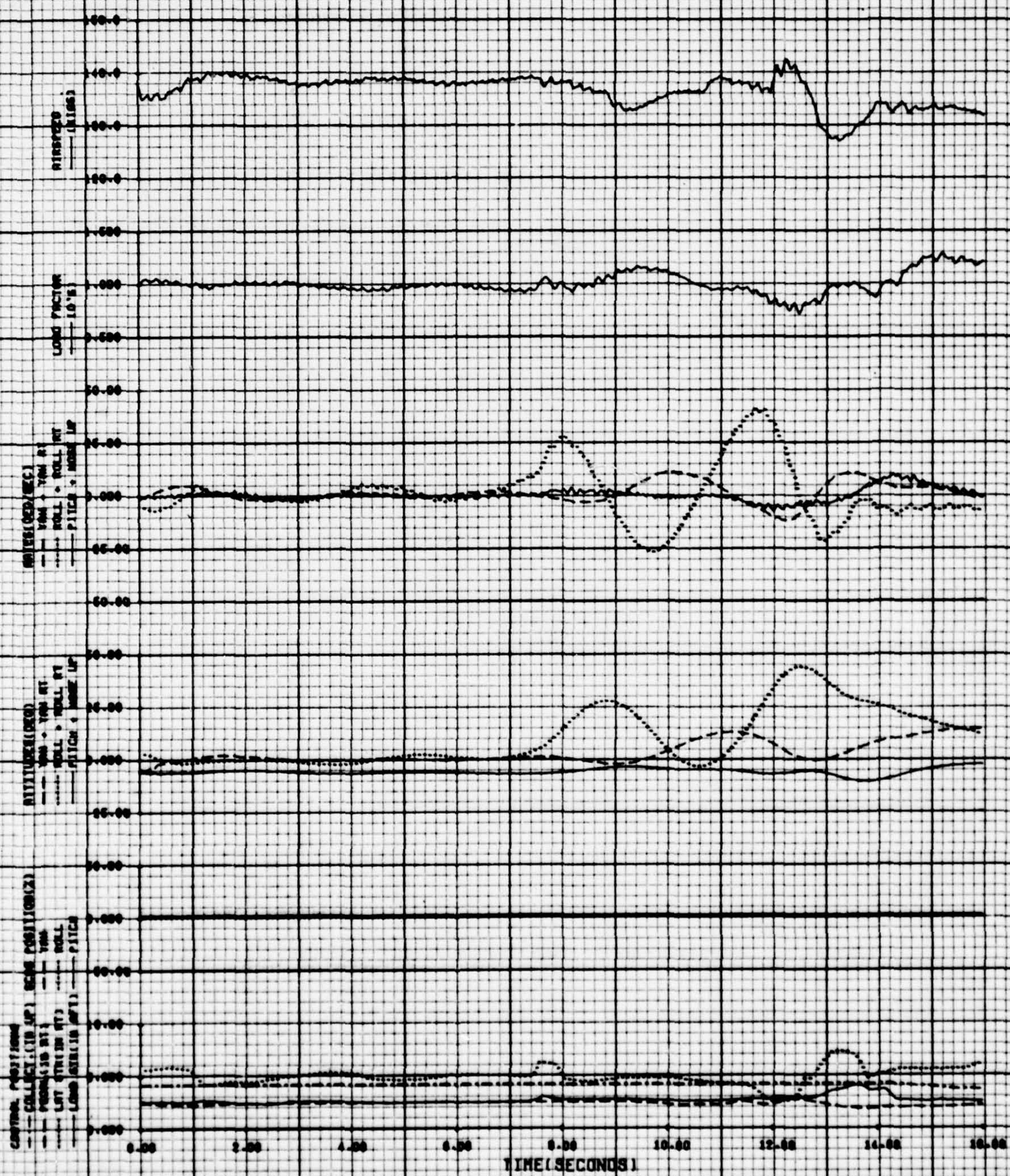


FIGURE 38
LONGITUDINAL LONG PERIOD RESPONSE
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
9100	194.0 (MID)	0.1 RT	5600	29.0	324	56	ON

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION

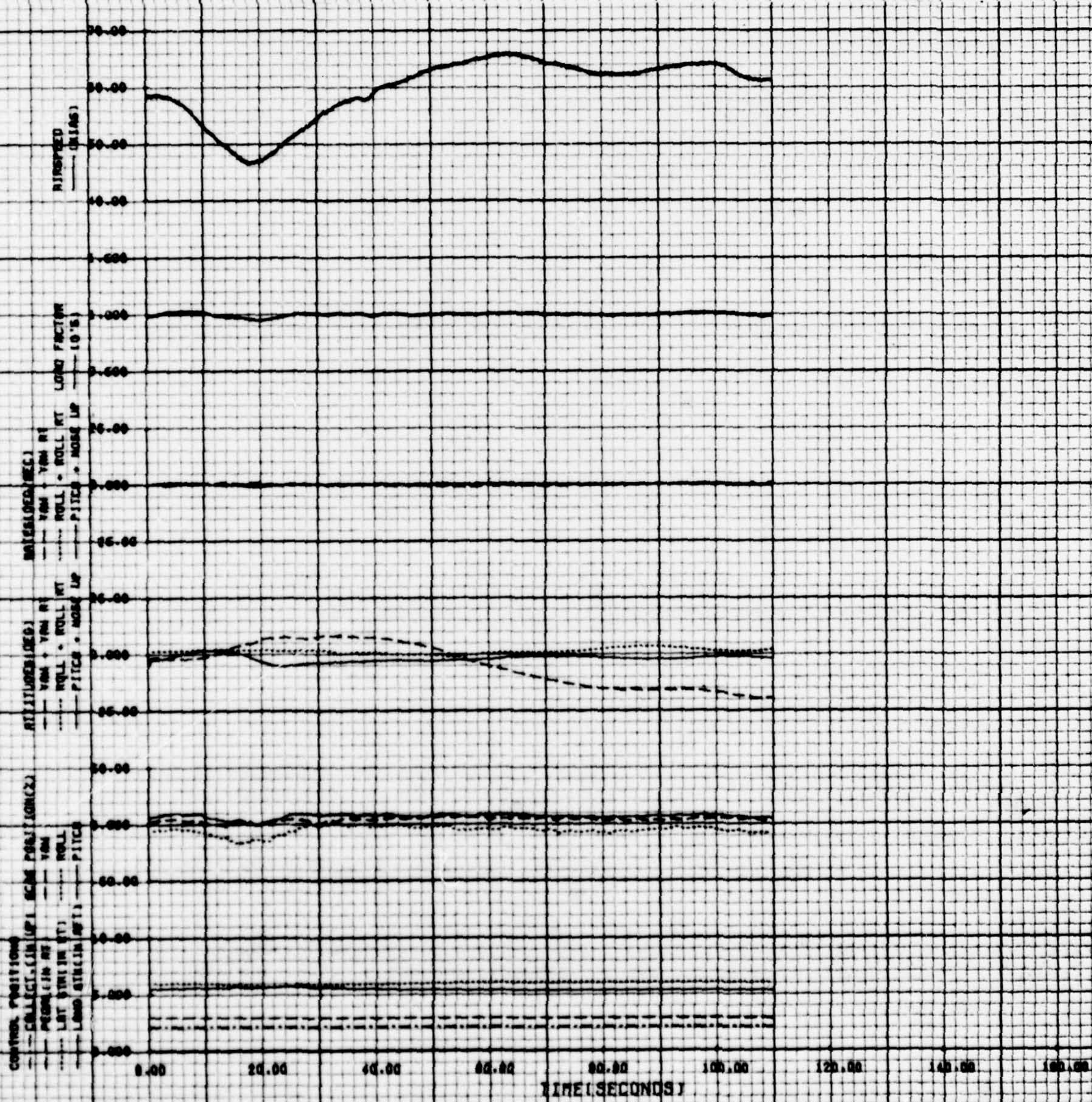


FIGURE 39
LONGITUDINAL LONG PERIOD RESPONSE
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
9060	194.0 (MID)	0.1 RT	5800	28.0	324	122	ON

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION

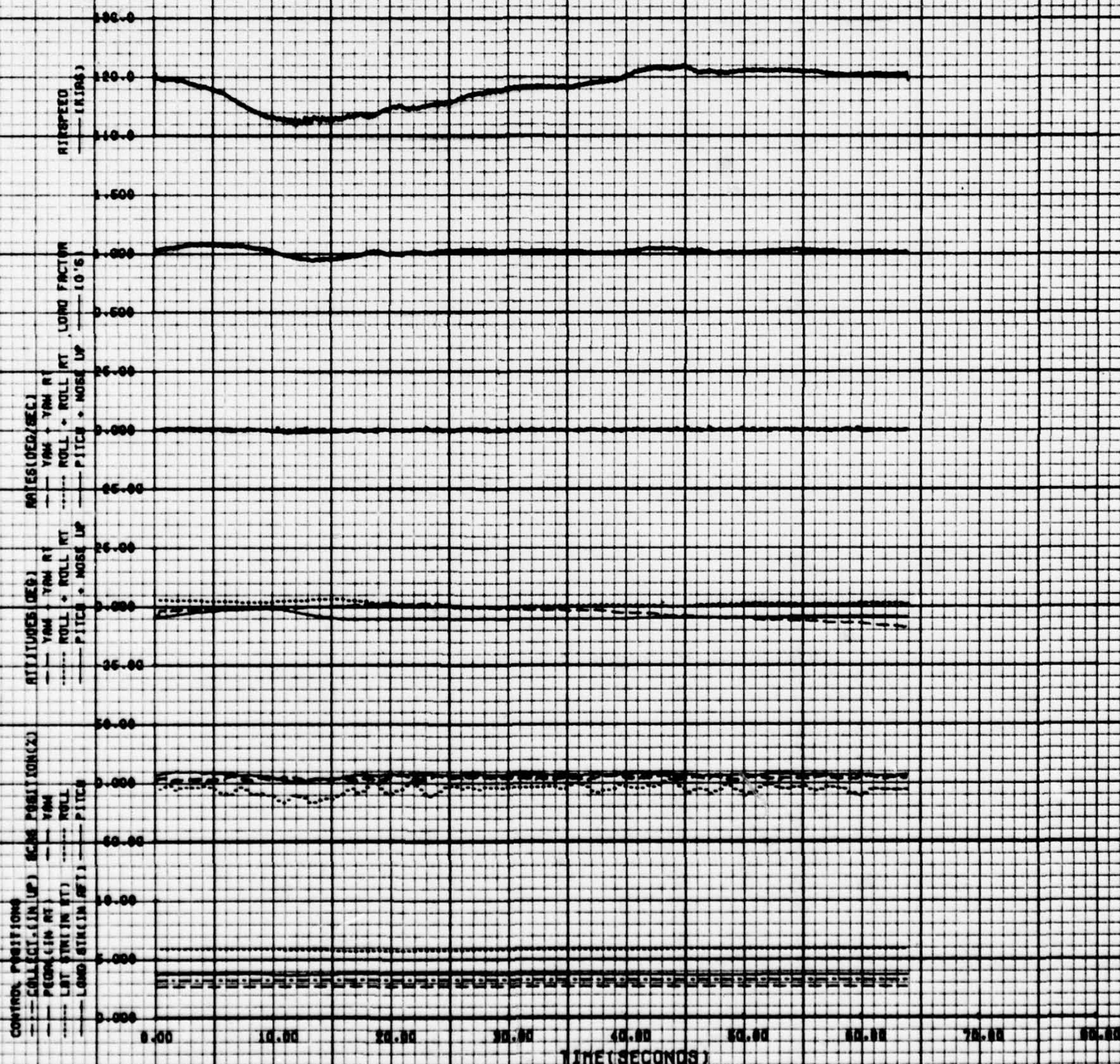


FIGURE 40
LONGITUDINAL LONG PERIOD RESPONSE
AH-1S USA S/N 76-22567

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	SCAS CONDITION
9020	194.0 (MID)	0.1 RT	5800	27.0	324	57	OFF

NOTES: 1. GUN STOWED
2. CLEAN CONFIGURATION

FIGURE 41
LATERAL CONTROL RESPONSE AND SENSITIVITY
AH-1S USA S/N 76-22567

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENS ALT (FT)	AVG OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIB AIRSPEED (KT)	TRIM FLIGHT CONDITION	SCAS CONDITION
8660	194.2(FWD)	0.1 RT	6900	28.0	324	64	LEVEL	ON

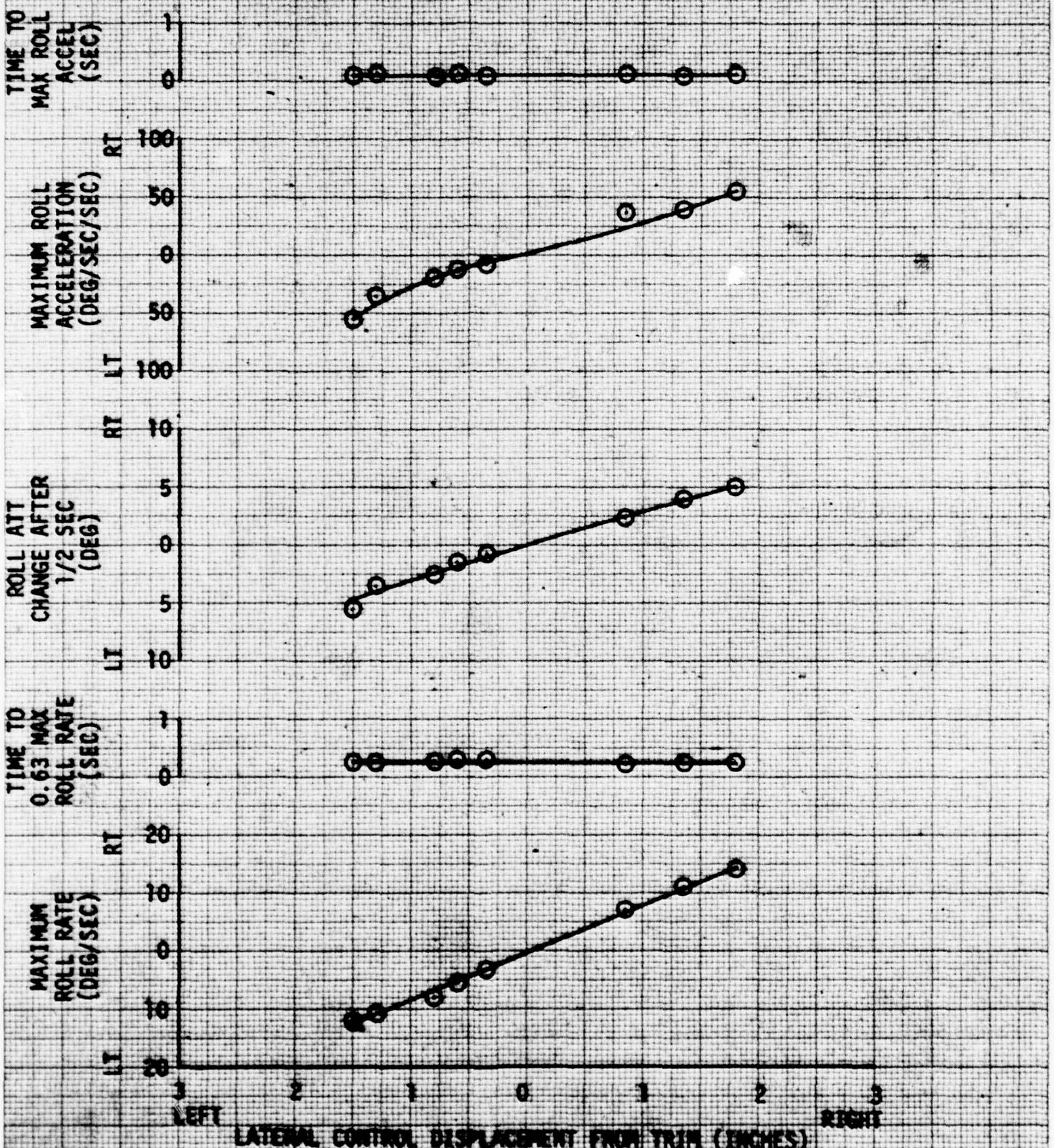


FIGURE 42
LONGITUDINAL CONTROL RESPONSE AND SENSITIVITY
AH-1S USA S/N 76-22567

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENS ALT (FT)	AVG OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIB AIRSPEED (KT)	TRIM FLIGHT CONDITION	SCAS CONDITION
8800	194.1(FWD)	0.1 RT	6100	26.0	324	64	LEVEL	ON

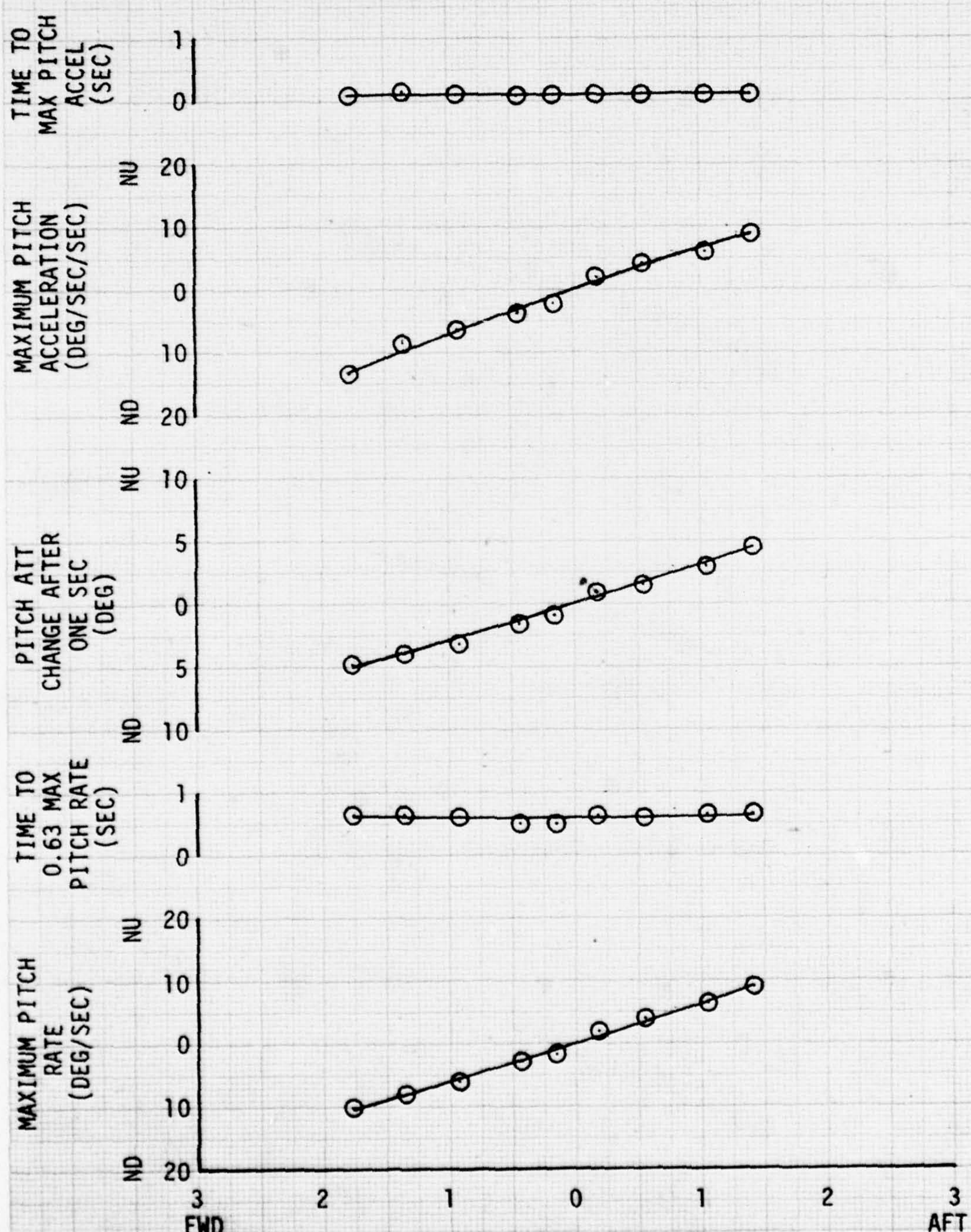


FIGURE 43
DIRECTIONAL CONTROL RESPONSE AND SENSITIVITY
AH-1S USA S/N 76-22567

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENS ALT (FT)	AVG OAT (°C)	ROTOR SPEED (RPM)	TRIM CALIB AIRSPEED (KT)	TRIM FLIGHT CONDITION	SCAS CONDITION
8600	194.3(FWD)	0.1 RT	6160	28.0	324	63	LEVEL	ON

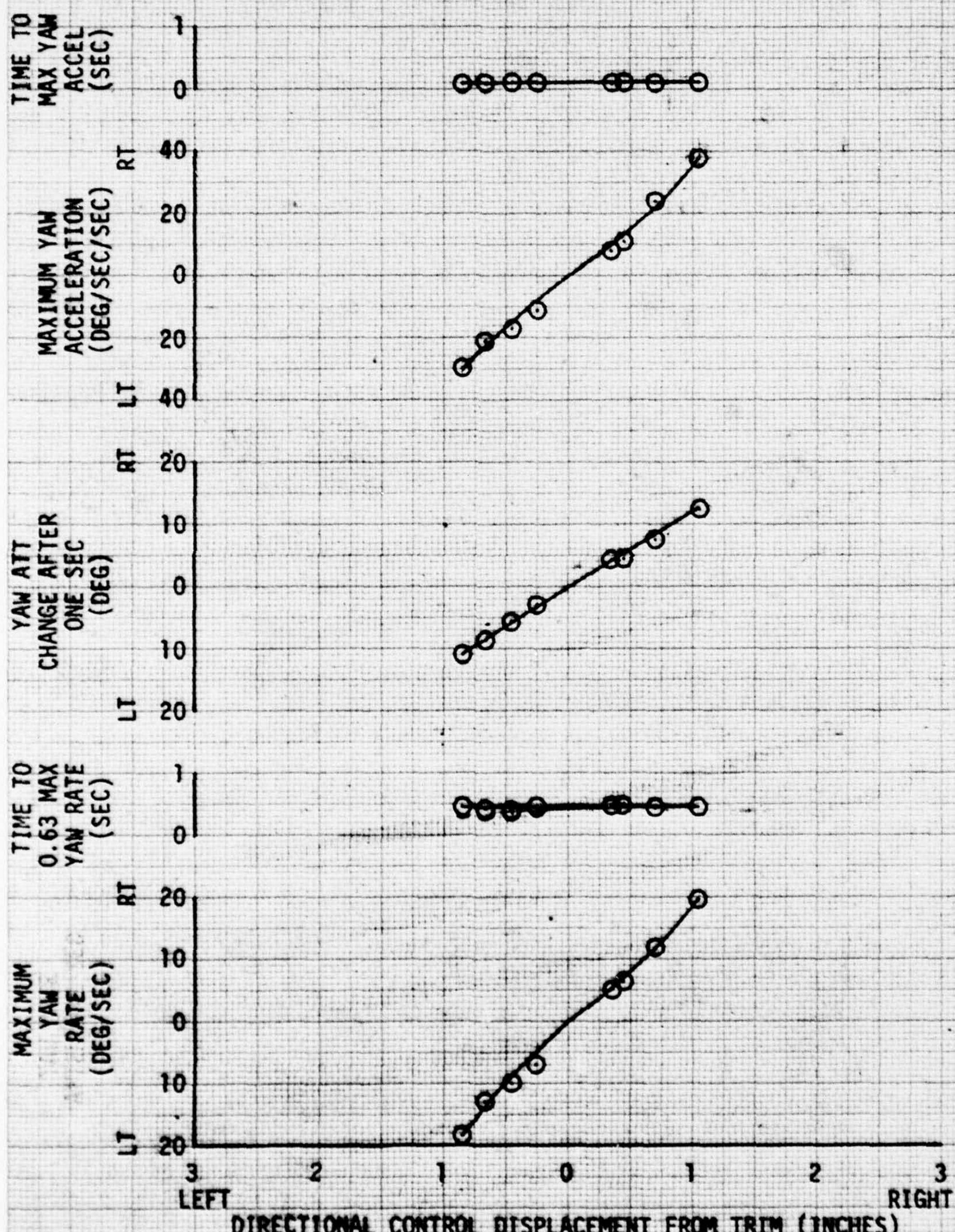


FIGURE 44
LOW-SPEED FORWARD AND REARWARD FLIGHT
AH-1S USA S/N 76-22567

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	SKID HEIGHT (FT)	SCAS CONDITION
9000	194.1(FWD)	0.1 RT	2300	30.0	324	10	ON

NOTES: 1. I DENOTES EXTREME TRAVEL FROM TRIM DURING ATTEMPTED STABILIZED POINT.
2. CLEAN CONFIGURATION.

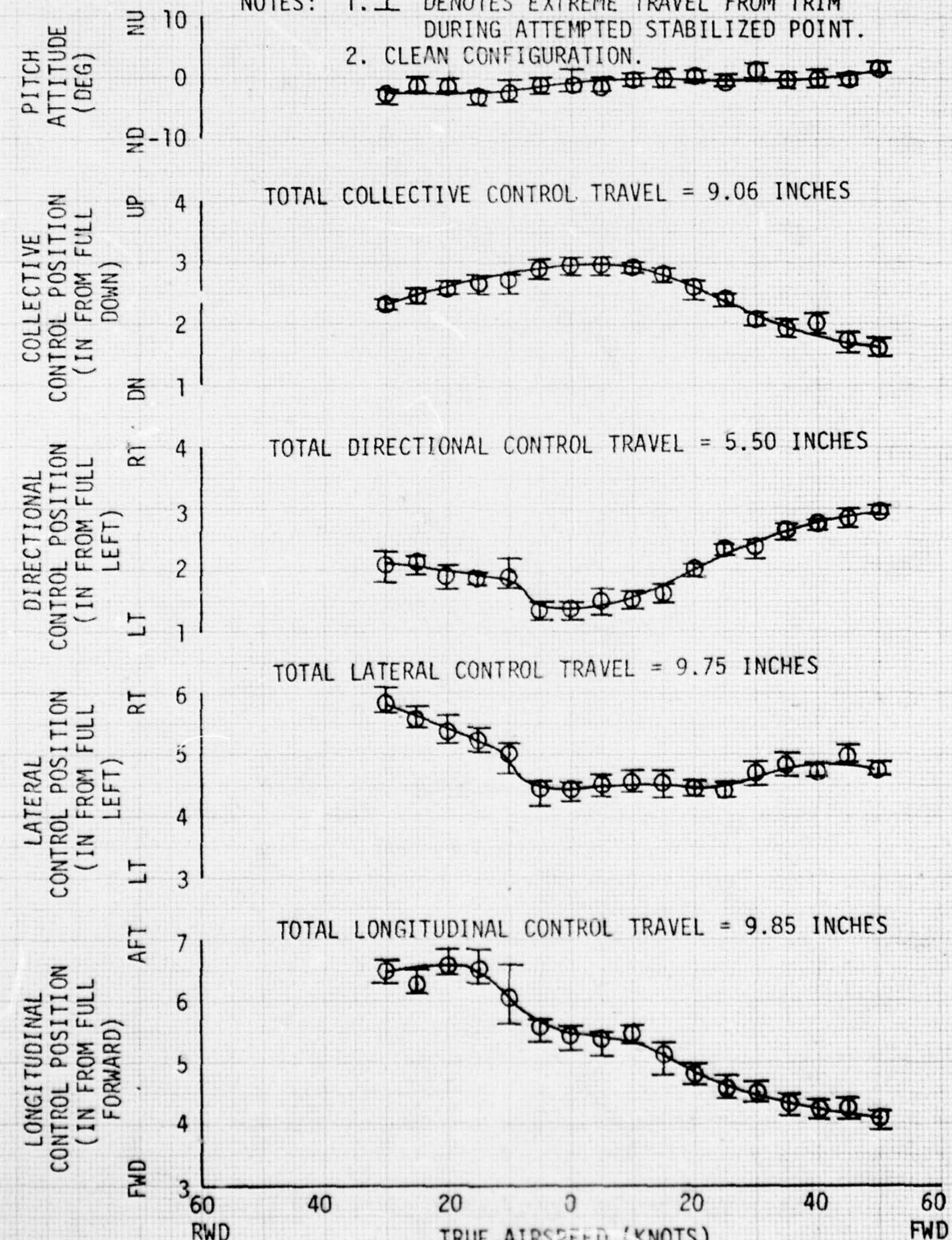


FIGURE 45
LOW-SPEED FORWARD AND REARWARD FLIGHT
AH-1S USA S/N 76-22257

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	SKID HEIGHT (FT)	SCAS CONDITION
9040	194.1(FWD)	0.1 RT	2300	31.0	324	10	OFF

NOTES: 1. I DENOTES EXTREME TRAVEL FROM TRIM DURING ATTEMPTED STABILIZED POINT.
2. CLEAN CONFIGURATION.

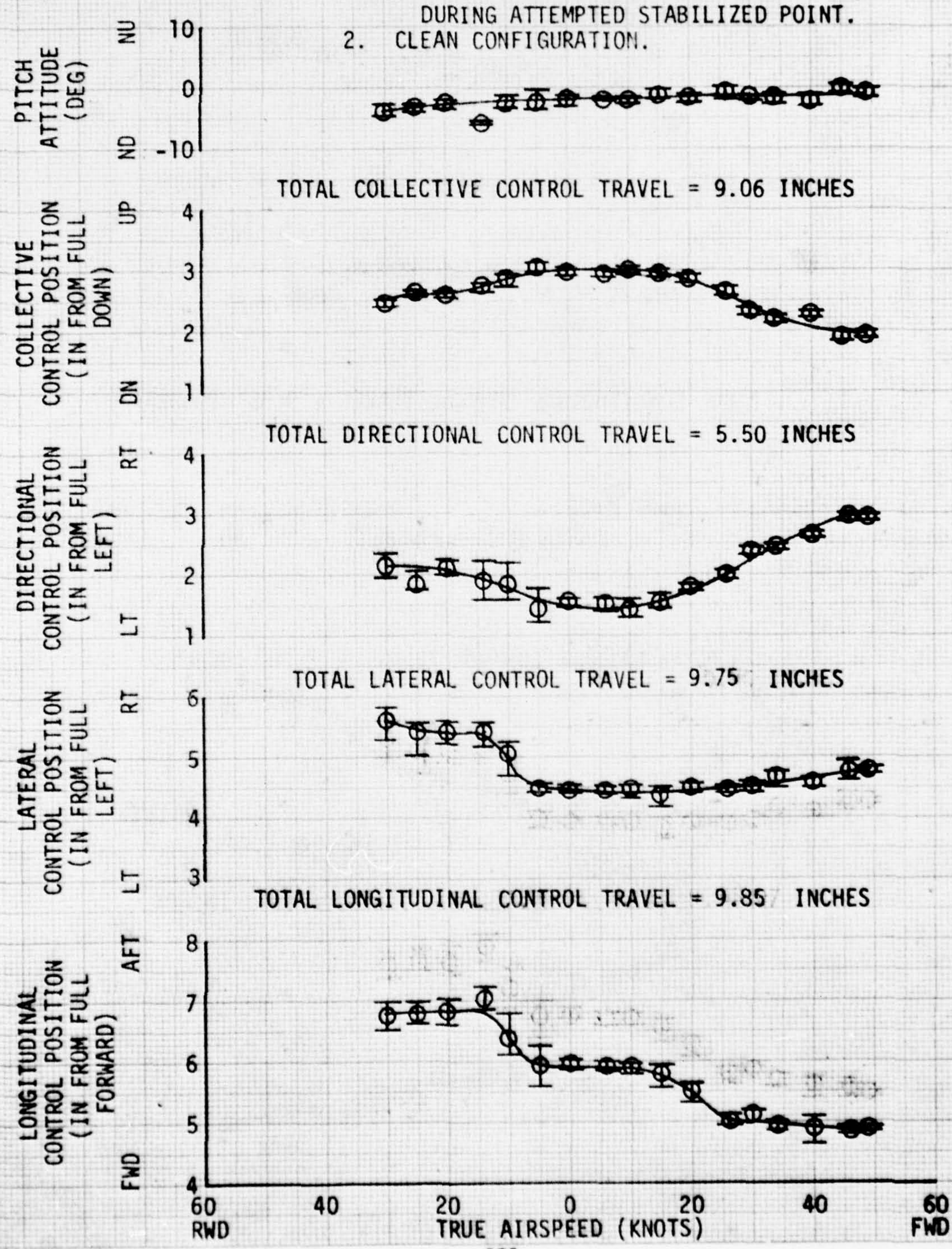


FIGURE 46
SIDEWARD FLIGHT
AH-1S USA S/N 76-22567

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	SKID HEIGHT (FT)	SCAS CONDITION
8760	194.2(FWD)	0.1 RT	2400	32.0	324	10	ON

NOTES: 1. I DENOTES EXTREME TRAVEL FROM TRIM DURING ATTEMPTED STABILIZED POINT.
2. CLEAN CONFIGURATION.

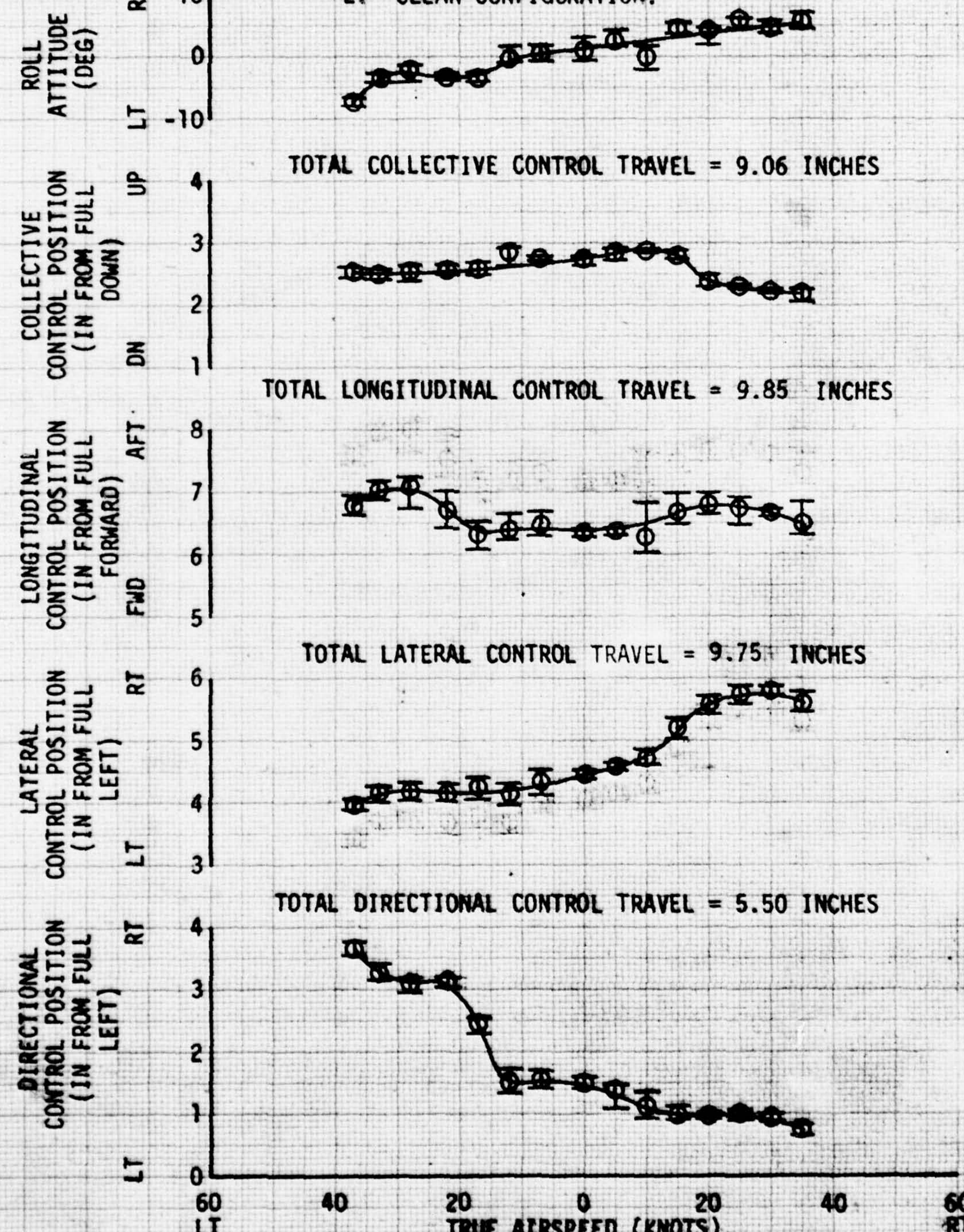


FIGURE 47
SIDEWARD FLIGHT
AH-1S USA S/N 76-22567

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	SKID HEIGHT (FT)	SCAS CONDITION
8760	194.2(FWD)	0.1 RT	2700	34.0	324	10	OFF

NOTES: 1. I DENOTES EXTREME TRAVEL FROM TRIM DURING ATTEMPTED STABILIZED POINT.
2. CLEAN CONFIGURATION.

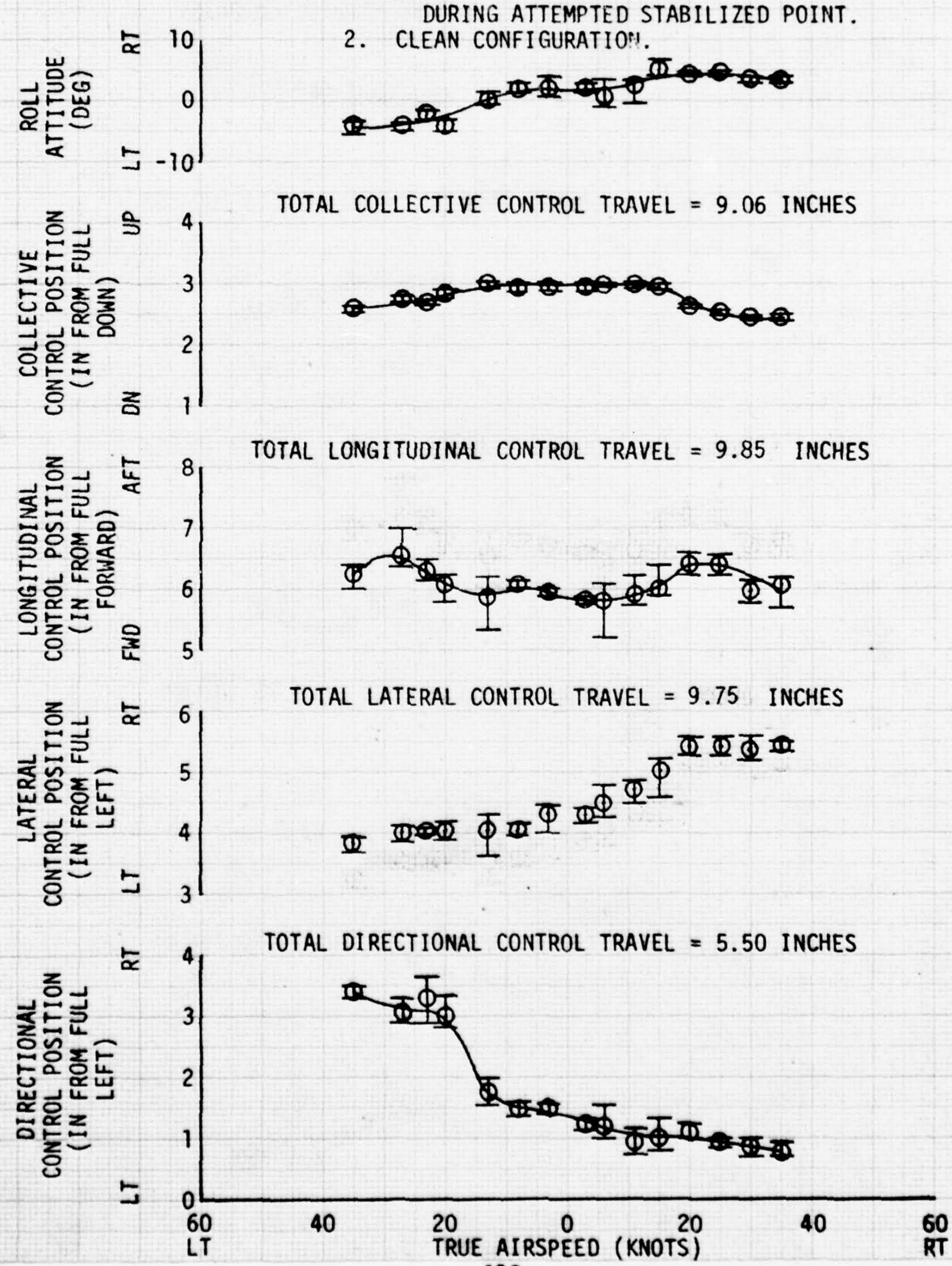


FIGURE 48
SIDEWARD FLIGHT
AH-1S USA S/N 76-22567
CRITICAL AZIMUTH - 065 DEGREES

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	SKID HEIGHT (FT)	SCAS CONDITION
8600	194.2(FWD)	0.1 RT	2900	35.0	324	10	ON

NOTES: 1. I DENOTES EXTREME TRAVEL FROM TRIM DURING ATTEMPTED STABILIZED POINT.
2. CLEAN CONFIGURATION.

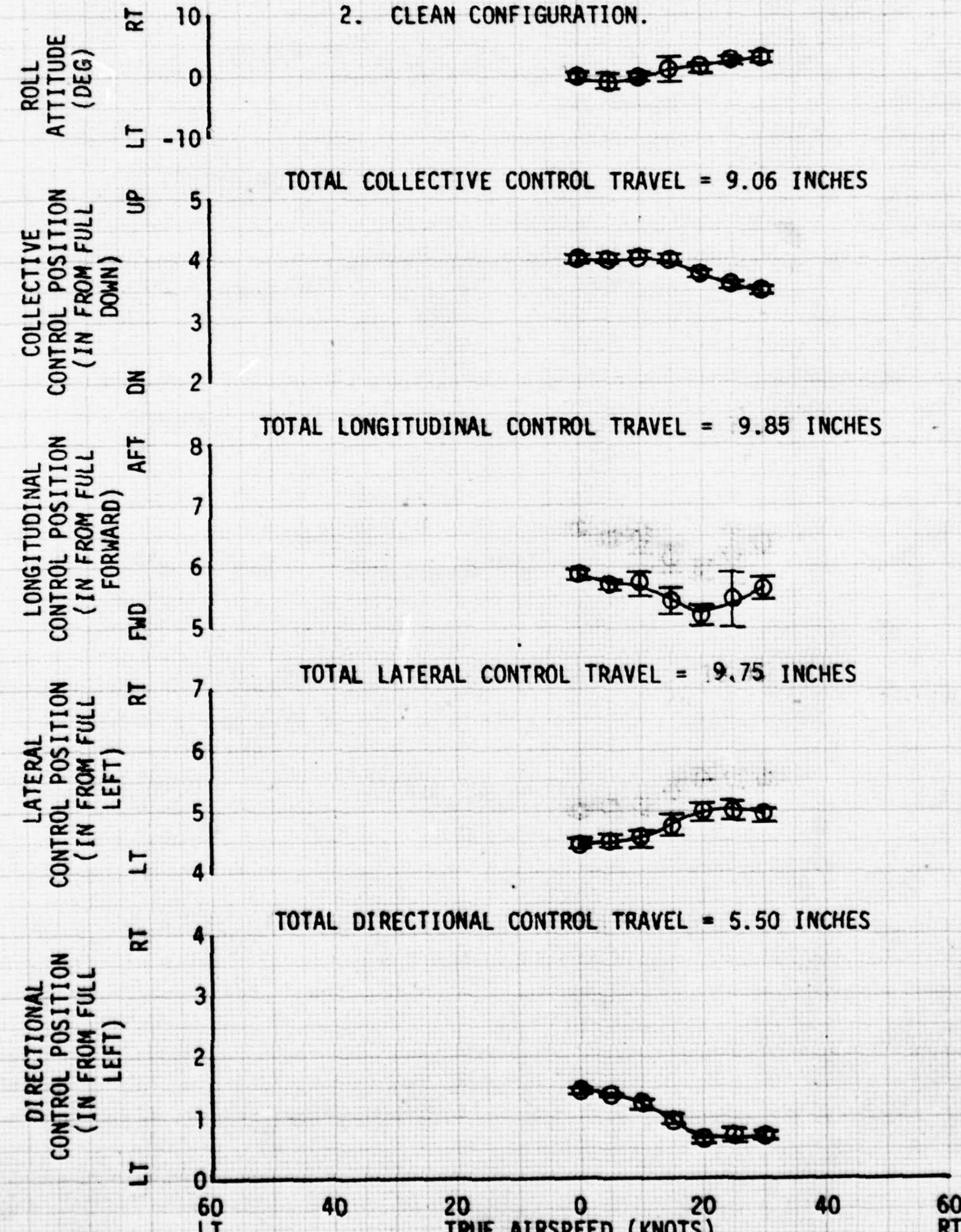


FIGURE 49
SIDEWARD FLIGHT
AH-1S USA S/N 76-22567
CRITICAL AZIMUTH - 065 DEGREES

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	SKID HEIGHT (FT)	SCAS CONDITION
8500	194.3(FWD)	0.1 RT	2900	35.0	324	10	OFF

NOTES: 1. I DENOTES EXTREME TRAVEL FROM TRIM DURING ATTEMPTED STABILIZED POINT.
2. CLEAN CONFIGURATION.

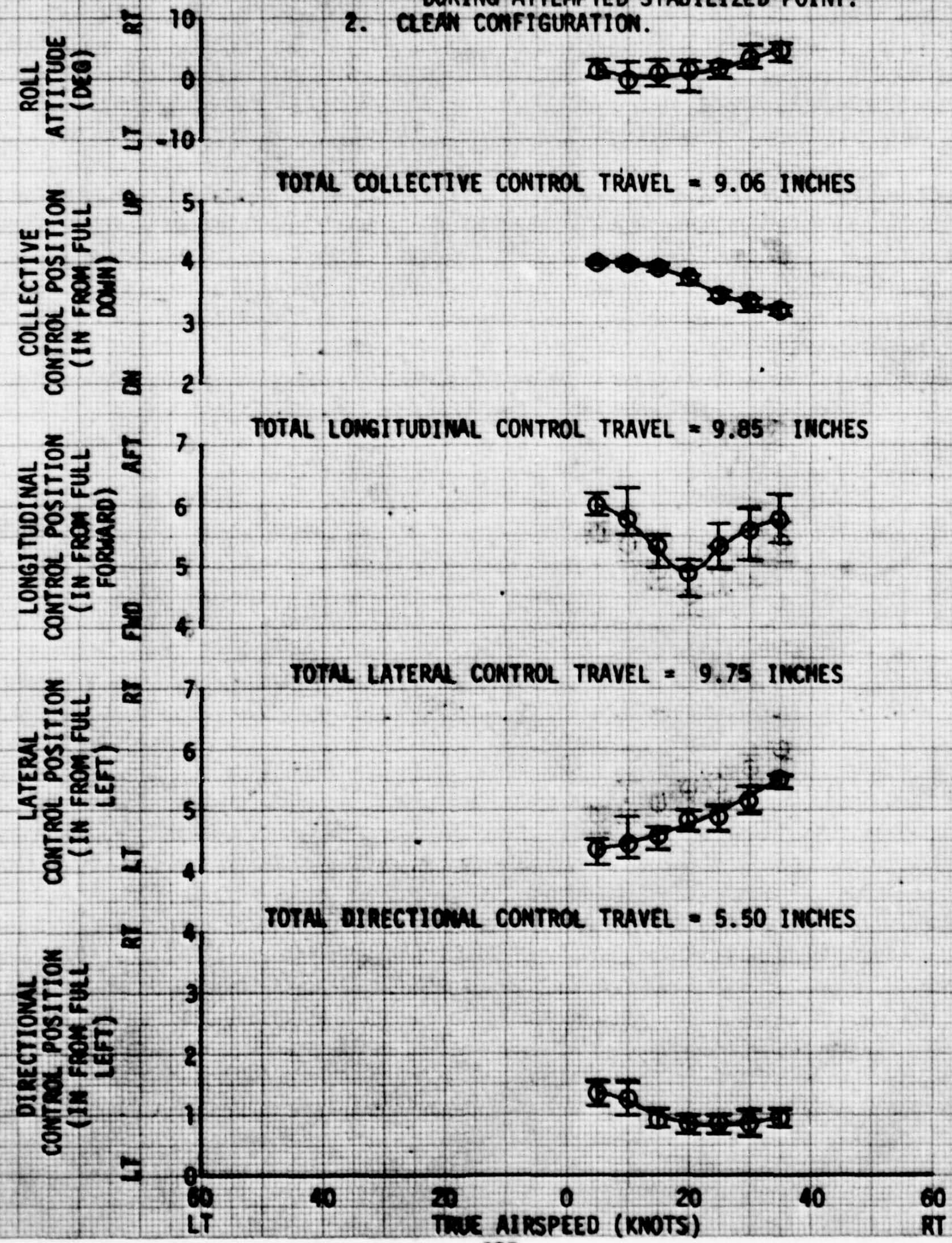


FIGURE 50
VIBRATION CHARACTERISTICS
AH-1S USA S/N 76-22567
CG VERTICAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9800	193.0(FWD)	0.4 RT	3500	33.0	324	INBOARD PODS	LVL FLT

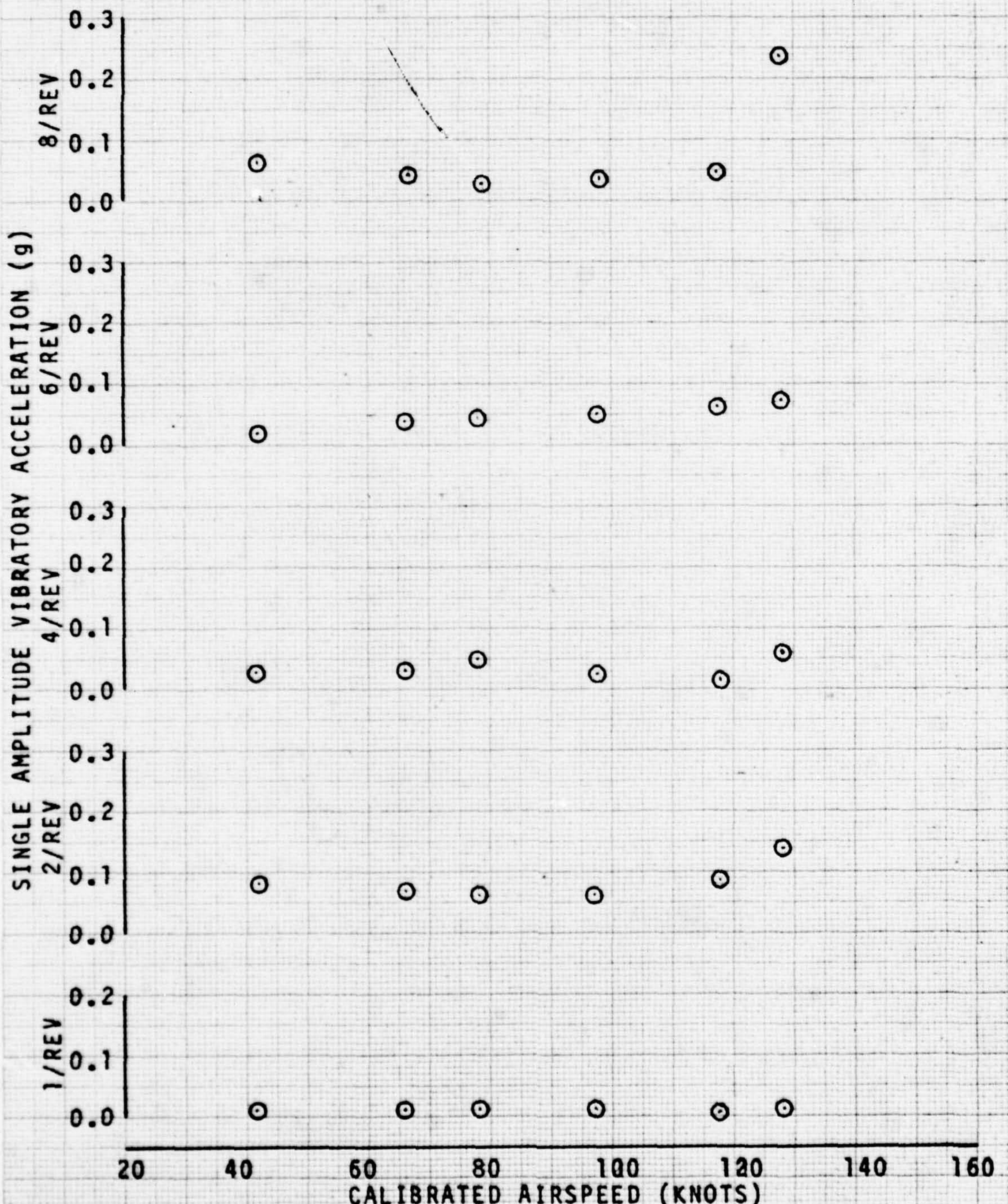


FIGURE 51
VIBRATION CHARACTERISTICS
AH-1S USA S/N 78-22567
CG LATERAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9800	193.0(FWD)	0.4 RT	3500	33.0	324	INBOARD PODS	LVL FLT

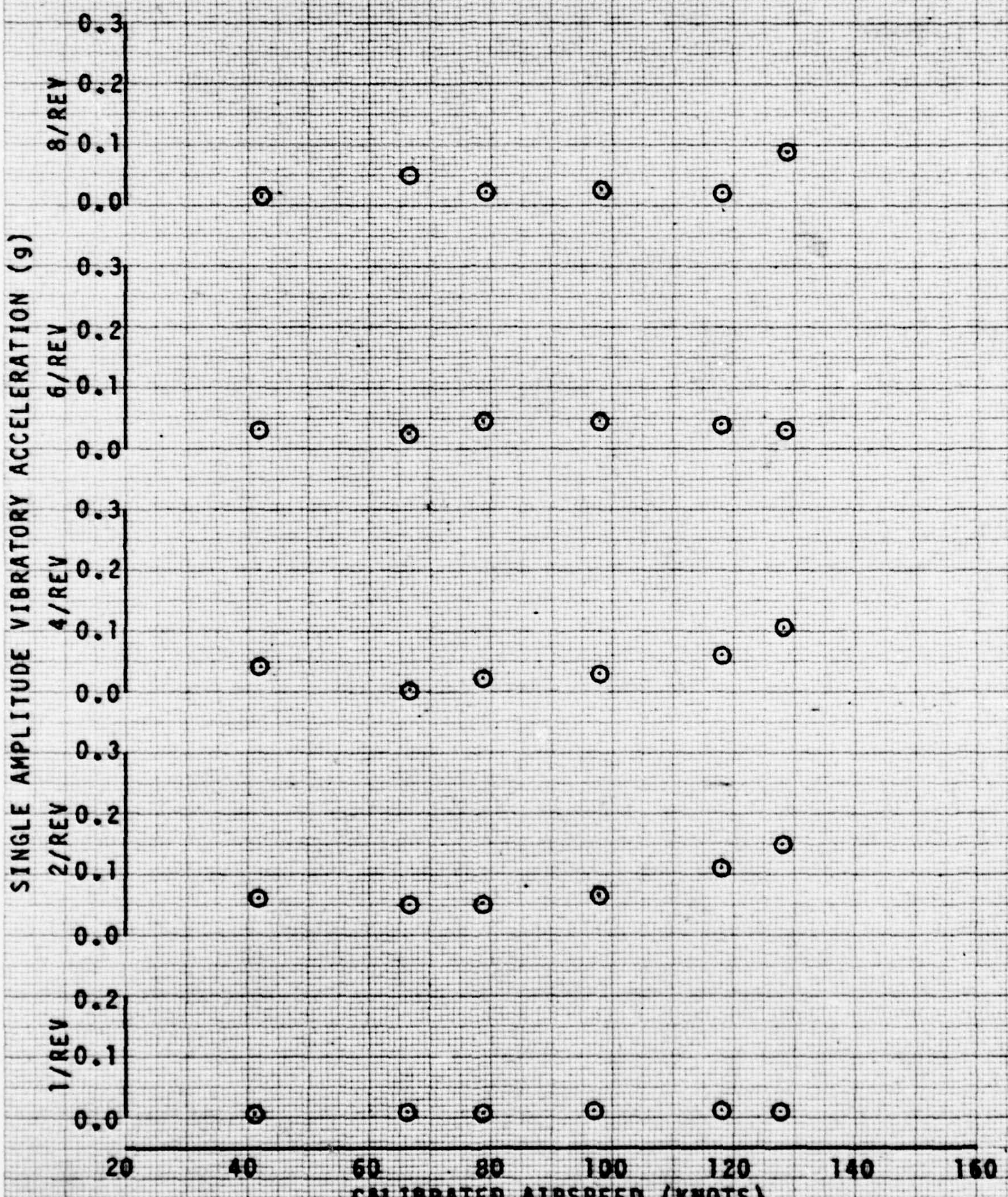


FIGURE 52
VIBRATION CHARACTERISTICS
AH-1S USA S/N 76-22567
TSU LATERAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9800	193.0(FWD)	0.4 RT	3500	33.0	324	INBOARD PODS	LVL FLT

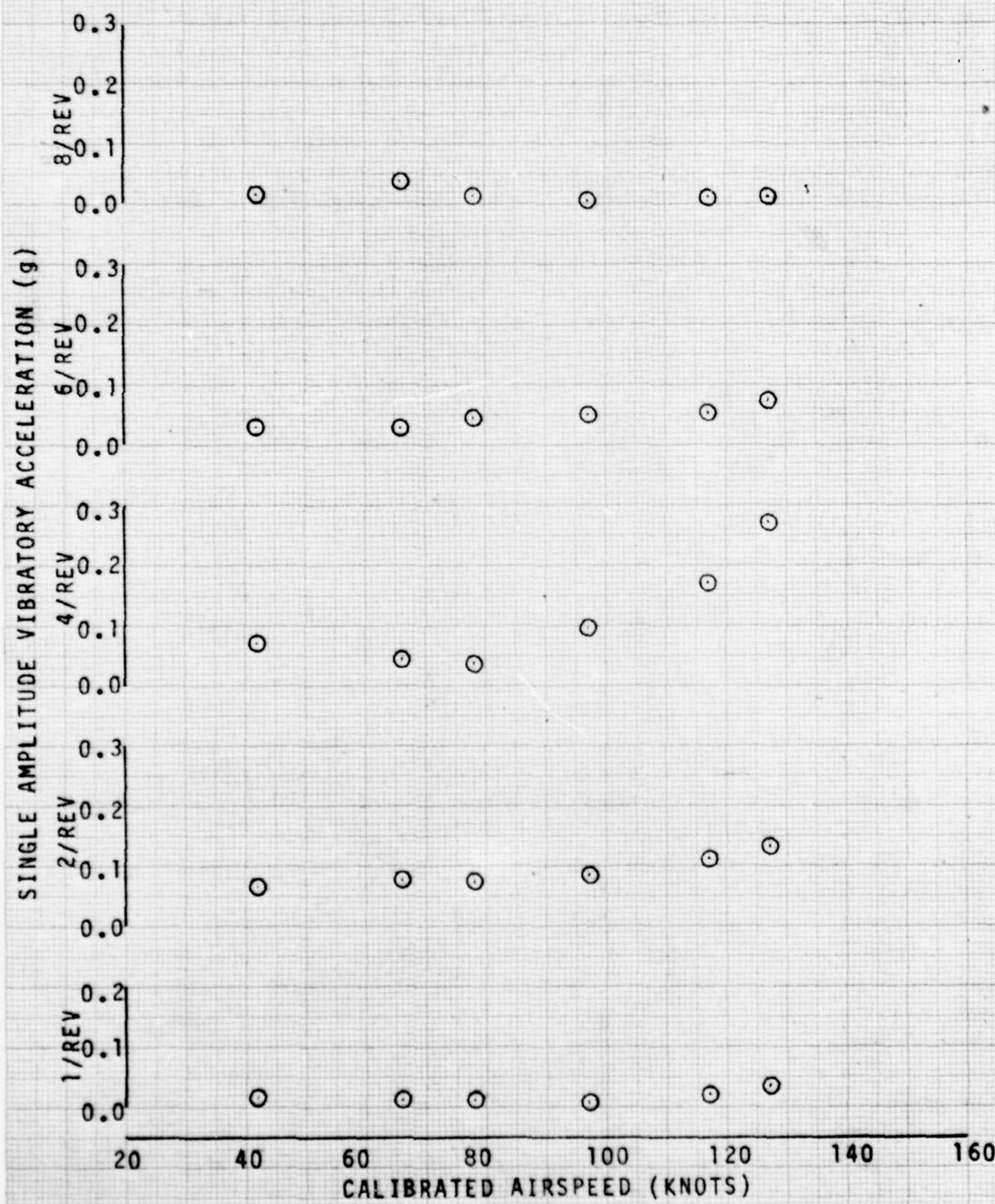


FIGURE 53
VIBRATION CHARACTERISTICS
AH-1S USA S/N 76-22567
TSU LONGITUDINAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (^{0}C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9800	193.0(FWD)	0.4 RT	3500	33.0	324	INBOARD PODS	LVL FLT

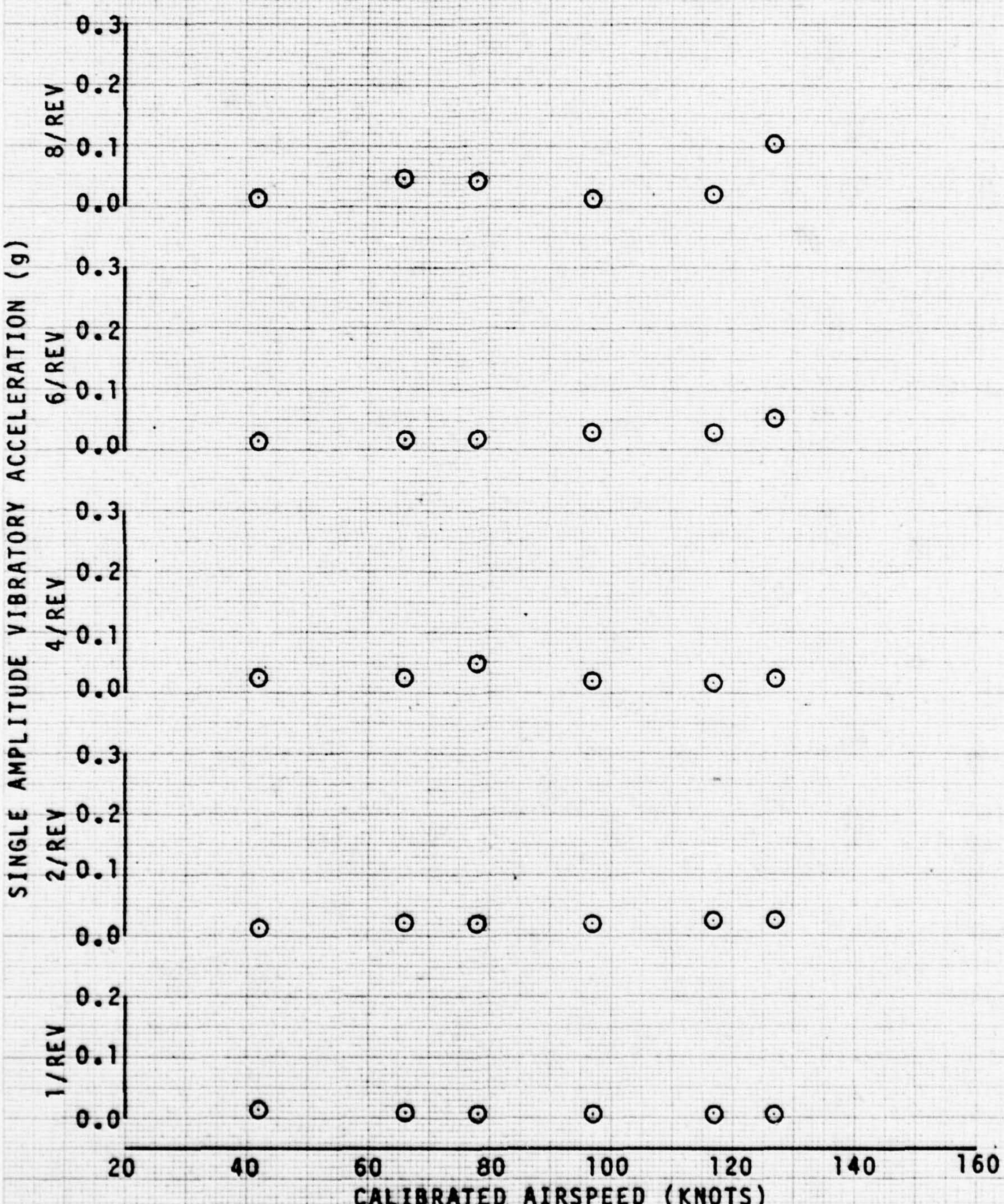


FIGURE 54
VIBRATION CHARACTERISTICS
AH-1S USA S/N 76-22567
GUNNER SIDE PANEL VERTICAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9800	193.0(FWD)	0.4 RT	3500	33.0	324	INBOARD PODS	LVL FLT

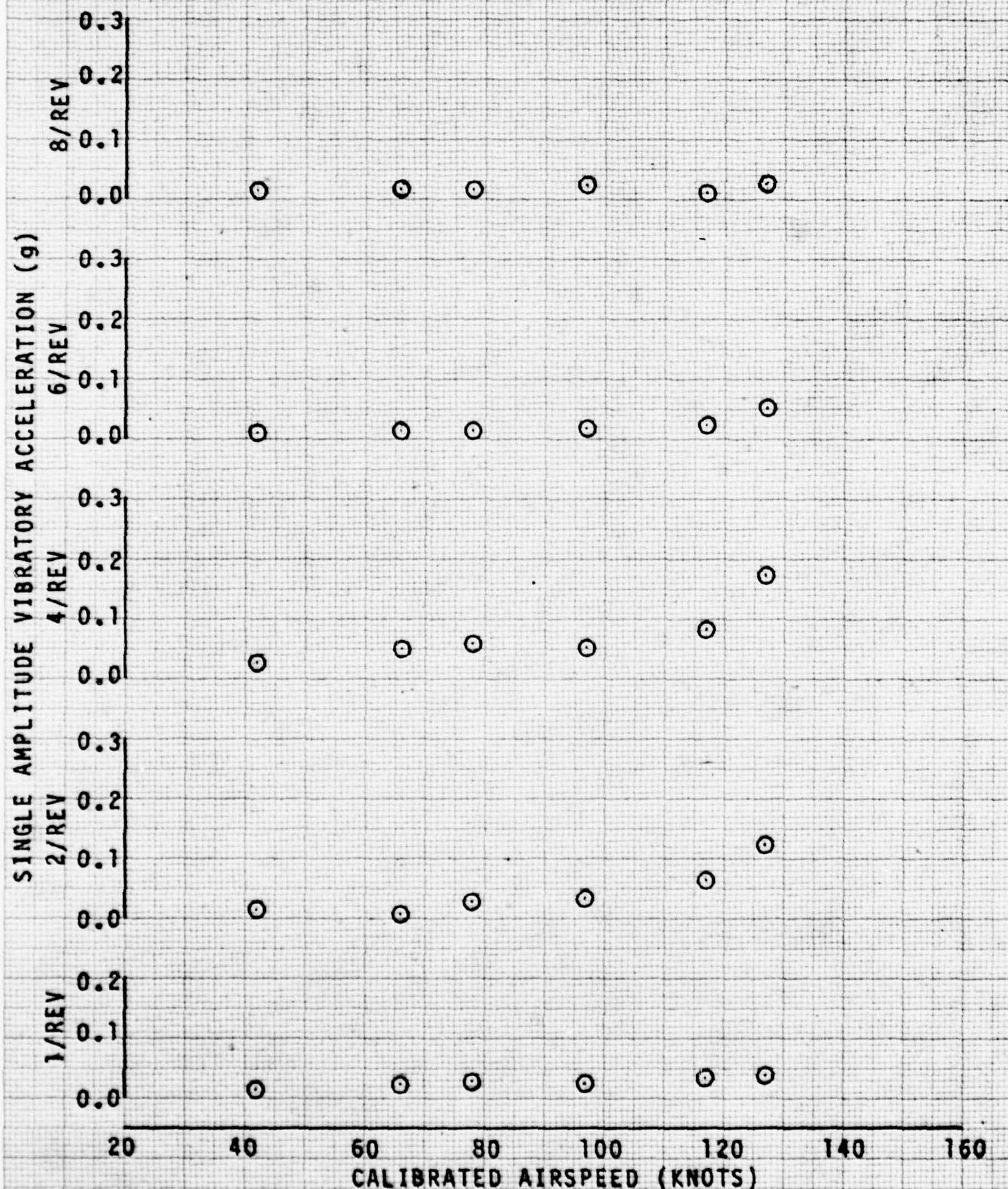


FIGURE 55
VIBRATION CHARACTERISTICS
AH-1S USA S/N 76-22567
GUNNER SIDE PANEL LATERAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9800	193.0(FWD)	0.4 RT	3500	33.0	324	INBOARD PODS	LVL FLT

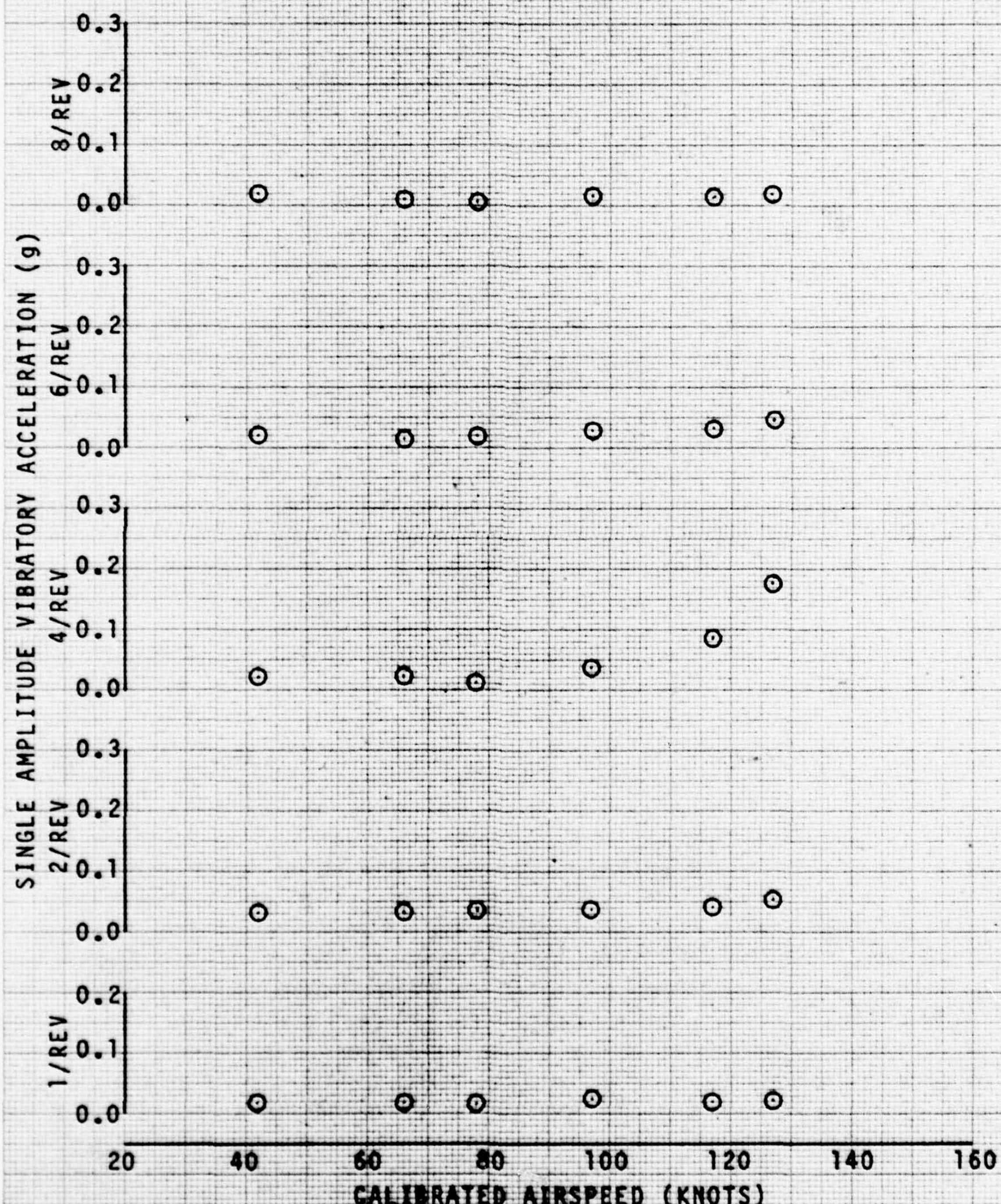


FIGURE 56
VIBRATION CHARACTERISTICS
AH-1S USA S/N 76-22567
PILOT SIDE PANEL VERTICAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9800	193.0(FWD)	0.4 RT	3500	33.0	324	INBOARD PODS	LVL FLT

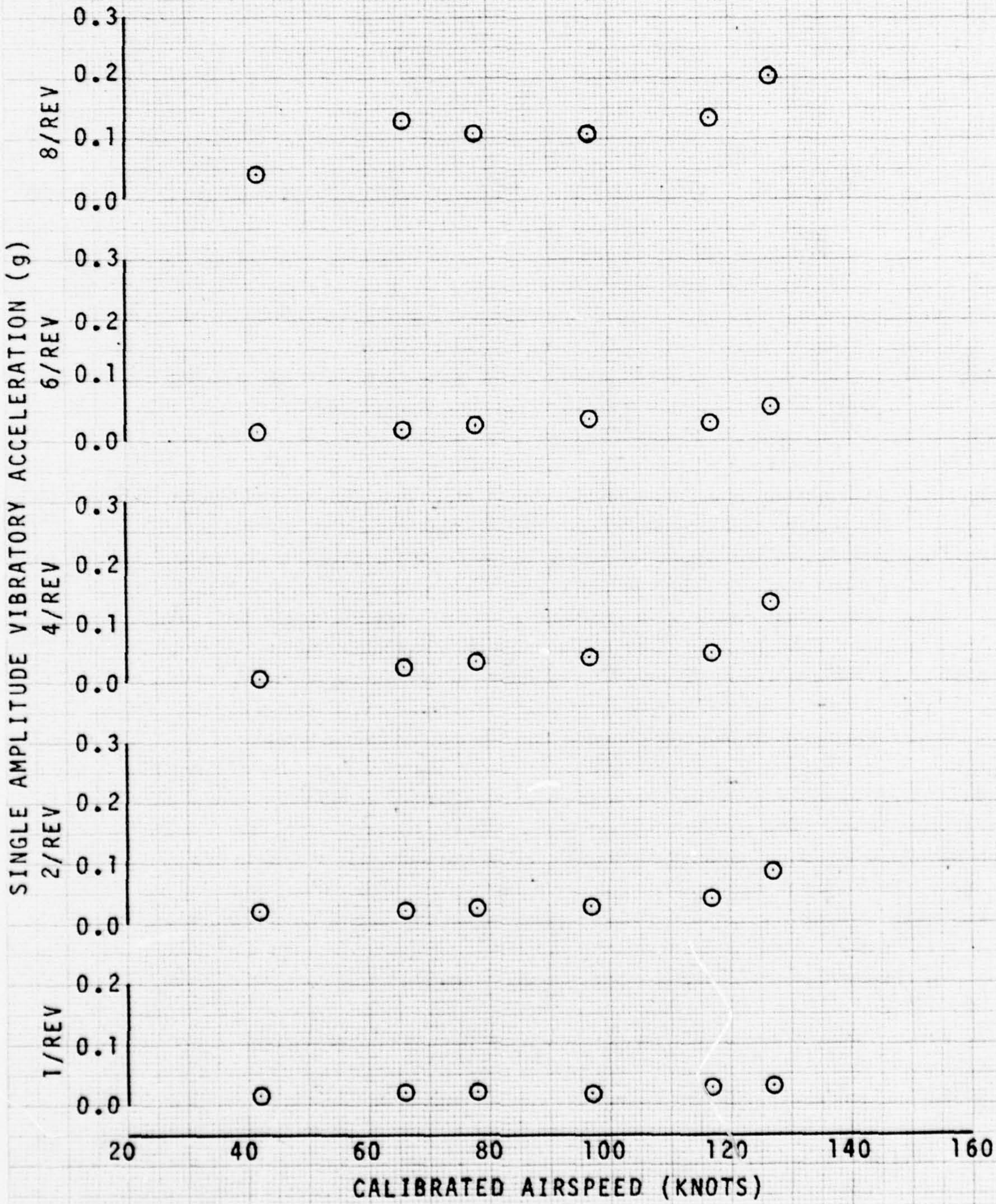


FIGURE 57
VIBRATION CHARACTERISTICS
AH-1S USA S/N 76-22567
PILOT SIDE PANEL LATERAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9800	193.0(FWD)	0.4 RT	3500	33.0	324	INBOARD PODS	LVL FLT

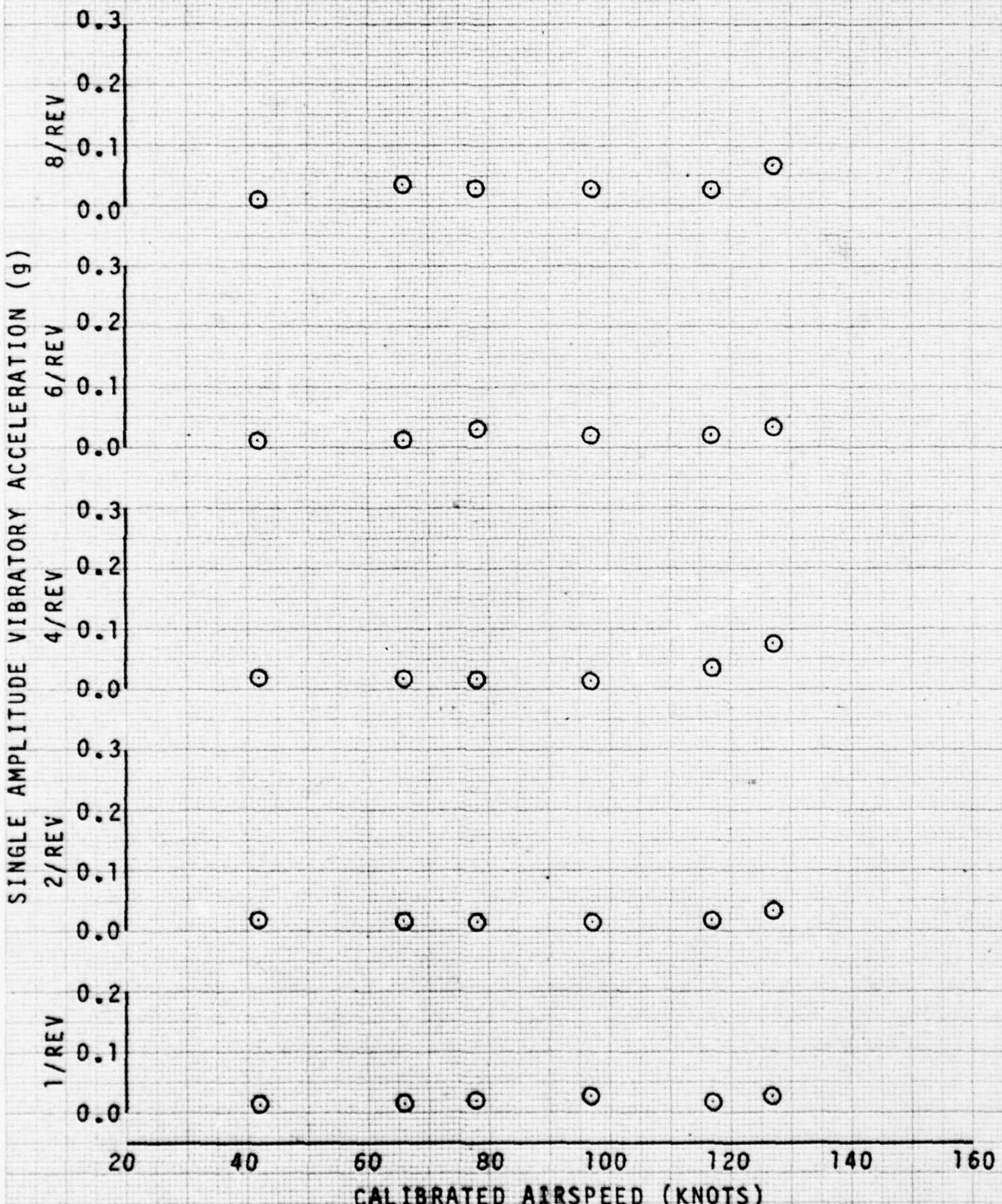


FIGURE 58
VIBRATION CHARACTERISTICS
AH-1S USA S/N 76-22567
GUNNER SEAT VERTICAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9800	193.0(FWD)	0.4 RT	3500	33.0	324	INBOARD PODS	LVL FLT

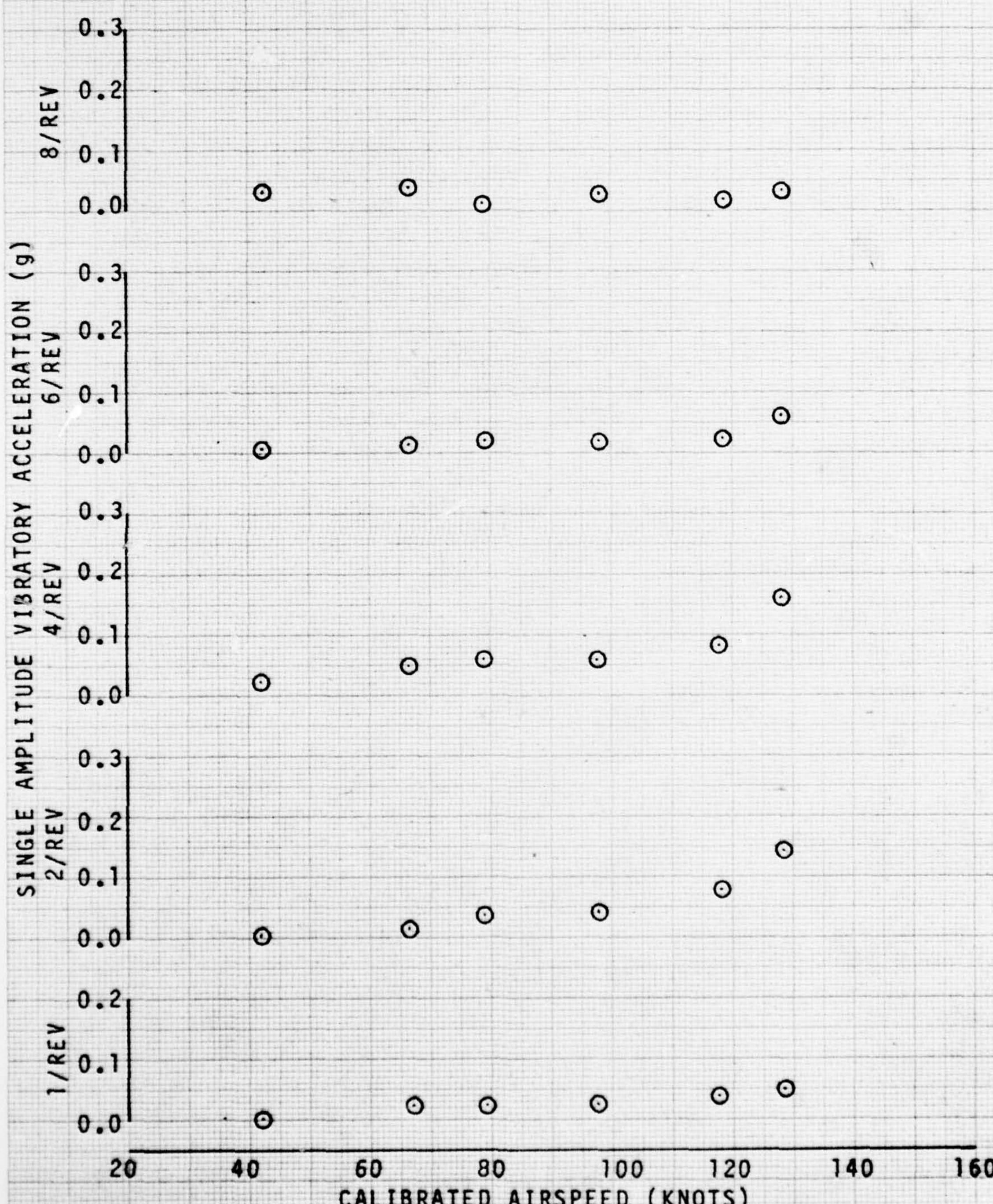


FIGURE 59
VIBRATION CHARACTERISTICS
AH-1S USA S/N 76-22567
GUNNER SEAT LATERAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9800	193.0(FWD)	0.4 RT	3500	33.0	324	INBOARD PODS	LVL FLT

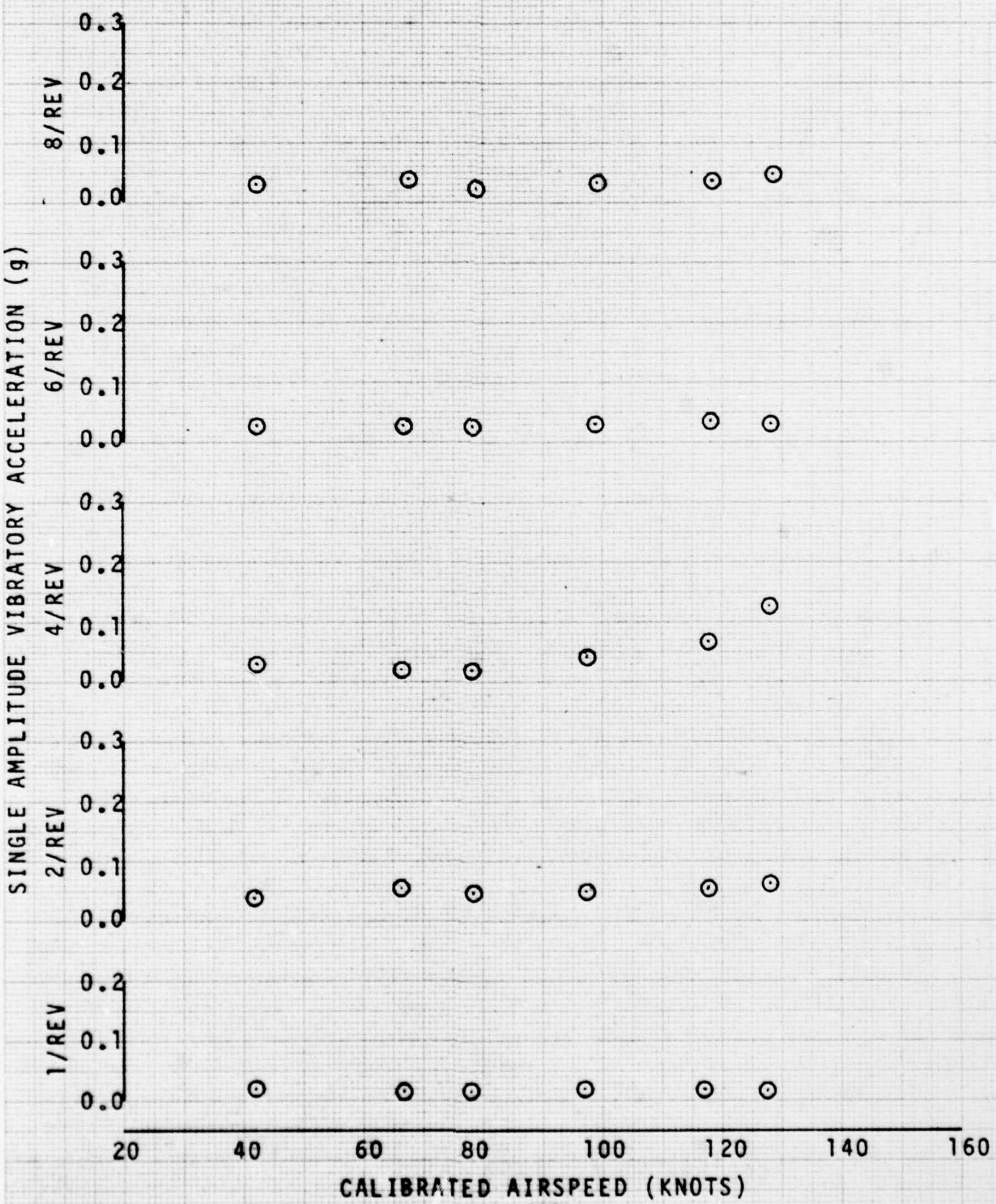


FIGURE 60
VIBRATION CHARACTERISTICS
AH-1S USA S/N 76-22567
GUNNER SEAT LONGITUDINAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9800	193.0(FWD)	0.4 RT	3500	33.0	324	INBOARD PODS	LVL FLT

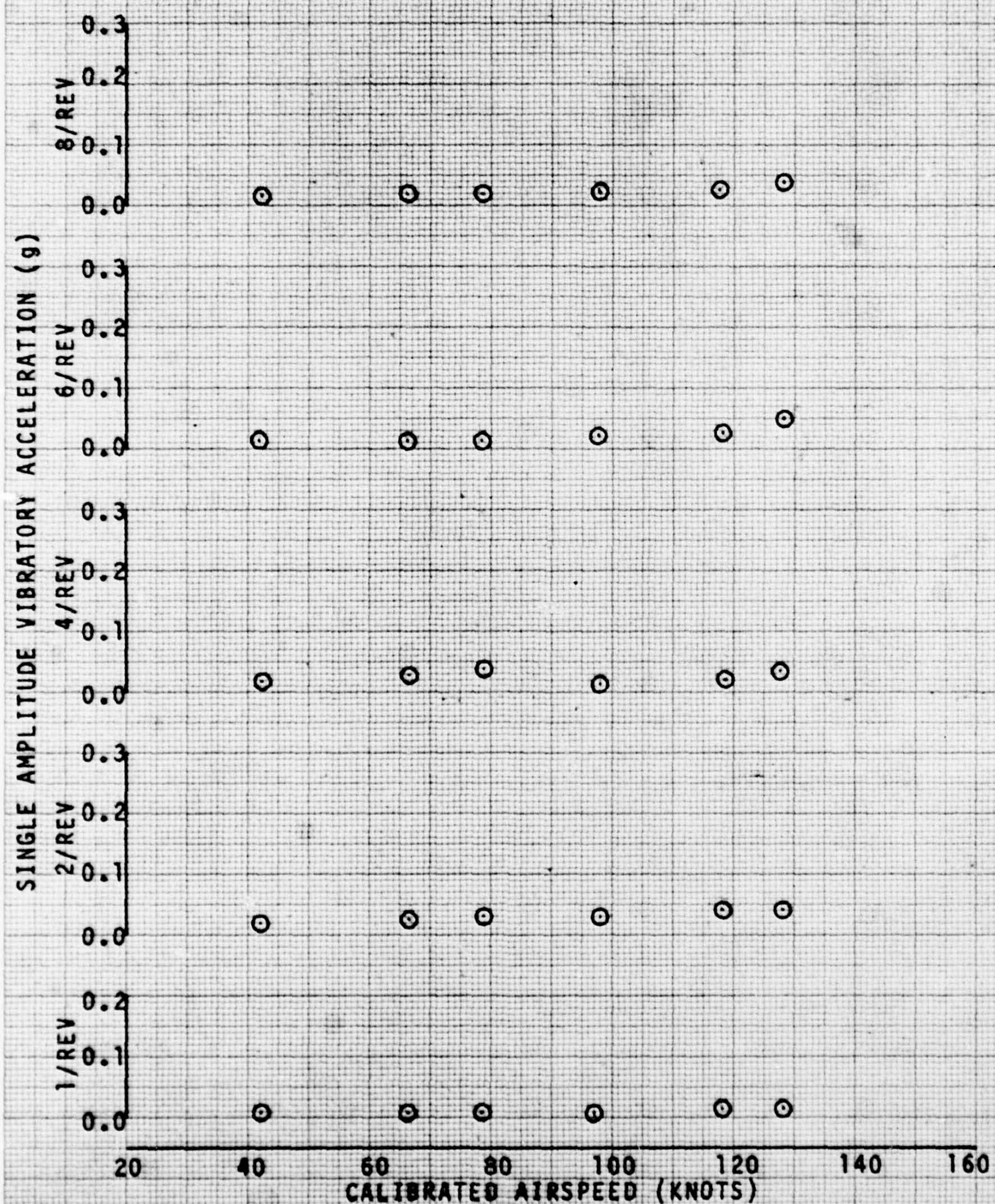


FIGURE 61
VIBRATION CHARACTERISTICS
AH-1S USA S/N 76-22567
PILOT SEAT VERTICAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (^{o}C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9800	193.0(FWD)	0.4 RT	3500	33.0	324	INBOARD PODS	LVL FLT

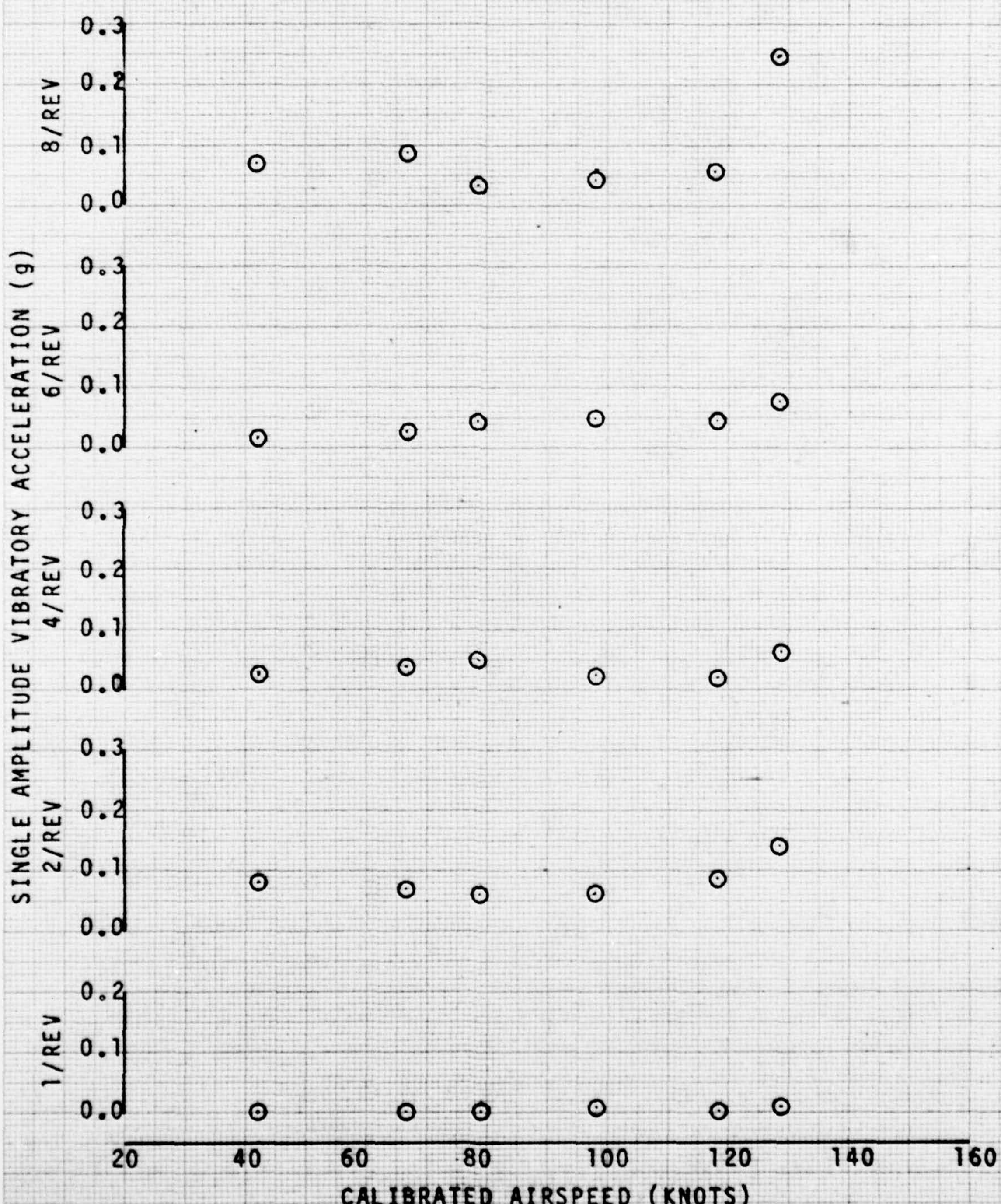


FIGURE 62
VIBRATION CHARACTERISTICS
AH-1S USA S/N 76-22567
PILOT SEAT LONGITUDINAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9800	193.0(FWD)	0.4 RT	3500	33.0	324	INBOARD PODS	LVL FLT

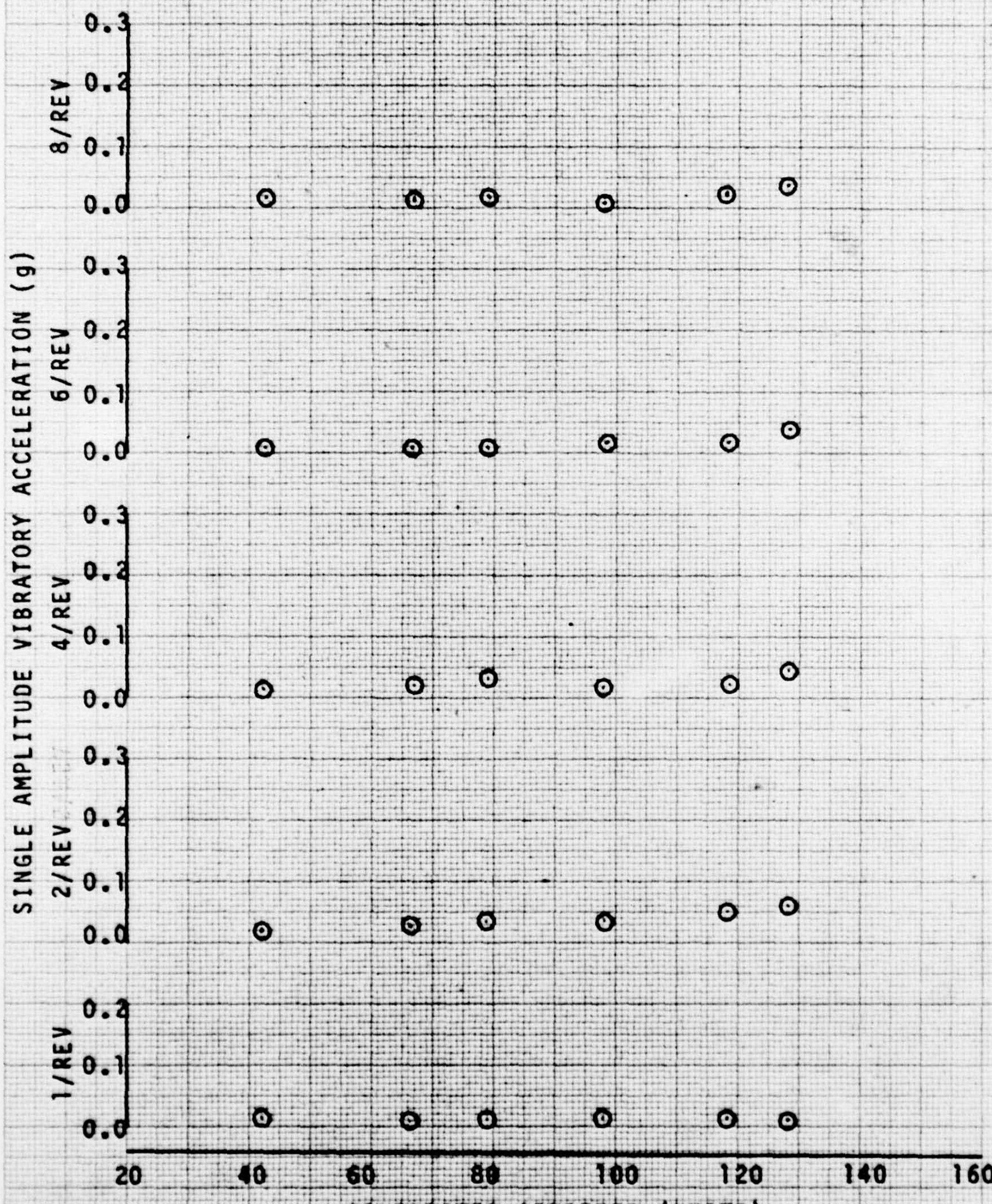


FIGURE 63
VIBRATION CHARACTERISTICS
AH-1S USA S/N 76-22567
GUN TURRET VERTICAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9800	193.0(FWD)	0.4 RT	3500	33.0	324	INBOARD PODS	LVL FLT

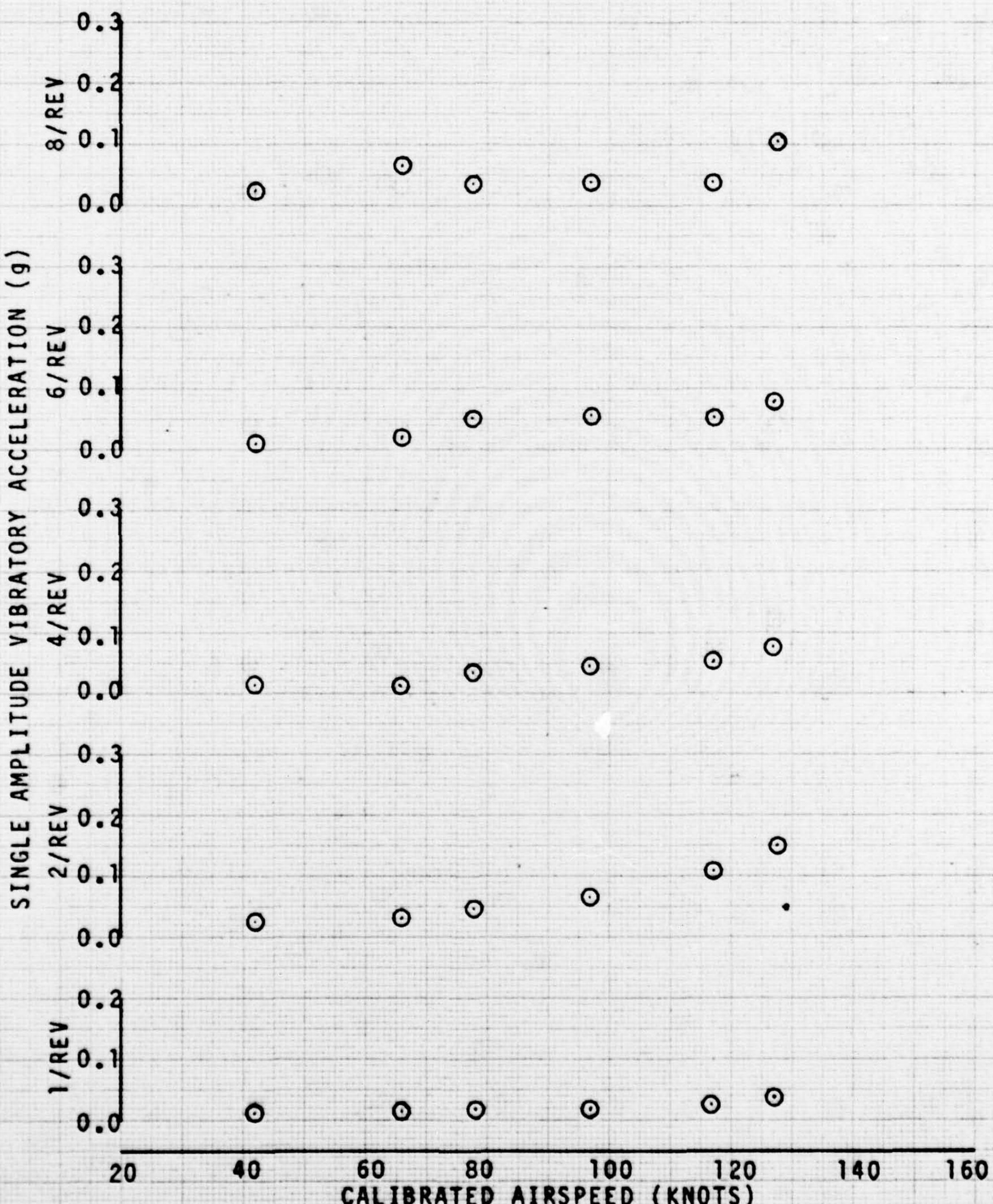


FIGURE 64
VIBRATION CHARACTERISTICS
AH-1S USA S/N 76-22567
GUN TURRET LATERAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9800	193.0(FWD)	0.4 RT	3500	33.0	324	INBOARD PODS	LVL FLT

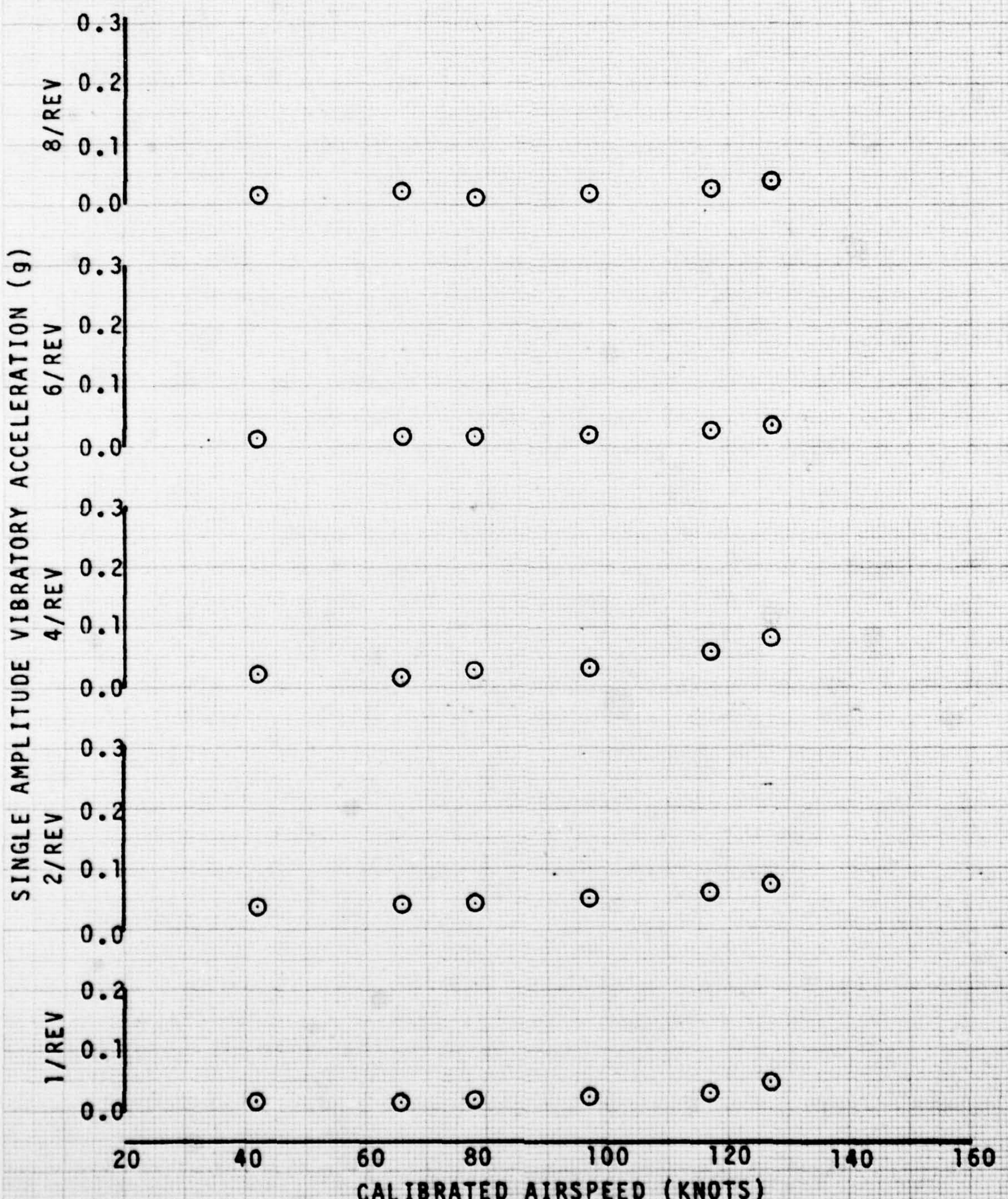


FIGURE 65
VIBRATION CHARACTERISTICS
AH-1S USA S/N 76-22567
GUN TURRET LONGITUDINAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9800	193.0(FWD)	0.4 RT	3500	33.0	324	INBOARD PODS	LVL FLT

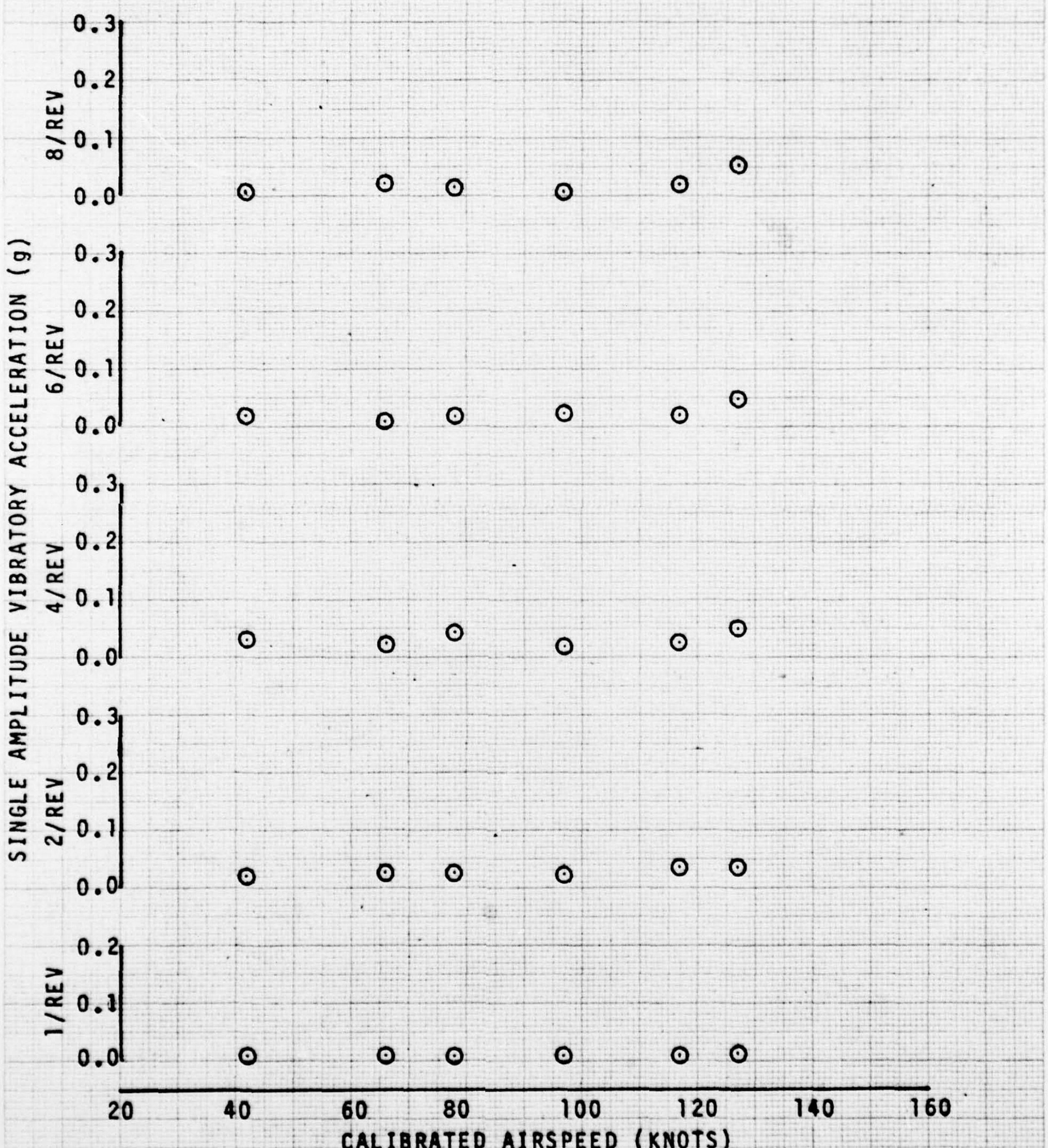


FIGURE 66
VIBRATION CHARACTERISTICS DURING GUN FIRING
AH-1S USA S/N 76-22567
PILOT SEAT LONGITUDINAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIG	FLIGHT CONDITION
9540	192.4(FWD)	0.4 RT	2700	34.0	324	INBOARD PODS	HOVER

NOTES: 1. GUN AZIMUTH = 0 DEG
2. GUN ELEVATION = 0 DEG

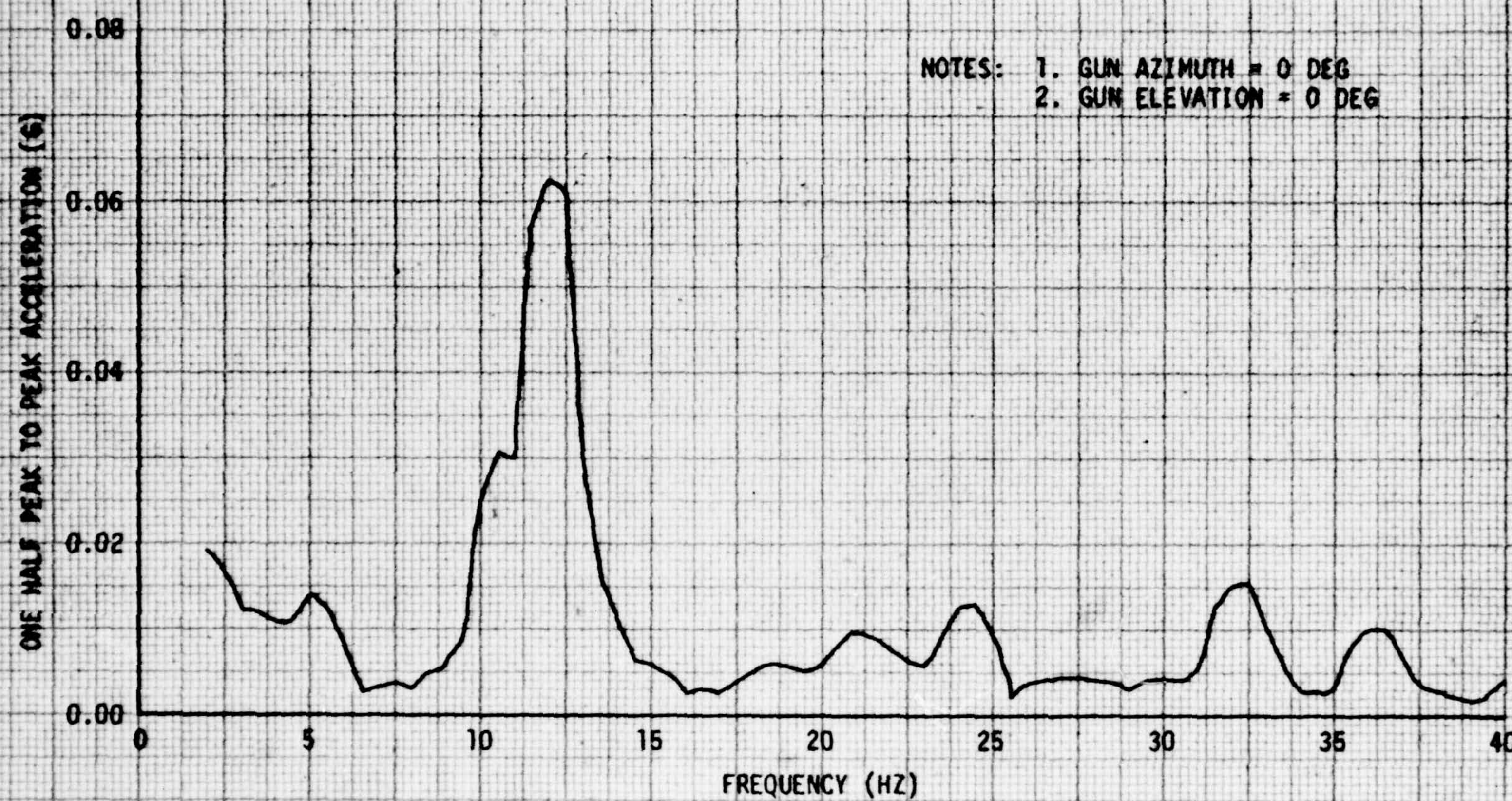


FIGURE 87

VIBRATION CHARACTERISTICS DURING GUN FIRING

AH-1S USA S/N 76-22567

GUNNER SEAT LATERAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	CONFIG	FLIGHT CONDITION
9700	192.8 (FWD)	0.4 RT	6000	27.0	324	78	INBOARD PODS	LEVEL FLT

NOTES: 1. GUN AZIMUTH = +90 DEG
2. GUN ELEVATION = 0 DEG

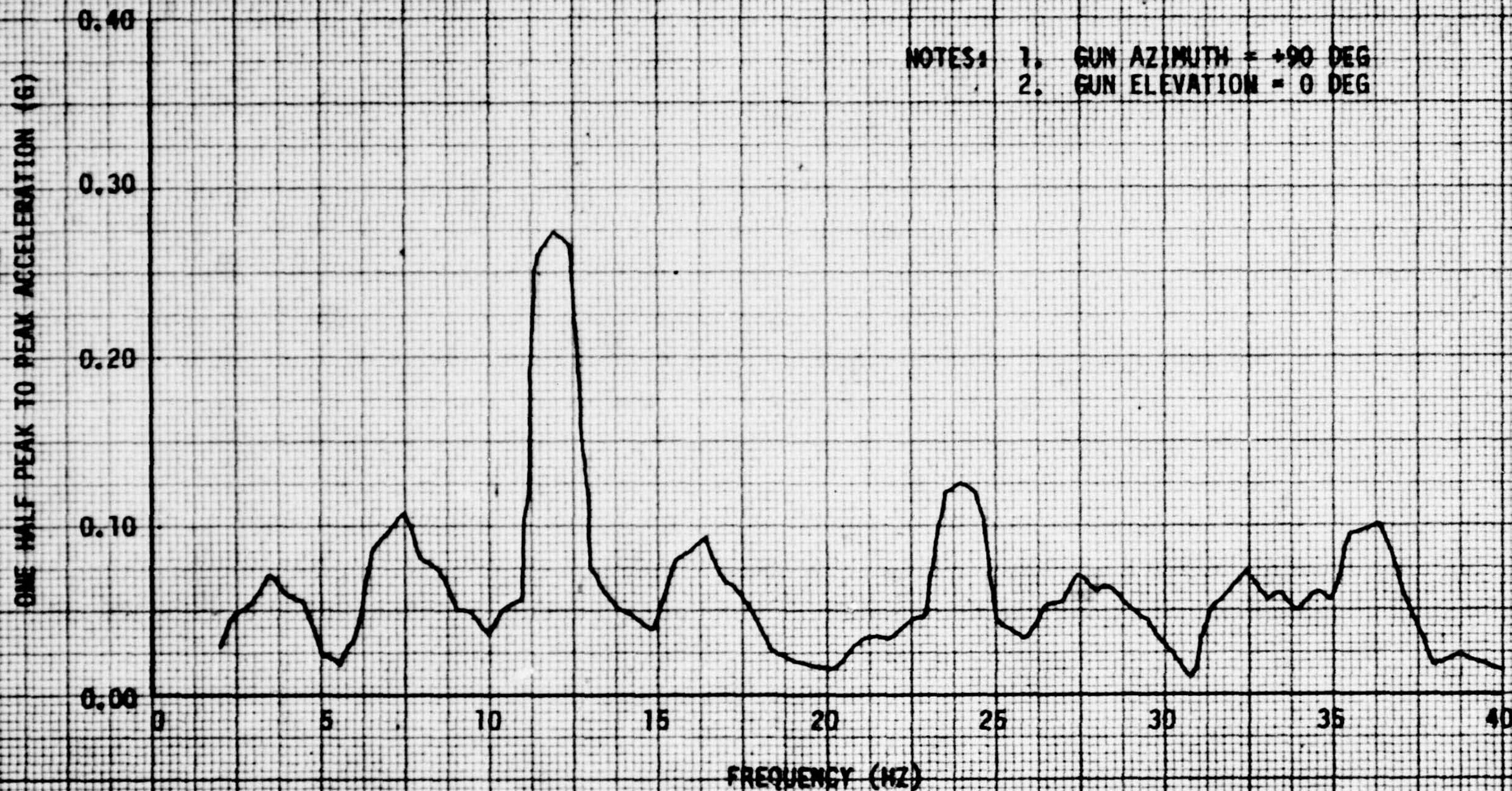


FIGURE 68
VIBRATION CHARACTERISTICS DURING GUN FIRING
AH-1S USA S/N 76-22567
GUNNER SEAT LATERAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	CONFIG	FLIGHT CONDITION
9660	192.8 (FWD)	0.4 RT	6200	26.5	324	114	INBOARD PODS	LEVEL FLT

NOTES: 1. GUN AZIMUTH = -90 DEG
2. GUN ELEVATION = 0 DEG

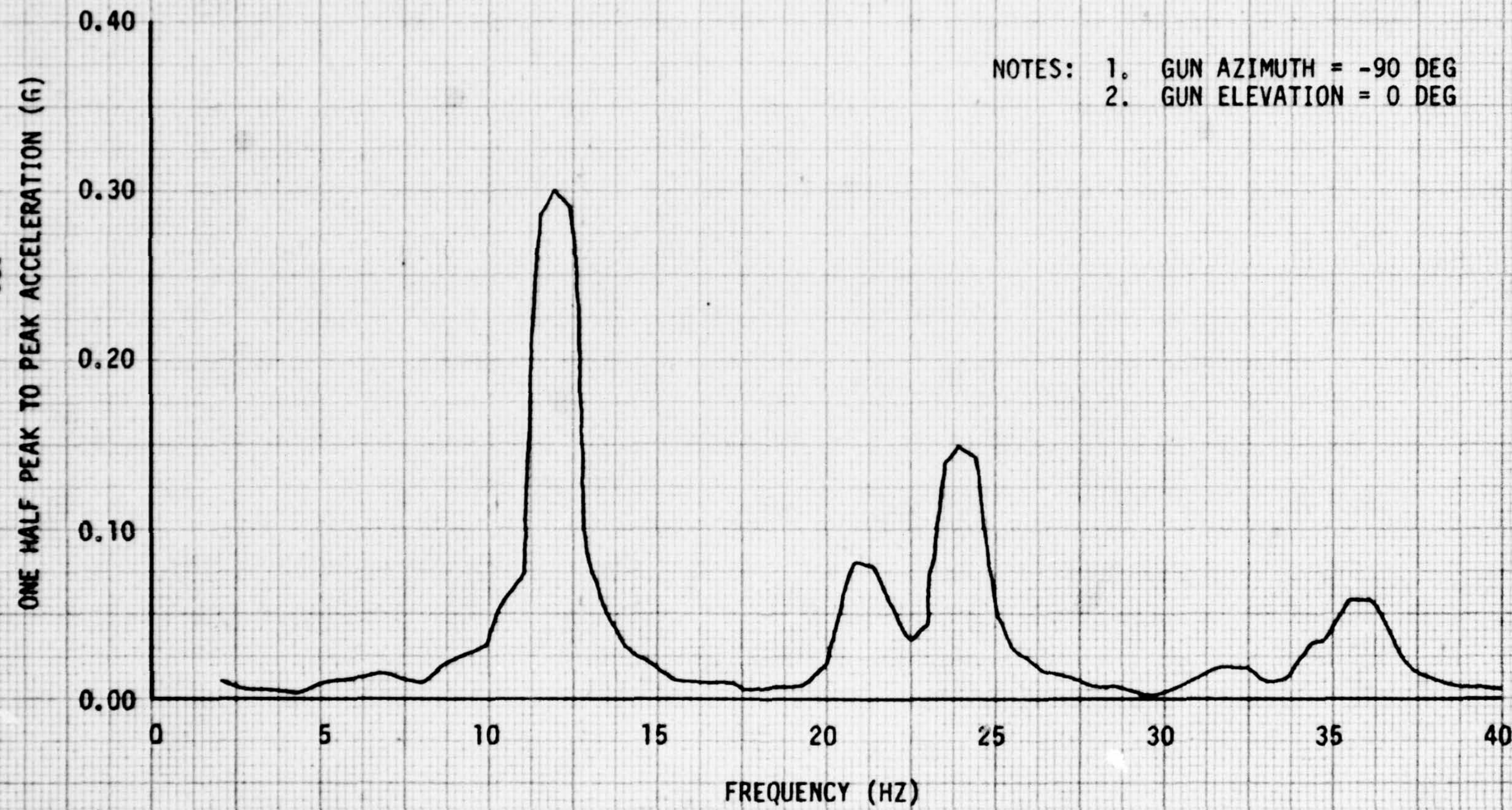


FIGURE 69
VIBRATION CHARACTERISTICS DURING GUN FIRING
AH-1S USA S/N 76-22567
PILOT SEAT VERTICAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	CONFIG	FLIGHT CONDITION
9640	192.9 (FWD)	0.4 RT	6100	27.0	324	126	INBOARD PODS	LEVEL FLT

NOTES: 1. GUN AZIMUTH = 0 DEG
2. GUN ELEVATION = -50 DEG

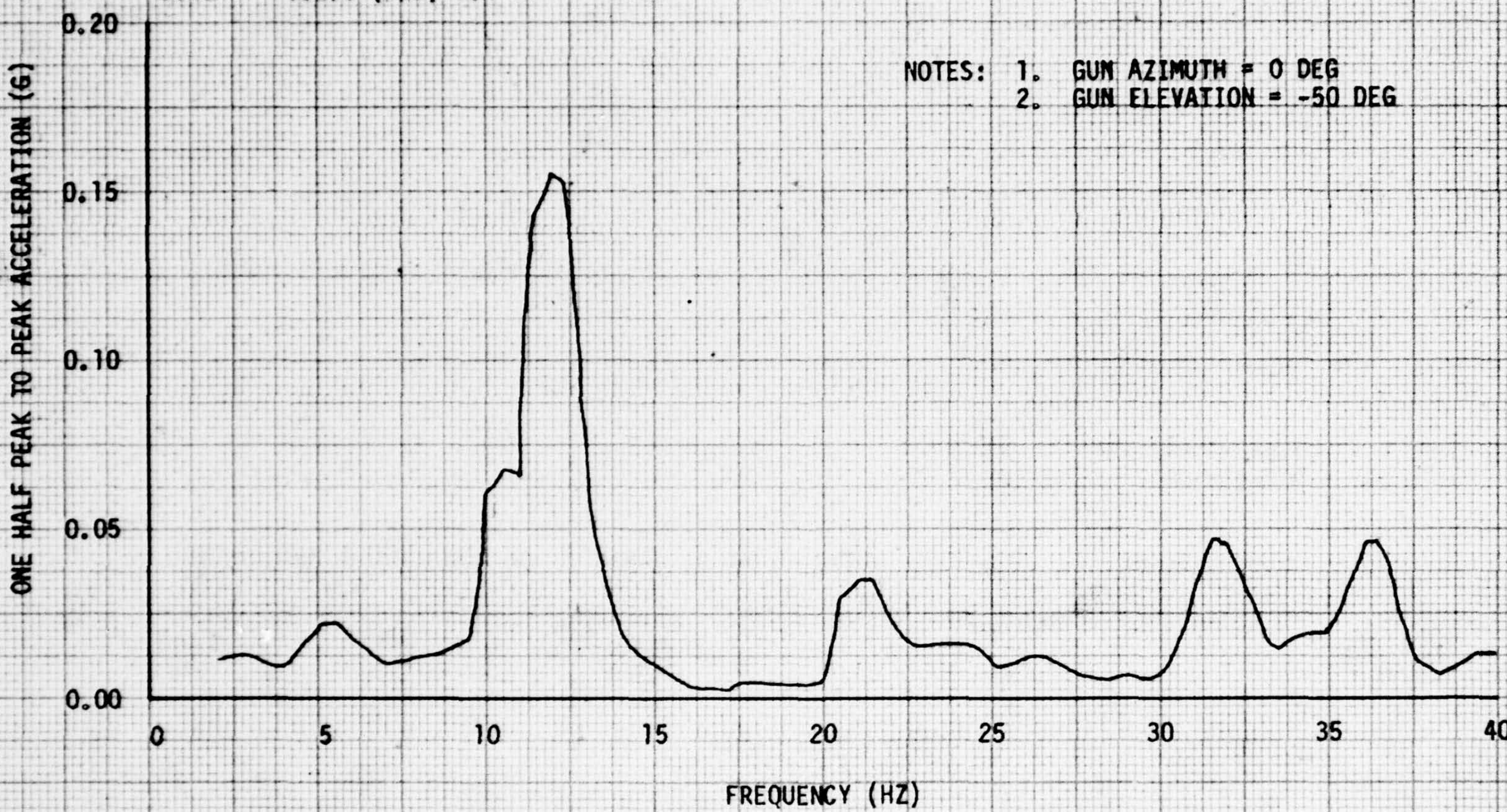
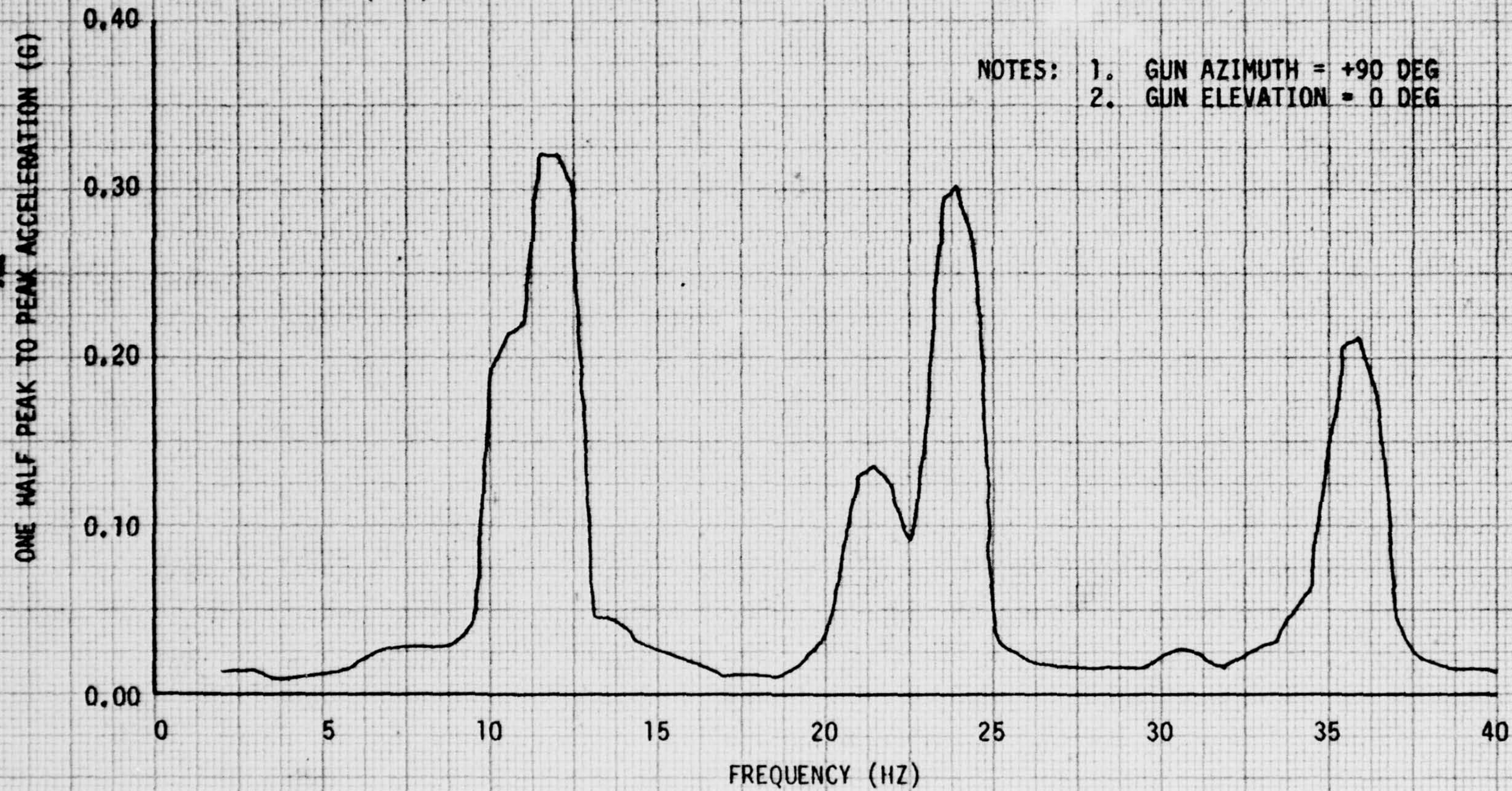


FIGURE 70
VIBRATION CHARACTERISTICS DURING GUN FIRING
AH-1S USA S/N 76-22567
GUNNER SEAT LATERAL

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	CONFIG	FLIGHT CONDITION
9640	192.9 (FWD)	0.4 RT	6000	26.5	324	156	INBOARD PODS	DIVE

NOTES: 1. GUN AZIMUTH = +90 DEG
2. GUN ELEVATION = 0 DEG



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SUPPLEMENTARY

INFORMATION

ERRATA

USAAEFA Project No. 78-03

Final Report

AH-1S Helicopter Installed with Enhanced Cobra Armament System
(AH-1S/ECAS)

United States Army Aviation Engineering Flight Activity
Edwards Air Force Base, California 93523

Remove pages 47 and 48 and replace with new page 47 and 48.

Since the period of the damped oscillation is equal to

$$\tau = 2\pi/\omega_n \sqrt{1-\zeta^2} \qquad (2)$$

The decrement can be rewritten as:

$$\delta = \ln \frac{x_1}{x_2} = 2\pi\zeta/\sqrt{1-\zeta^2} \qquad (3)$$

As seen in figure 3 for small values of ζ.

$$\delta<3, \quad \zeta \simeq \ln \frac{x_1}{x_2} \; /2\pi \qquad (4)$$

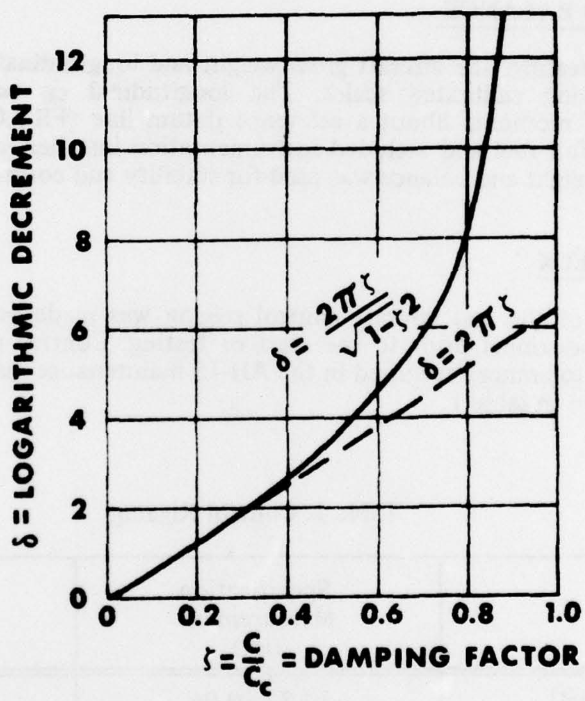

Figure 3. Logarithmic Decrements as Function of ζ.

The frequency is defined as $\omega = 2\pi/\tau$ rad/sec; the natural frequency is defined as

$$\omega_n = 2\pi/\tau \sqrt{1-\zeta^2} \qquad (5)$$

VIBRATION

3. The FM vibration data were reduced by means of a fast Fourier transform from the analog flight tape. Vibration levels, representing peak amplitudes, were extracted from this analysis at selected harmonics of the main rotor frequency. Gun firing vibration levels were quantified and presented in spectral plot format for analysis. The Vibration Rating Scale, presented in figure 4, was used to augment crew comments on aircraft vibration levels.

AIRSPEED CALIBRATION

4. A contractor supplied airspeed calibration (fig. 5) was utilized to determine airspeed.

WEIGHT AND BALANCE

5. Prior to testing, the aircraft gross weight and longitudinal and lateral cg were determined using calibrated scales. The longitudinal cg was calculated by a summation of moments about a reference datum line (FS 0.0). The aircraft was weighed with full fuel and included instrumentation installed in inboard wing pods. A calculated weight and balance was used for stability and control tests.

RIGGING CHECK

6. A check of the test aircraft control rigging was made on site by USAAEFA maintenance personnel prior to the start of testing. Control rigging was found to be within the tolerances specified in the AH-1S maintenance manual (ref 14, app A) and is presented in table 1.

Table 1. Control Rigging

Control	Specification Measurement (in.)	USAAEFA Measurement (in.)
Longitudinal[1]	12.82 ±0.06	12.88
Lateral[1]	12.52 ±0.06	12.58
Collective[2]	3.84 to 3.90	3.90
Directional[3]	4.07 ±0.03	4.09

[1] Cyclic control locked with fixture.
[2] Collective control full down.
[3] Full left pedal.