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ENGINE/AIRFRAME RESPONSE EVALUATION OF THE AH - 64A HELICOPTER

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NOVEMBER 1985

FINAL REPORT

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US ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523 - 5000

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) An engineering evaluation of the AH-64A helicopter was conducted in Mesa, Arizona, on 3 October 1985. The US Army Aviation Engineering Flight Activity and the US Army Aviation Development Test Activity both participated in the test. The engine controls on the test aircraft had been modified to correct the poor engine/airframe response characteristics which had been reported as a deficiency on previous tests. The purpose of the evaluation was to verify that the modified engine controls had corrected the engine/airframe response.		

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Maneuvers investigated included quick stops, pull-ups, pushovers, jump takeoffs, side flares, and recoveries from low power descents. The engine/airframe response of the AH-64A with the modified engine controls is satisfactory. *11*

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INTRODUCTION

BACKGROUND

1. The engine/airframe response of the AH-64A helicopter was severely degraded when the T700-GE-701 engines replaced the T700-GE-700 engines. Excessive rotor speed decay during power demands and subsequent airframe oscillations were listed as a deficiency in first article preproduction tests conducted by both the US Army Aviation Engineering Flight Activity (USAAEFA) and the US Army Aviation Development Test Activity (USAADTA). McDonnell Douglas Helicopter Company (MDHC), formerly Hughes Helicopters Incorporated, and General Electric have modified the engine controls to solve this problem. The USAAEFA and USAADTA tested an interim configuration of the modified controls in May 1985 (ref 1, app A) and determined that the engine/airframe response characteristics were improved but remained a deficiency. The US Army Aviation Systems Command requested USAAEFA (ref 2) and USAADTA to conduct an evaluation of the final configuration of the engine controls.

TEST OBJECTIVE

2. The objective of this test was to determine if the modified engine controls had corrected or improved the engine/airframe response.

DESCRIPTION

3. The test helicopter (USA S/N 82-23355) was the first production AH-64A Helicopter. It differed from a standard production AH-64A in that the weapons systems were not installed and the aircraft had instrumentation installed to record data for engineering evaluations. The standard AH-64A helicopter is described in reference 3, appendix A. Both the electronic control unit (ECU) and the hydromechanical unit engine controls were modified to correct the engine/airframe response. Additionally, a potentiometer was added to measure collective control position and send that signal to the ECU. These modified engine controls are further described in appendix B.

TEST SCOPE

4. This evaluation was conducted at Mesa, Arizona, on 3 October 1985. Two flights were conducted for a total of 2.3 hours. An MDHC pilot was in the front cockpit for all tests. The USAAEFA and USAADTA pilots each flew one flight. The evaluation was

conducted within the limits of the airworthiness release (ref 4, app A). The aircraft was flown in the 8-HELLFIRE configuration with an engine start gross weight of 15,540 pounds with the longitudinal center of gravity at fuselage station 205.3. Tests were conducted at both field elevation (1387 feet) and 5000 feet pressure altitude.

TEST METHODOLOGY

5. The AH-64A engine/airframe response characteristics were evaluated during performance of representative mission maneuvers. The test aircraft was stabilized at predetermined test conditions and baseline data were recorded. Specific test maneuvers are briefly discussed in the results and discussion section of this report. Flight test data were obtained from calibrated test instrumentation and were recorded on magnetic tape. Real time telemetry was used to monitor selected parameters throughout the test. A detailed listing of the test instrumentation is contained in appendix C. Test techniques and data analysis methods are described in appendix D. The Handling Qualities Rating Scale (HQRS) shown in appendix D was used to quantify pilot comments.

RESULTS AND DISCUSSION

GENERAL

6. The AH-64A helicopter was evaluated to determine engine/airframe response characteristics resulting from a modified engine control system. Engine airframe response tests included jump takeoffs, side flares, nap-of-the earth (NOE) quick stops, power recovery from autorotation, and NOE ridgeline crossing maneuvers. The engine/airframe response characteristics of the AH-64A with the modified engine controls are satisfactory.

ENGINE/AIRFRAME RESPONSE

7. Jump takeoffs were performed from the ground with the Hover Augmentation System engaged and initial collective control positions of full down and 40% from full down. Collective control was rapidly increased to 70% from full down (approximately 100% indicated engine torque). Side flare maneuvers were performed at 50 feet above ground level (AGL) and approximately 70 knots ground speed, terminating at a stable hover over a predetermined point. During both jump takeoffs and sideflares, the minimum rotor speed observed was 96.5% and the engine/airframe oscillations were well damped and not apparent to the pilot (figs. 1 and 2, app E). No warning lights were activated and the maneuvers were easily accomplished with satisfactory heading control.

8. Quick stop maneuvers were performed at 50 feet AGL with an entry speed of 80 KTAS over a paved runway (fig. 3). The maneuvers were terminated at a stable hover over a predetermined point. Both moderate and aggressive quick stops were accomplished. The minimum rotor speed observed was 97%. Residual engine/airframe oscillations were well damped and the aircraft heading could be easily maintained within ± 3 degrees (HQRS 3).

9. Power recovery from autorotation was performed from stable 80 knots true airspeed (KTAS) descent (power levers at fly) with collective control positioned to maintain 1 to 5 percent split between the main rotor speed (N_R) and the power turbine speed (N_p). Collective control was increased to 60% from full down in 1 to 4 seconds during recovery. Power recoveries from autorotation (figs. 4 and 5, app E) resulted in the largest loss of rotor speed. However, the rotor speed droop was very predictable, in that larger and faster collective pulls resulted in larger magnitudes of rotor speed droop. Additionally, residual oscillations in engine torque were not large and were well damped. Residual airframe oscillations, observed during previous testing of the interim engine control configuration, were not present and heading control was easily maintained during the power recovery from autorotation.

10. Ridgeline crossing maneuvers were performed at 100 ft AGL from initial airspeeds of 70, 90, 110 KTAS using synchronous collective and cyclic control which resulted in maximum rotor speed excursions of 95% to 111%. Residual airframe oscillations, observed during the previous testing of the interim engine control configuration, were not present and heading control was easily maintained during aggressive ridgeline crossing maneuvers (fig. 6).

11. Rotor speed droop in all the maneuvers tested was minimal to moderate and in all cases predictable (i.e., more aggressive maneuvers resulted in more droop). The engine/airframe oscillations seen during previous testing were well damped and of small magnitude. The engine/airframe response of the AH-64A with the modified engine controls is satisfactory.

CONCLUSION

12. The engine/airframe response of the AH-64A with the modified engine controls is satisfactory (para 6).

RECOMMENDATION

13. The AH-64A production configuration should incorporate production engine controls which provide the engine/airframe response characteristics exhibited by the test configuration.

APPENDIX A. REFERENCES

1. Final Report, USAAEFA Project No. 85-08, *Engine/Airframe Response Evaluation of the AH-64A Helicopter* June 1985.
2. Letter, AVSCOM, AMSAV-ED, 5 September 1985, subject: AH-64 Main Rotor Speed Droop Improvements Flight Evaluation.
3. Technical Manual, TM 55-1520-238-10, *Operator's Manual for Army AH-64 Helicopter*, 28 June 1984, with change 1 dated 15 October 1985.
4. Letter, AVSCOM, AMSAV-PSA, 8 May 1985, subject: Contractor Flight Release for AH-64A, S/N 82-23355, PV-01, Contract DAAK50-81-C-0001 and DAAJ09-85-C-A003.

APPENDIX B. DESCRIPTION

GENERAL

1. Three engine control configurations are described here: 1) the production T700-GE-701 controls which were used during the first article production tests; 2) the interim configuration (used during ref 1, app A testing), and 3) the latest configuration (used during this test).

Hydromechanical Unit

2. The latest hydromechanical unit (HMU) was modified from the production HMU to increase the acceleration fuel schedule 10% between 70% and 87% gas generator speed (Ng). Above 87% Ng the fuel schedule was increased by less than 10%. There was no increase at less than 61% Ng (the engine start range). Figure 1 presents the acceleration fuel schedule for the production HMU, the interim HMU (used during the ref 1 testing), and the HMU used during this test.

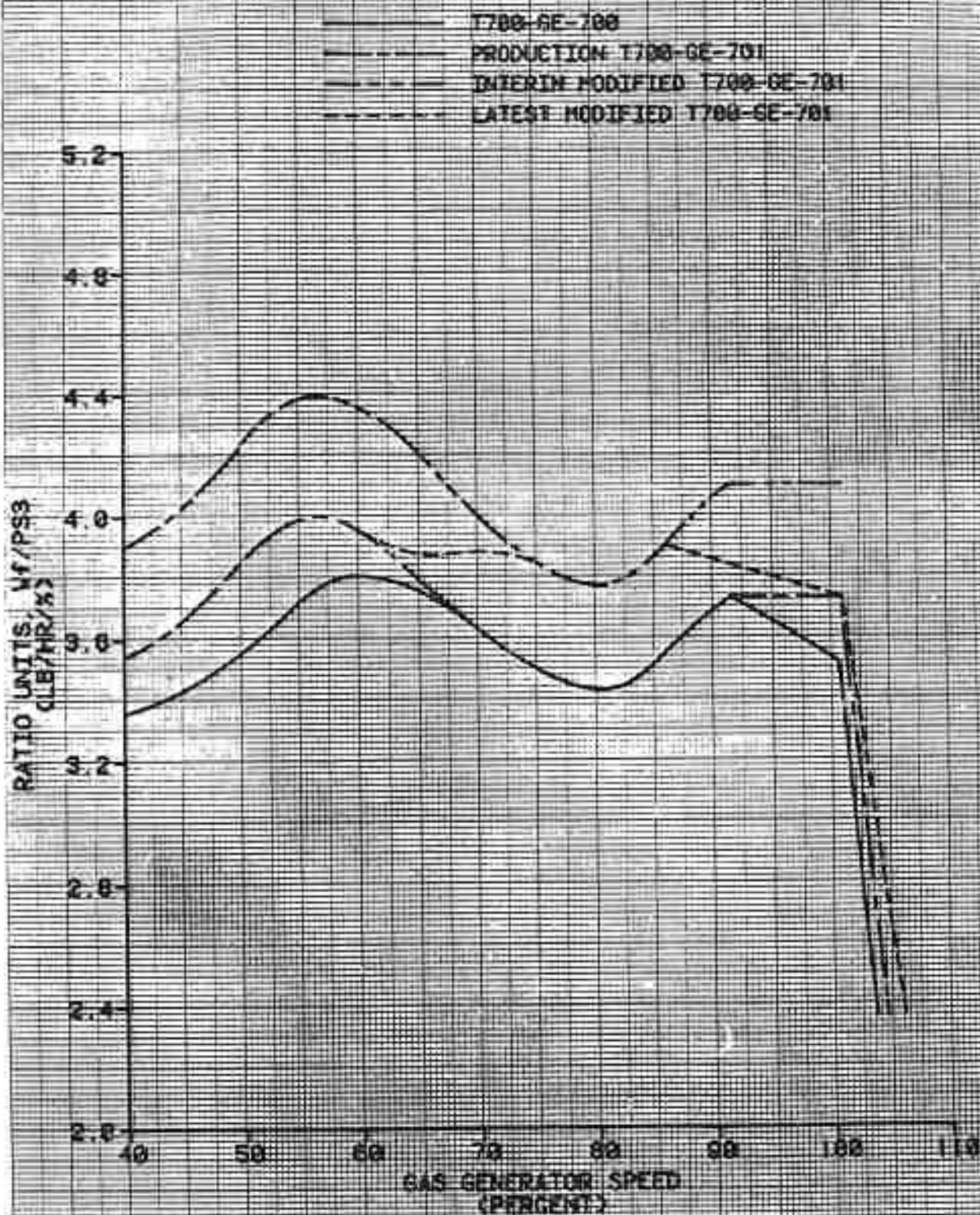
Electrical Control Unit

3. The gain of the power turbine speed (Np) governor in the production electrical control unit (ECU) switched from high to low as engine torque decreased below 20 ft-lb. Approximately one second after torque increased through 20 ft-lb, the gain switched back to high. In the interim ECU, this switching occurred at 50 ft-lb. On both of these ECU's, if the Np governor gain was low as Np increased through 112%, the gain switched to high with no delay. On the latest ECU, the high to low gain switching occurred as engine torque decreased through 50 ft-lb. On the ECU used during this test, the low to high gain switching occurred approximately 1/2 second after engine torque increased through 50 ft-lb or immediately when Np reached 107%.

4. Both the interim and latest ECU incorporated a collective control rate-of-movement signal to increase fuel flow with upward collective control movement. One volt per %/second of collective control movement was sent from the potentiometer to the ECU. The maximum signal was 2.5 volts in the interim ECU and 1.5 volts in the latest one.

5. There were two additional differences between the interim and latest ECU's. The first was the incorporation of a "notch" filter in the latest ECU to eliminate signals at approximately 2.7 Hz. This was to eliminate an engine/rotor system dynamic instability which had been encountered during contractor testing. Incorporation of the "notch" filter allowed a gain change to be made in the governor dynamics to improve damping of oscillations at

FIGURE 1
ACCELERATION FUEL SCHEDULE
GENERAL ELECTRIC T700



approximately 0.4 Hz without reducing damping at 2.7 Hz. This gain change was made to eliminate the residual engine/airframe oscillations found during previous tests. The gain was changed from 0.135 (production and interim value) to 0.0425. A schematic of the latest ECU configuration is shown in figure 2.

APPENDIX C. INSTRUMENTATION

1. An airborne data acquisition system was installed and maintained by McDonnell Douglas. The system utilized pulse code modulation (PCM) encoding. Magnetic tape was used to record parameters aboard the aircraft.
2. A boom was mounted on the aircraft extending 52 inches forward of the nose. A pitot-static tube, an angle-of-attack sensor, and an angle-of-sideslip sensor were mounted on the boom.
3. Instrumentation and related special equipment installed are presented in the following lists.

Pilot Station (aft cockpit displays)

Pressure altitude (boom)
Airspeed (boom)
Vertical rate of climb
Main rotor speed
Engine torque (both engines)
Engine measured gas temperature (both engines)
Engine power turbine speed (both engines)
Engine gas generator speed (both engines)
Angle of sideslip
Event switch
Radar altitude
Control Positions
 Longitudinal
 Lateral
 Directional
 Collective
Stabilator incidence angle
Normal acceleration (cg)
Horizontal situation indicator with Doppler interface
Primary attitude reference
Turn needle and ball
CG lateral acceleration (sensitive indicator)

Copilot Station Displays

Airspeed (ship)
Altitude (ship)
Main rotor speed
Engine torque (both engines)
Engine measured gas temperature (both engines)
Engine gas generator speed (both engines)
Fuel used (both engines)
Total air temperature
Time code display

Event switch
Data system controls
Doppler

PCM Parameters (Magnetic Tape)

Time code
Event
Main rotor speed
Fuel temperature (both engines)
Fuel used (both engines)
Engine fuel flow (both engines)
Engine torque (both engines)
Engine measured gas temperature (both engines)
Engine gas generator speed (both engines)
Engine power turbine speed (both engines)
Airspeed (boom)
Airspeed (ship, pilot and copilot/gunner)
Altitude (boom)
Altitude (ship, pilot and copilot/gunner)
Total air temperature
Angle of attack (boom)
Angle of sideslip (boom)
Control positions
 Longitudinal cyclic
 Lateral cyclic
 Pedal
 Collective
Stabilator incidence angle
Aircraft attitudes
 Pitch
 Roll
 Yaw
Aircraft angular velocities
 Pitch
 Roll
 Yaw
Vibration Accelerometers
 Pilot seat (3 axes)
 Copilot seat (3 axes)
 Aircraft cg (3 axes)
Stability augmentation system actuator positions
 Longitudinal
 Lateral
 Directional
Control actuator positions
 Collective pitch
 Cyclic pitch

Cyclic roll
Tail rotor
Air data system
Longitudinal velocity
Lateral velocity
Pressure altitude
Outside air temperature
Angle of sideslip
Resultant airspeed
Radar altitude
CG normal acceleration
CG lateral acceleration
Rotor azimuth

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. The test techniques used during this evaluation are described in the Results and Discussion section of this report. Pilot comments on the workload required to accomplish the maneuvers were quantified using a modified Cooper-Harper Handling Qualities Rating Scale (fig. 1).

DEFINITIONS

2. The following definition of deficiency was used during this evaluation.

Deficiency - A defect or malfunction discovered during the life cycle of an item of equipment that constitutes a safety hazard to personnel; will result in serious damage to the equipment if operation is continued; or indicates improper design or other cause of failure of an item or part, which seriously impairs the equipment's operational capability.

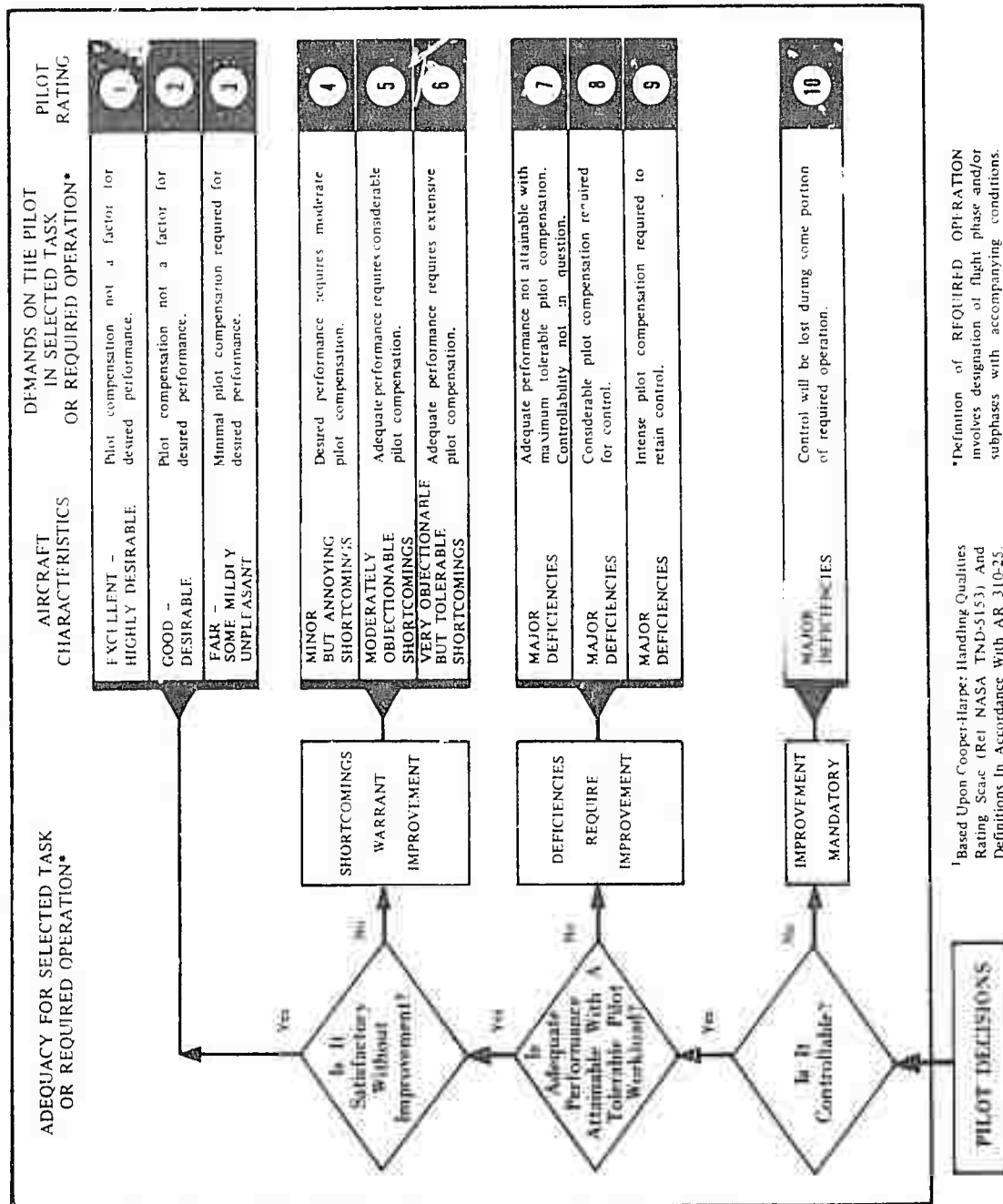


Figure 1. Handling Qualities Rating Scale

APPENDIX E. TEST DATA

<u>Figure</u>	<u>Figure Number</u>
Jump Takeoff	1A - 1F
Sideflare	2A - 2F
Quick Stop	3A - 3F
Recovery from Autorotation	4A - 4F, 5A - 5F
Ridgeline Maneuver	6A - 6F

FIGURE 1A
JUMP TAKEOFF
AH-64A USA S/N 82-23355

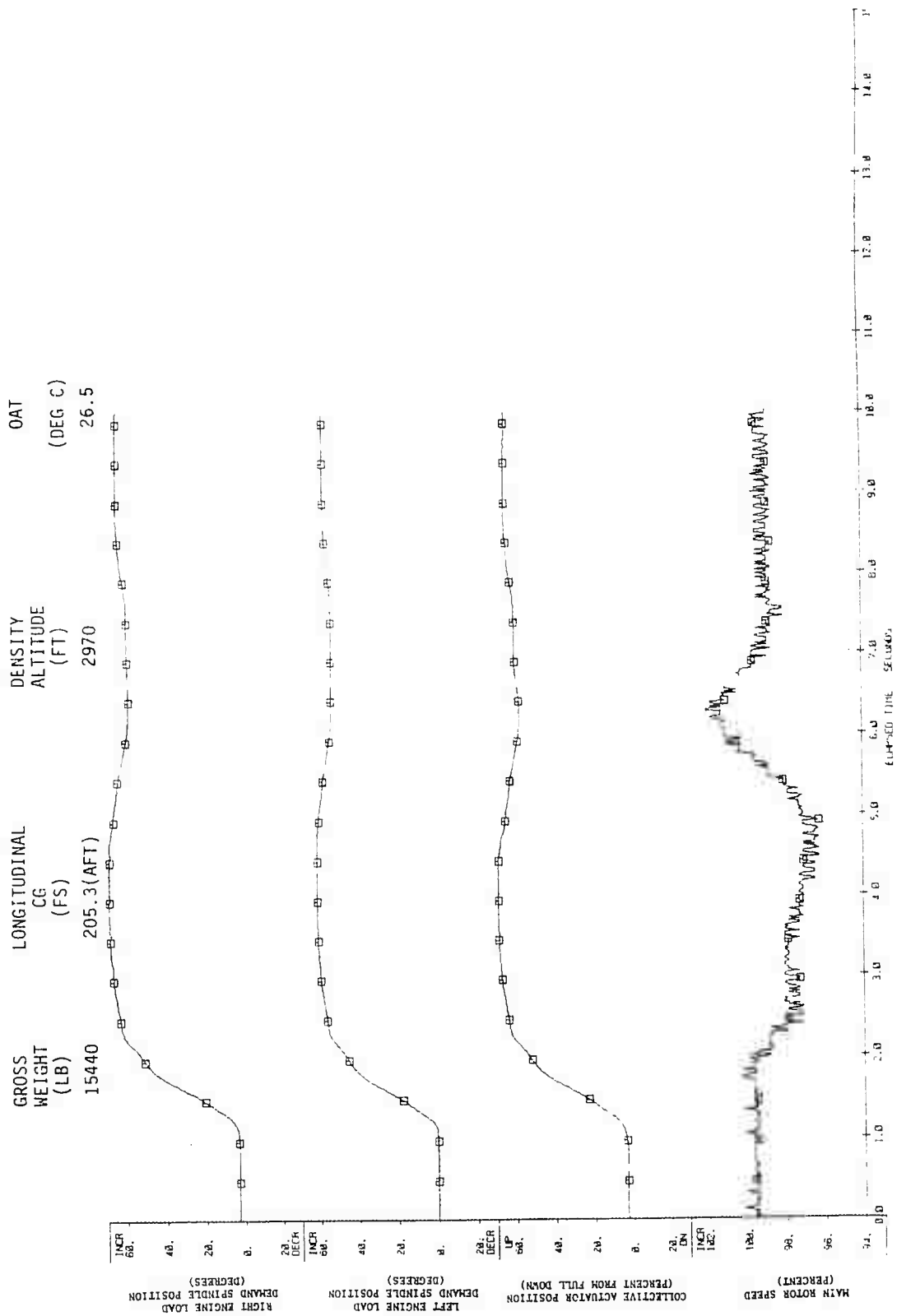


FIGURE 1B
JUMP TAKEOFF
AH-64A USA S/N 82-23355
LONGITUDINAL COG 205.3 (AFT)
DENSITY ALTITUDE (FT) 2070
DAY (DEG C) 26.5

GROSS WEIGHT (LB) 15440

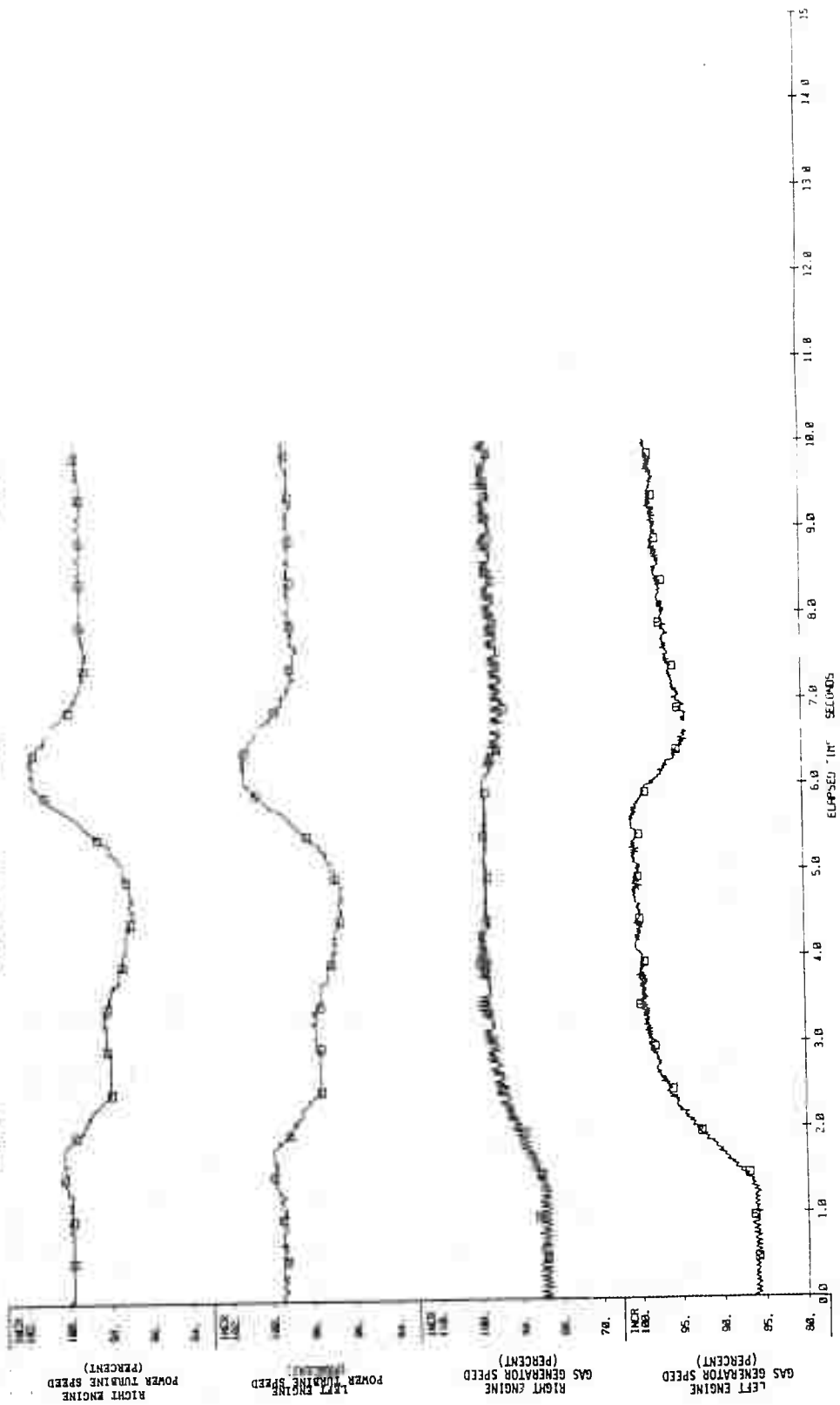


FIGURE 1C
JUMP TAKEOFF
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15440	LONGITUDINAL CG (FS)	205.3 (AFT)	DENSITY ALTITUDE (FT)	2970	OAT (DEG C)	26.5
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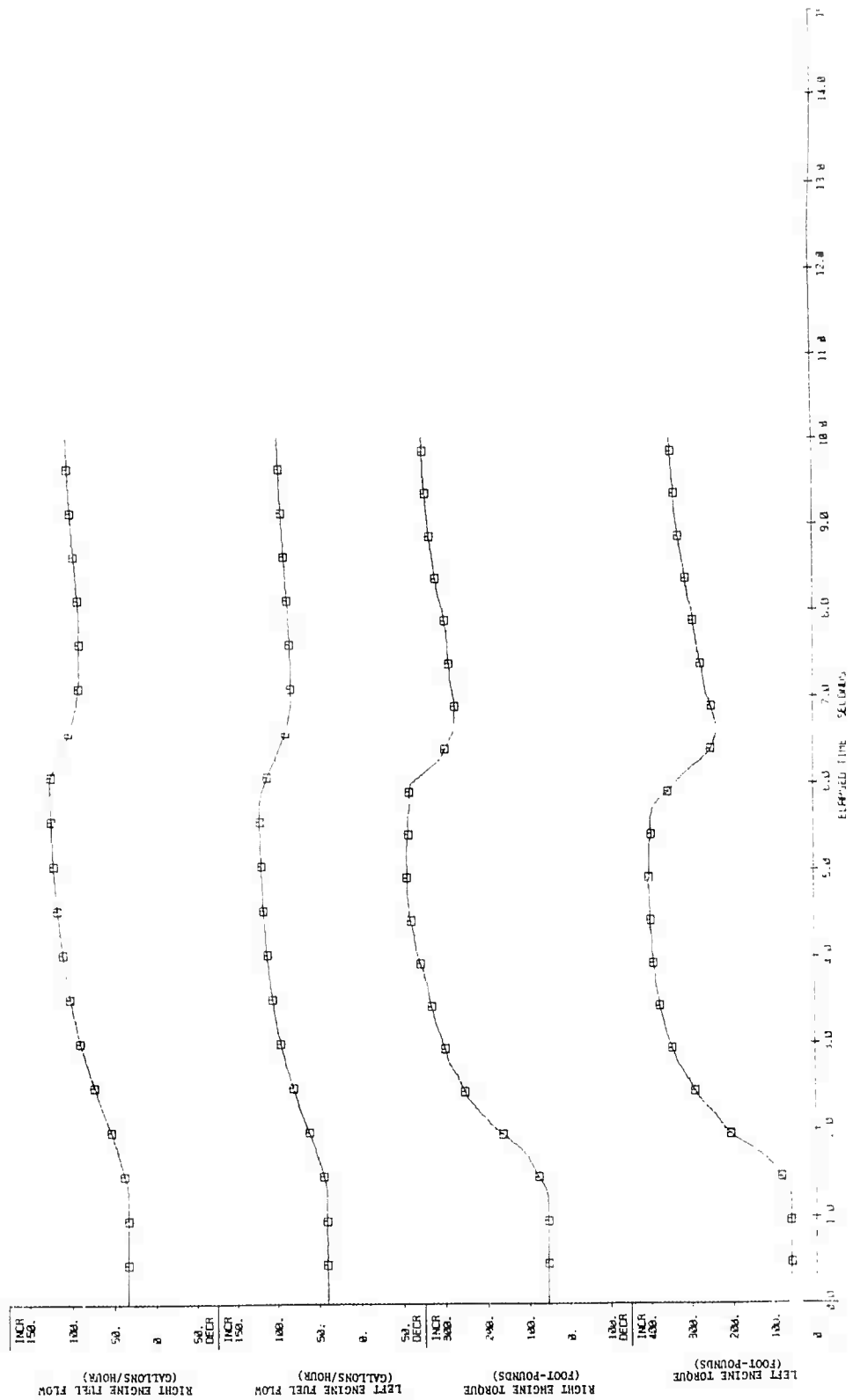


FIGURE 1D
 JUMP TAKEOFF
 AH-64A USA S/N 82-23355
 LONGITUDINAL CG (FS) 205.3 (AFT)
 GROSS WEIGHT (LB) 15440
 DENSITY ALTITUDE (FT) 2970
 OAT (DEG C) 26.5

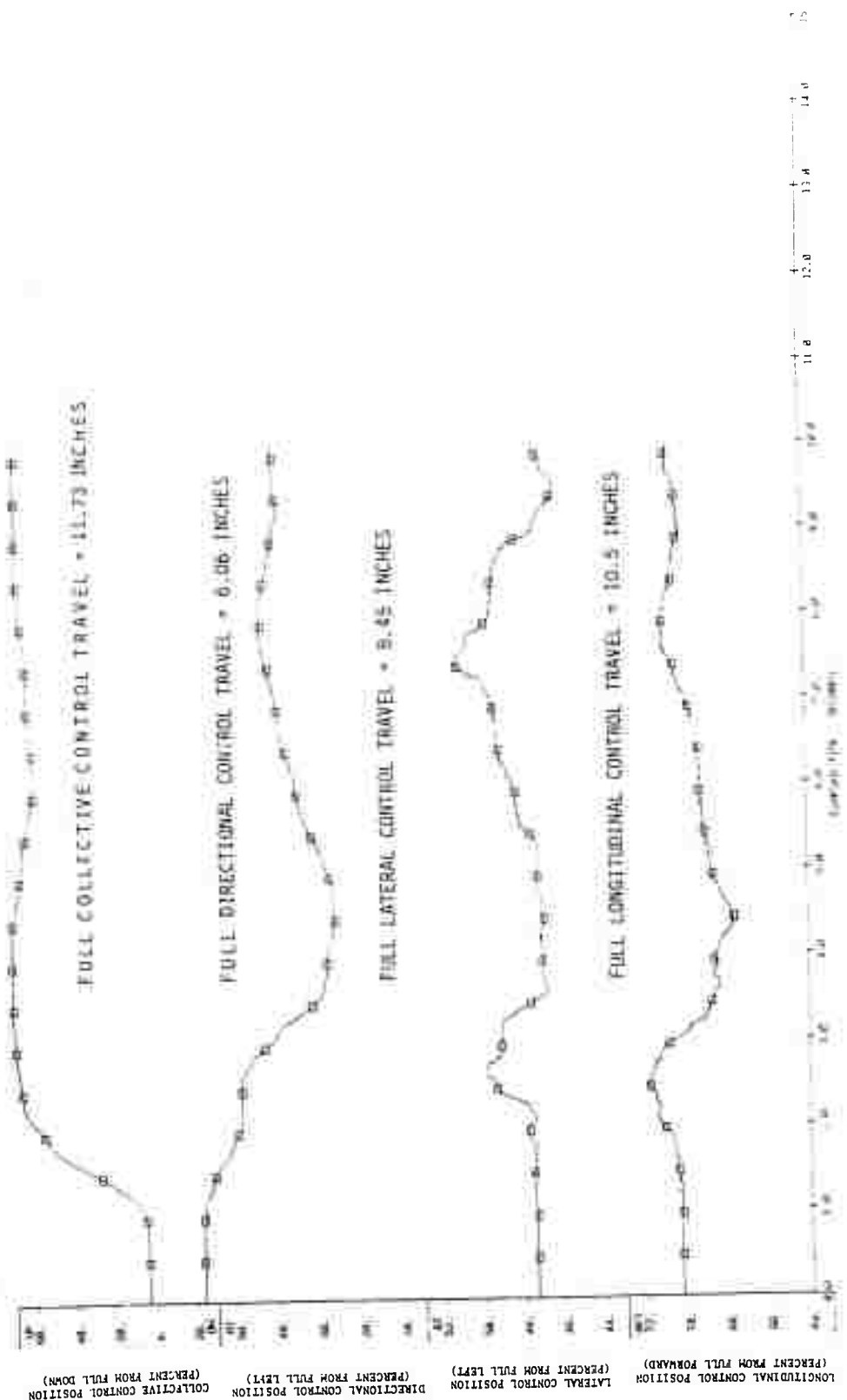


FIGURE 1E
JUMP TAKEOFF
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15440	LONGITUDINAL CG (FS)	205.3(AFT)	DENSITY ALTITUDE (FT)	2970	OAT (DEG C)	26.5
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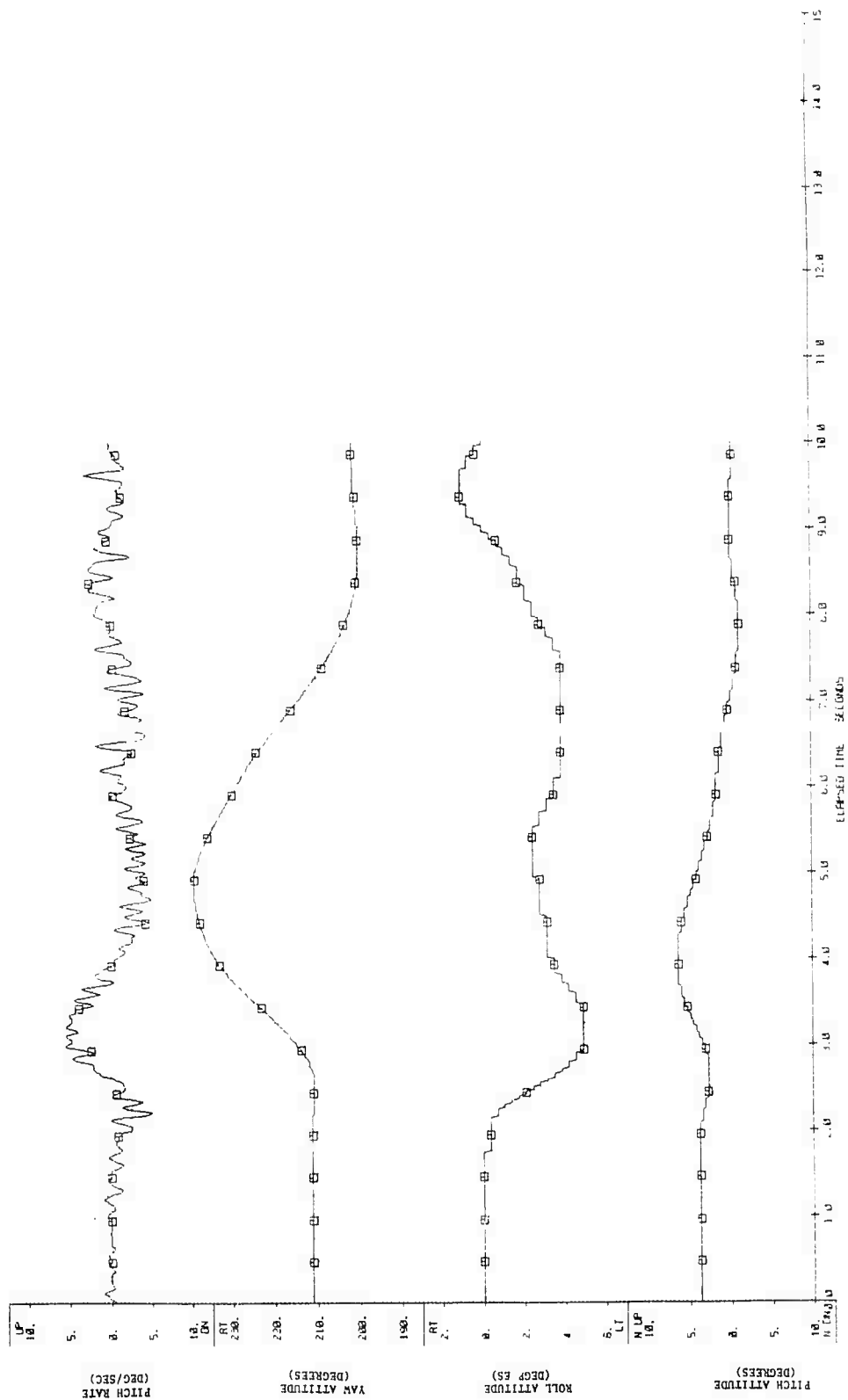
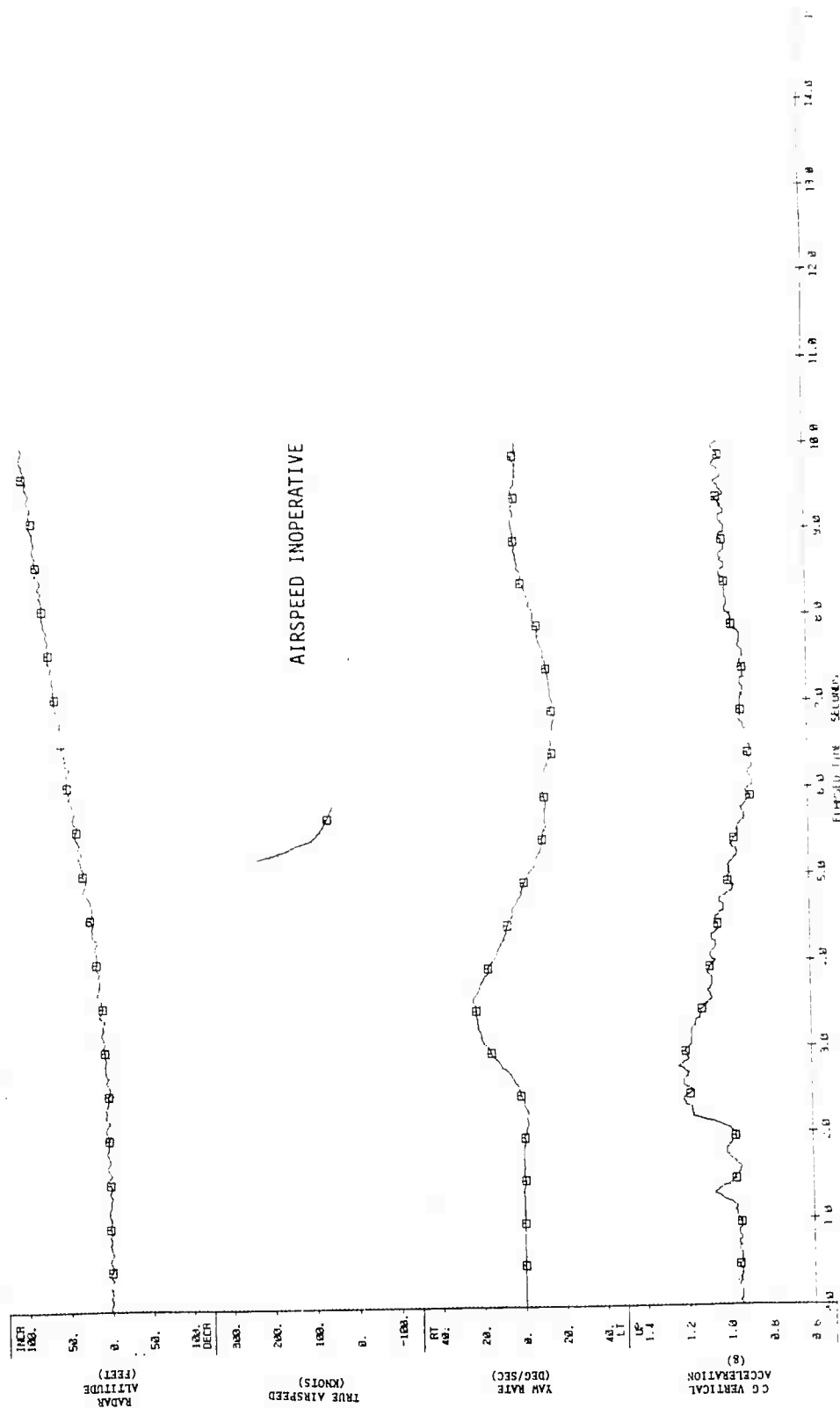


FIGURE 1F
JUMP TAKEOFF
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15440	LONGITUDINAL CG (FS)	205.3(AFT)	DENSITY ALTITUDE (FT)	2970	OAT (DEG C)	26.5
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AIRSPEED INOPERATIVE

FIGURE 2A
SIDE FLARE
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	14650	LONGITUDINAL CG (FS)	205.5(AFT)	DENSITY ALTITUDE (FT)	1440	OAT (DEG C)	20.5
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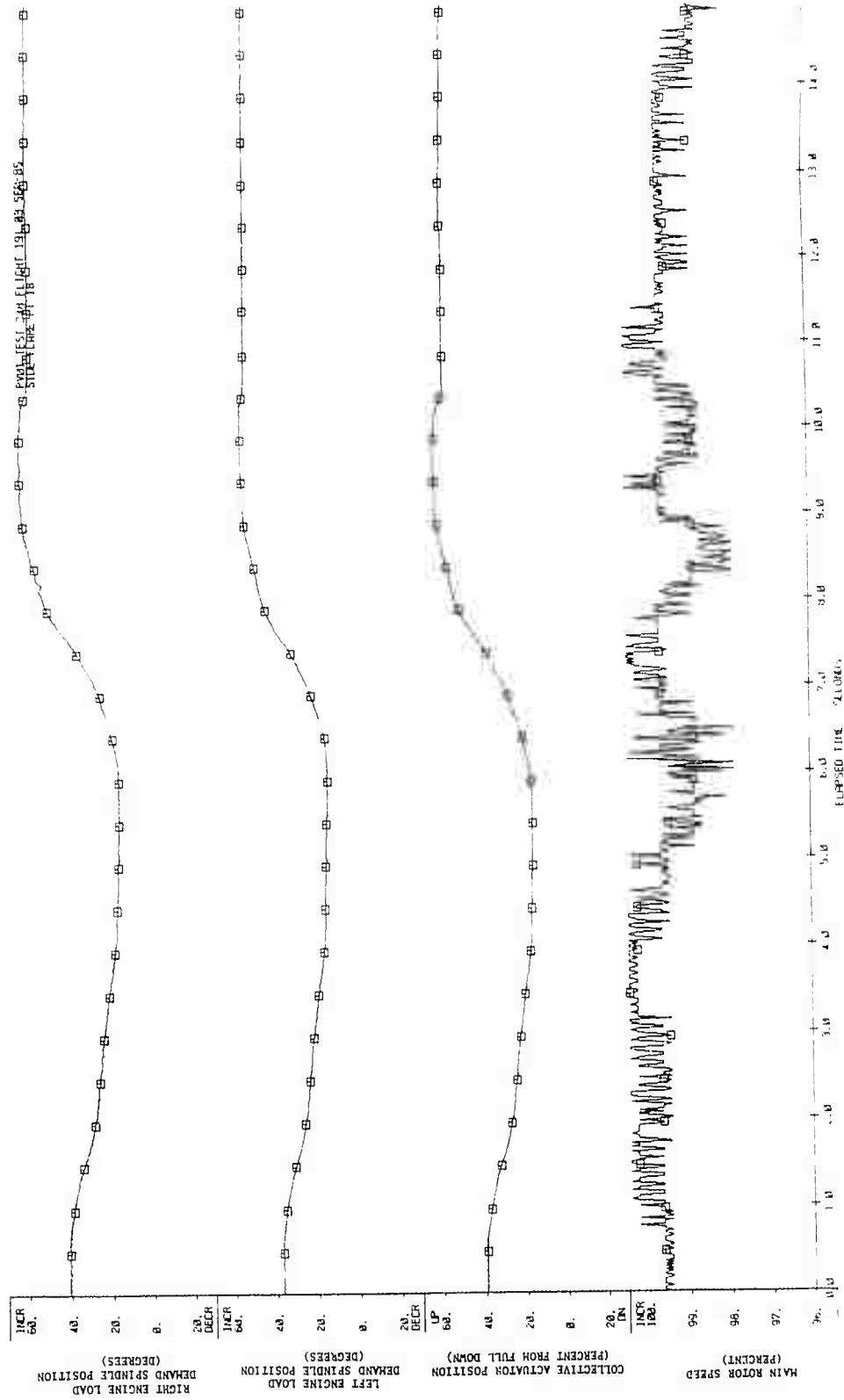


FIGURE 2B
SIDE FLARE
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB) 14650
LONGITUDINAL CG (FS) 205.5 (AFT)
DENSITY ALTITUDE (FT) 1440
OAT (DEG C) 20.5

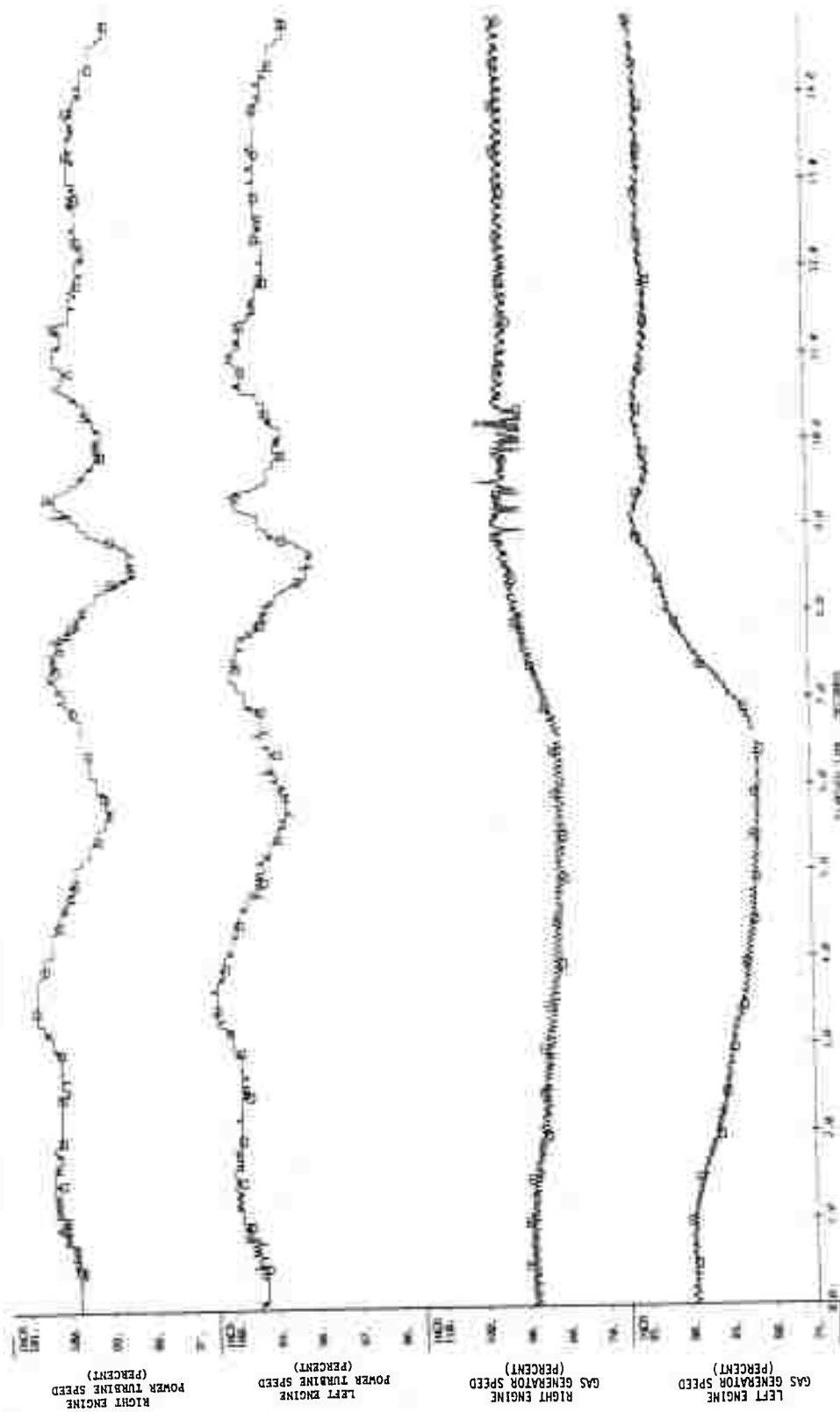


FIGURE 2C
SIDE FLARE
AH-64A USA S/N 82-23355

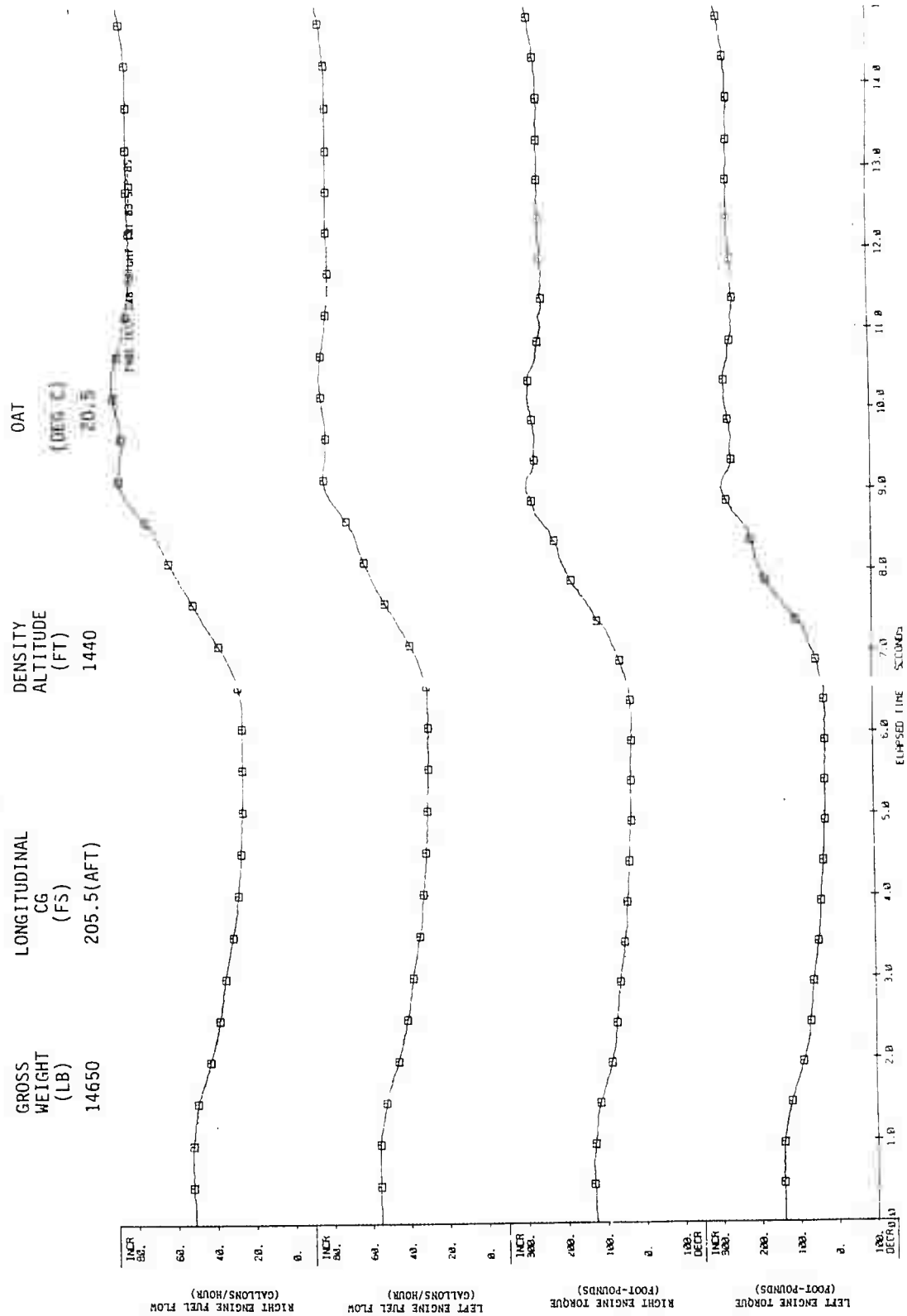


FIGURE 2D
SIDE FLARE
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB) 14650
LONGITUDINAL CG (FS) 205.5(AFT)
DENSITY ALTITUDE (FT) 1440
OAT (DEG C) 20.5

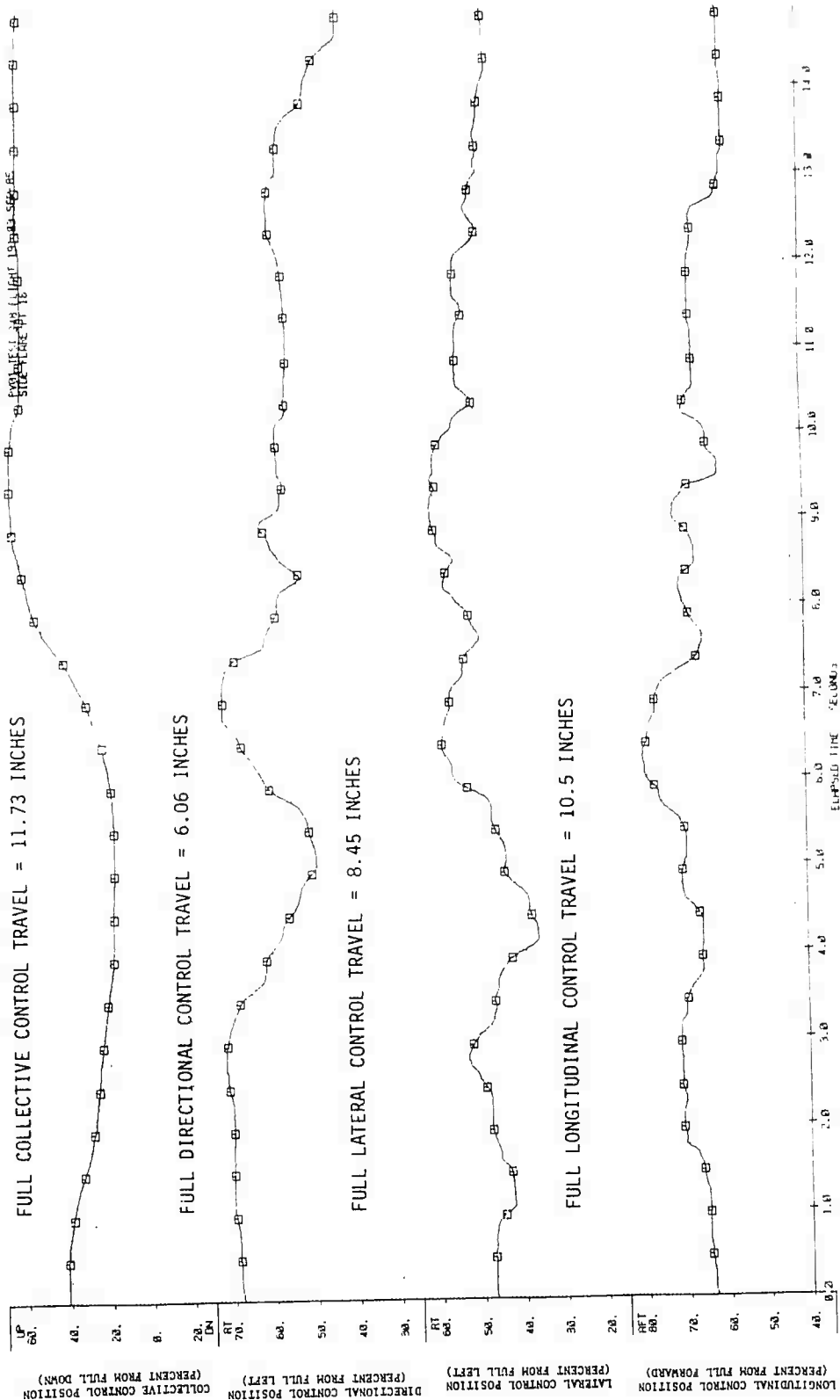


FIGURE 2E
SIDE FLARE
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
14650	205.5(AFT)	1440	20.5

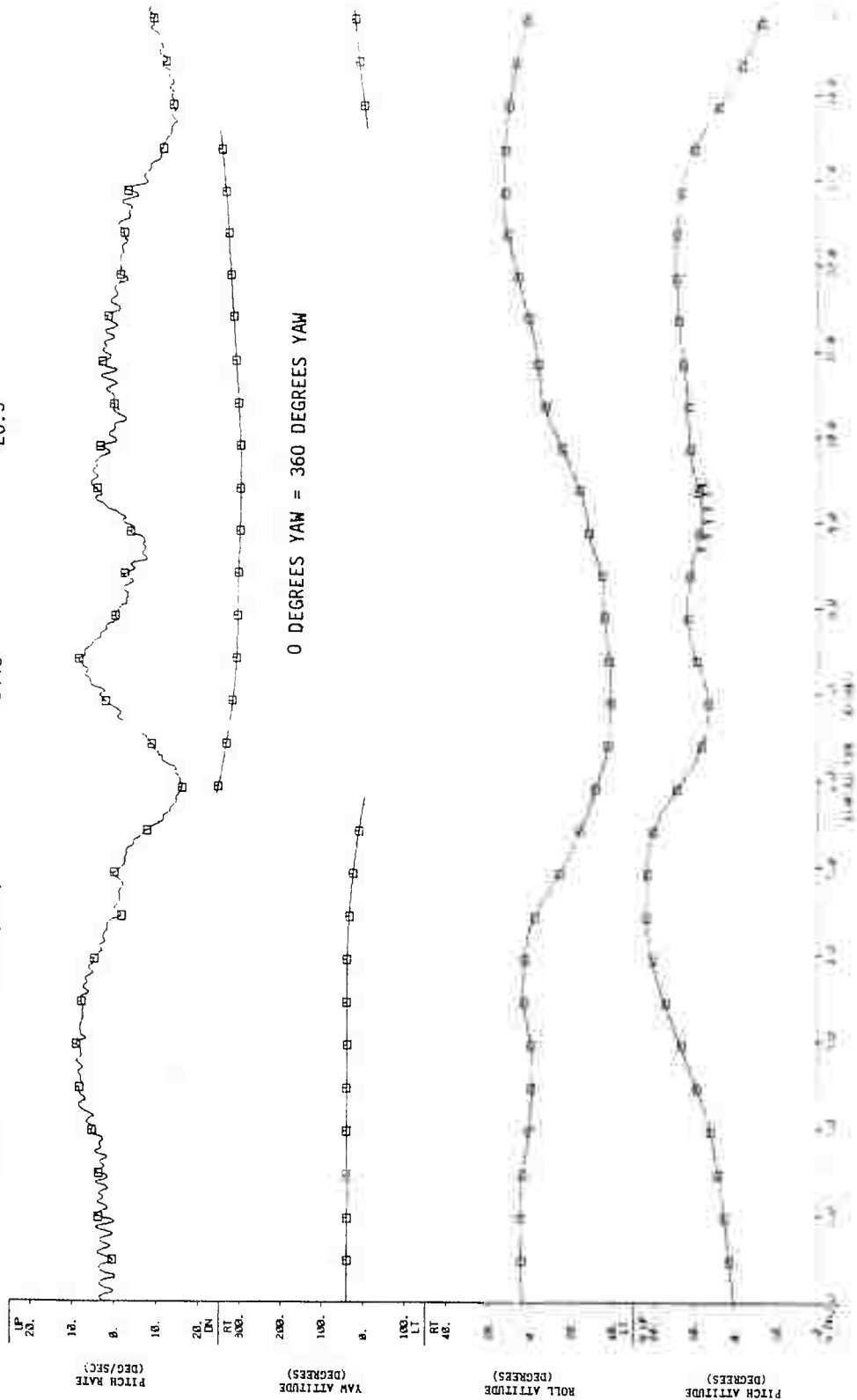


FIGURE 2F
SIDE FLARE
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
14650	205.5(AFT)	1440	20.5

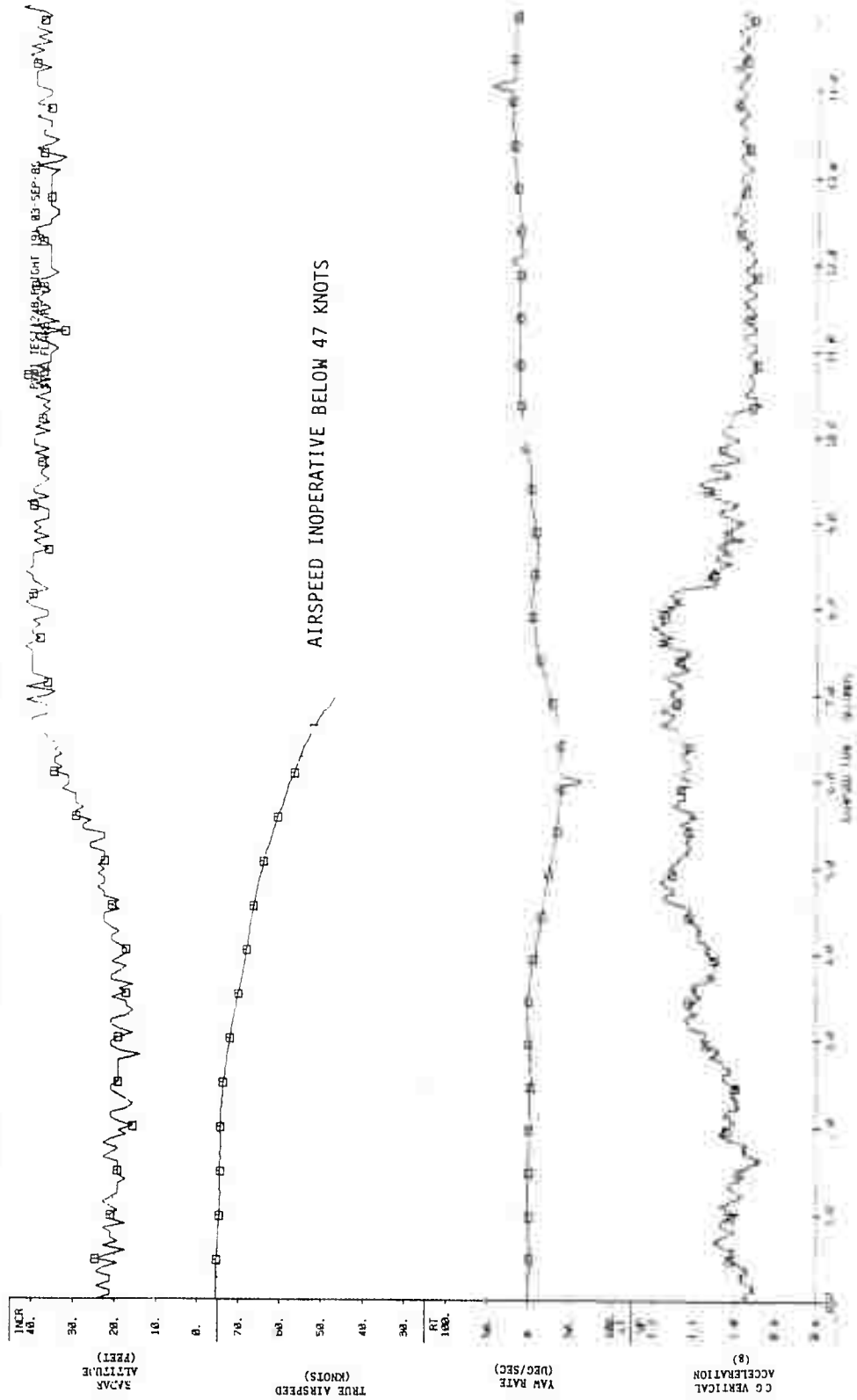


FIGURE 3A
QUICK STOP
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
14690	205.4 (AFT)	1440	20.5

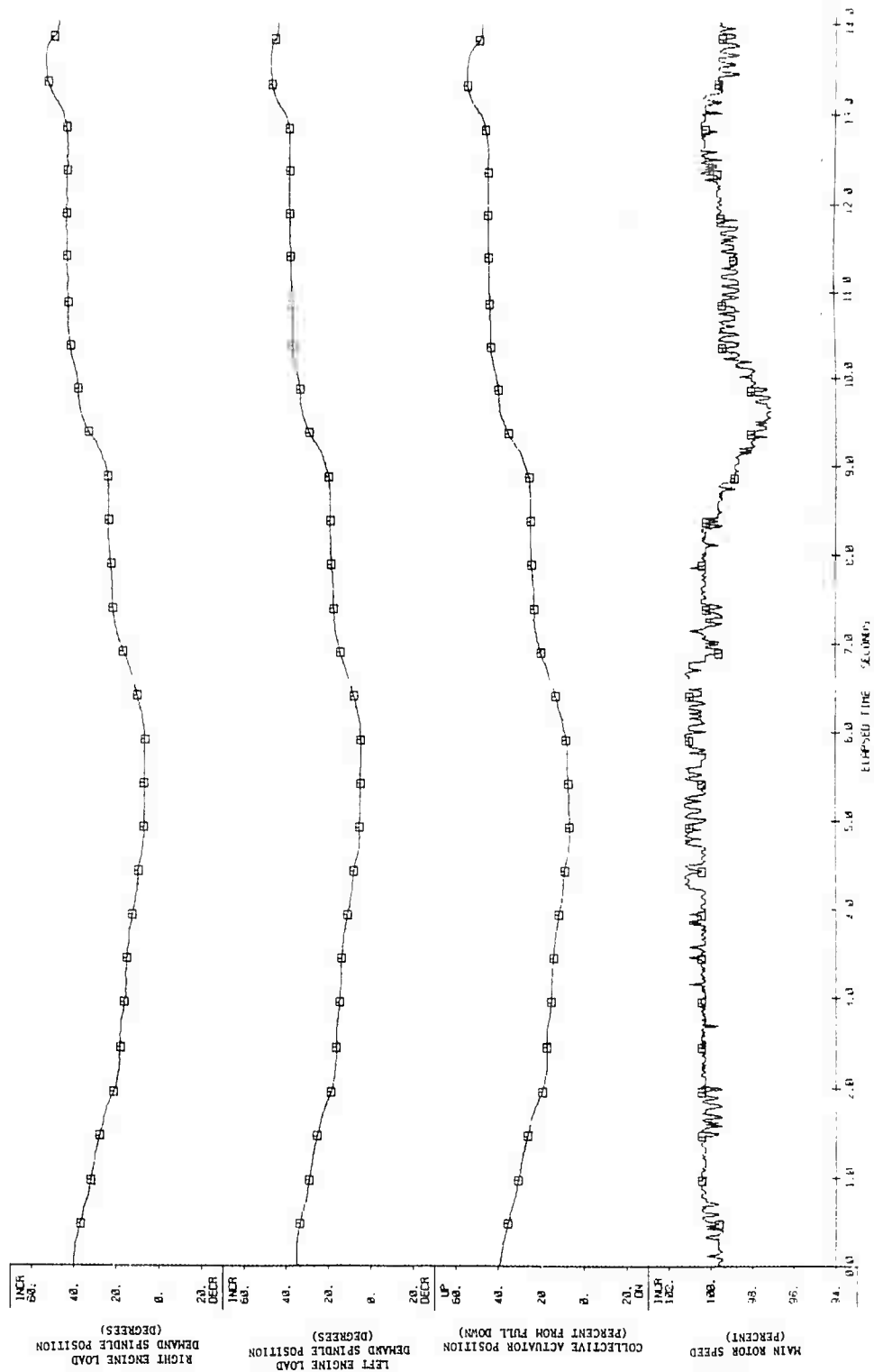


FIGURE 3B
QUICK STOP
USA S/N 82-23355

GROSS WEIGHT (LB) 14690 LONGITUDINAL CG (FS) 205.4 (AFT)	DENSITY ALTITUDE (FT) 1440 OAT (DEG C) 20.5
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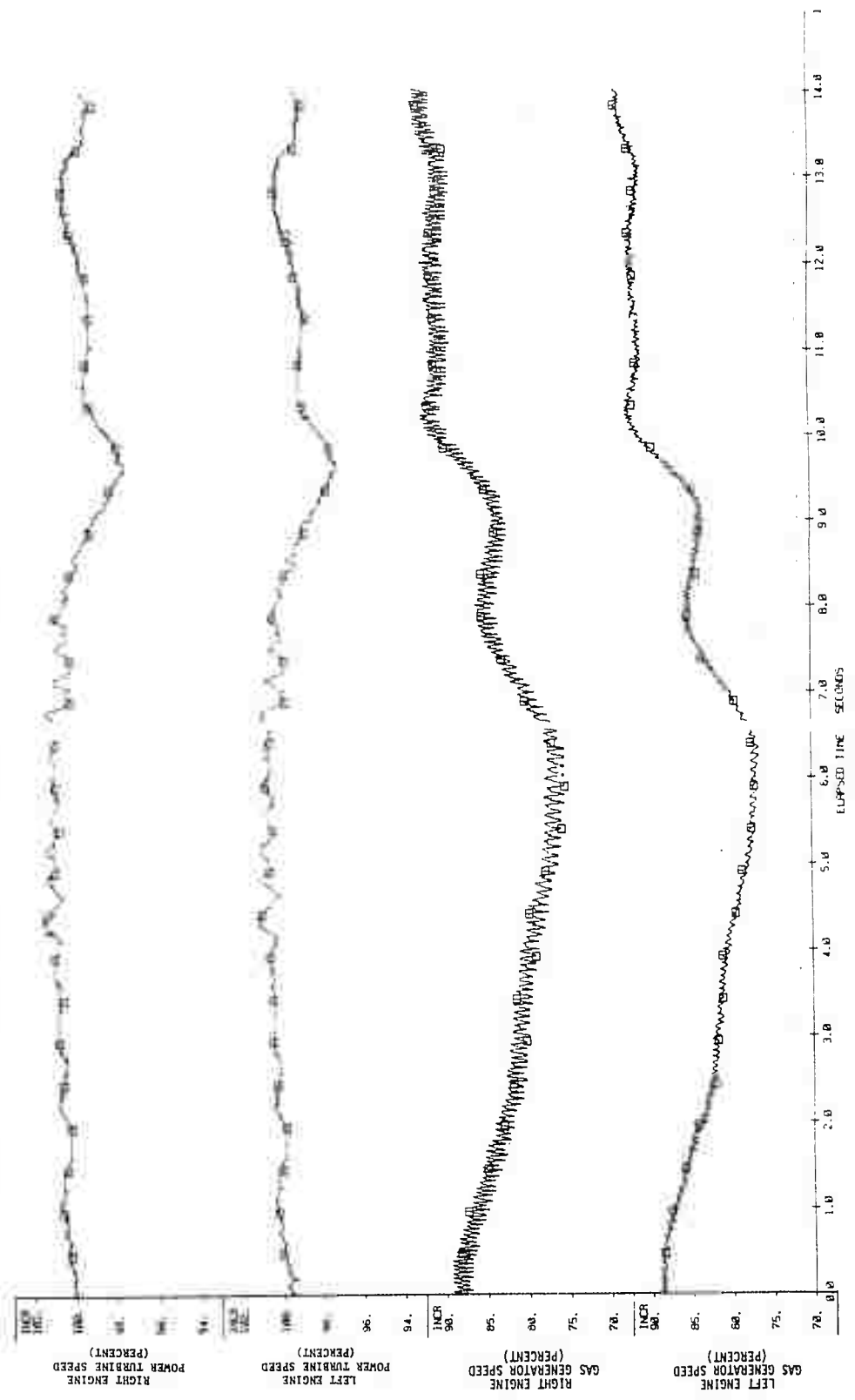


FIGURE 3C
QUICK STOP
AH-64A USA S/N 82-23355

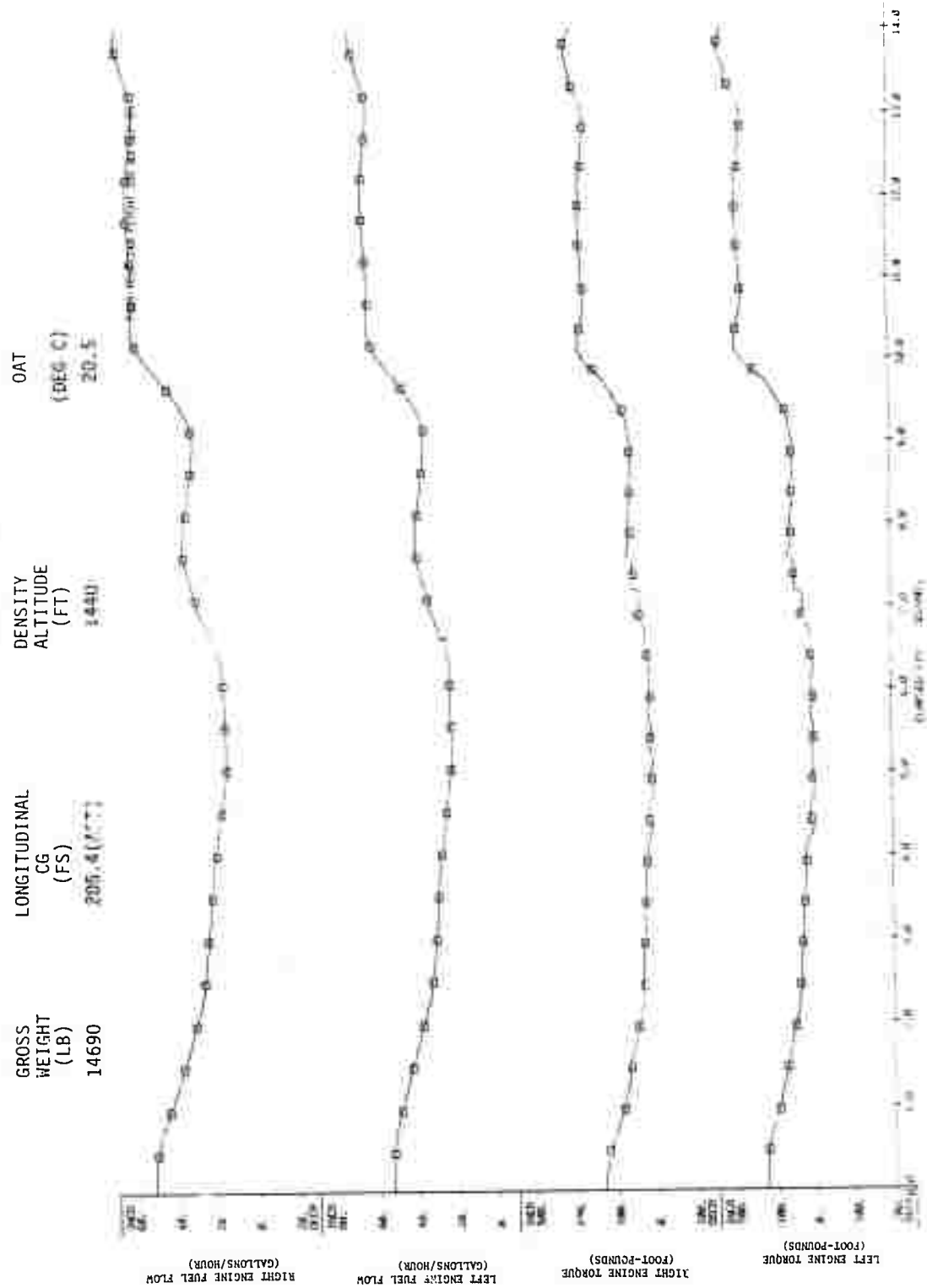


FIGURE 3D
QUICK STOP
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
14690	205.4(AFT)	1440	20.5

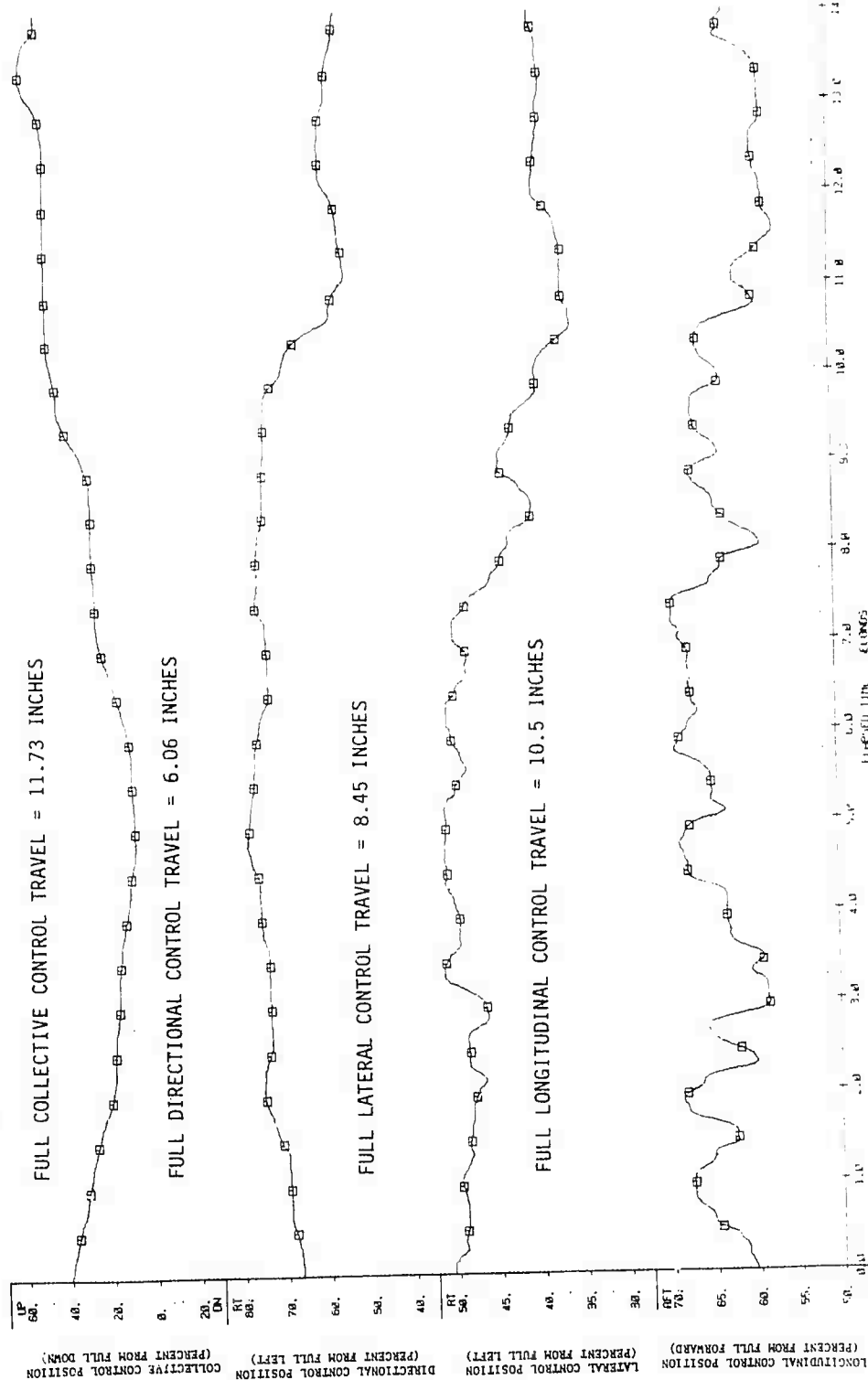


FIGURE 3E
QUICK STOP
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
14690	205.4 (AFT)	1440	20.5

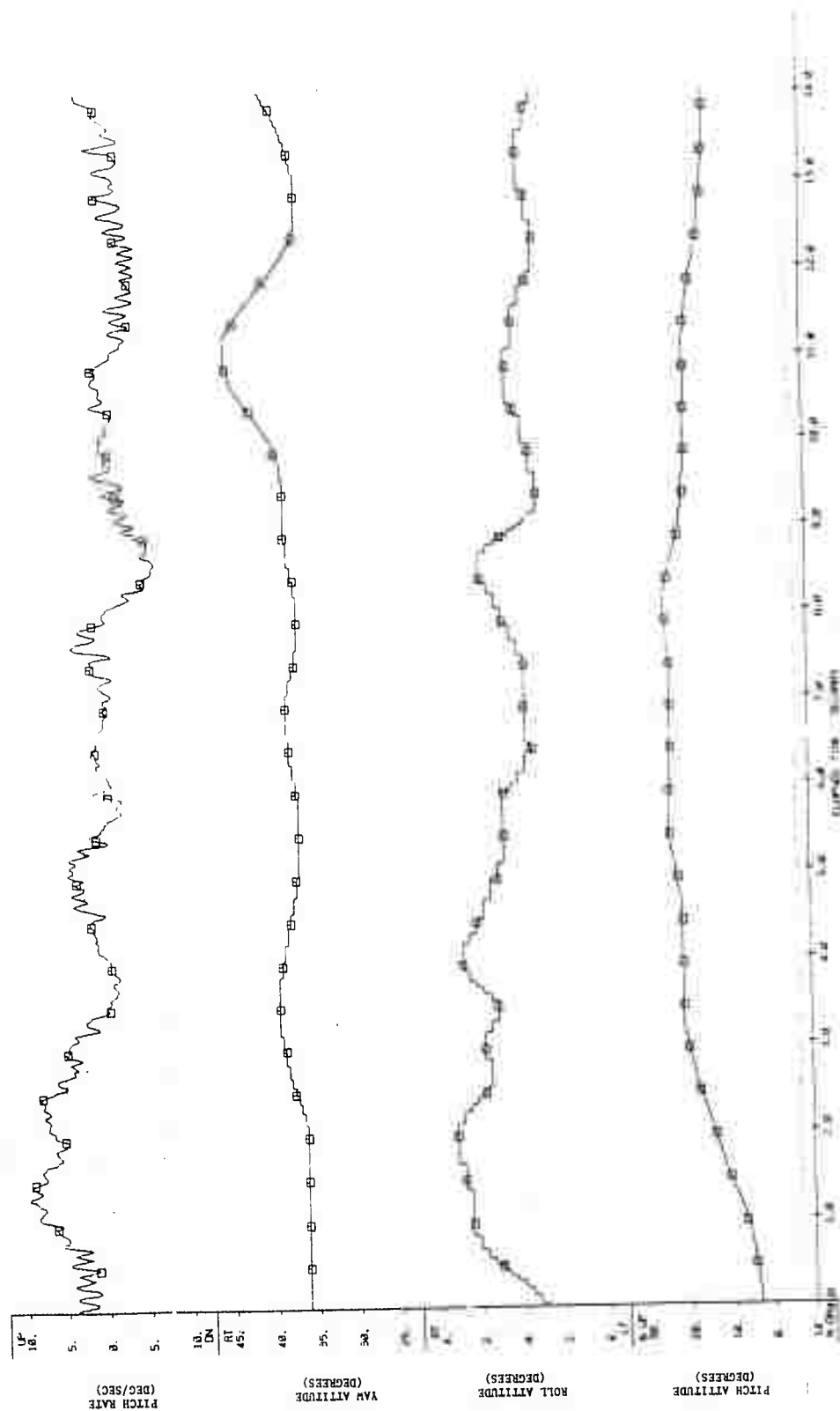


FIGURE 3F
QUICK STOP
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	14690	LONGITUDINAL CG (FS)	205.4(AFT)	DENSITY ALTITUDE (FT)	1440	OAT (DEG C)	20.5
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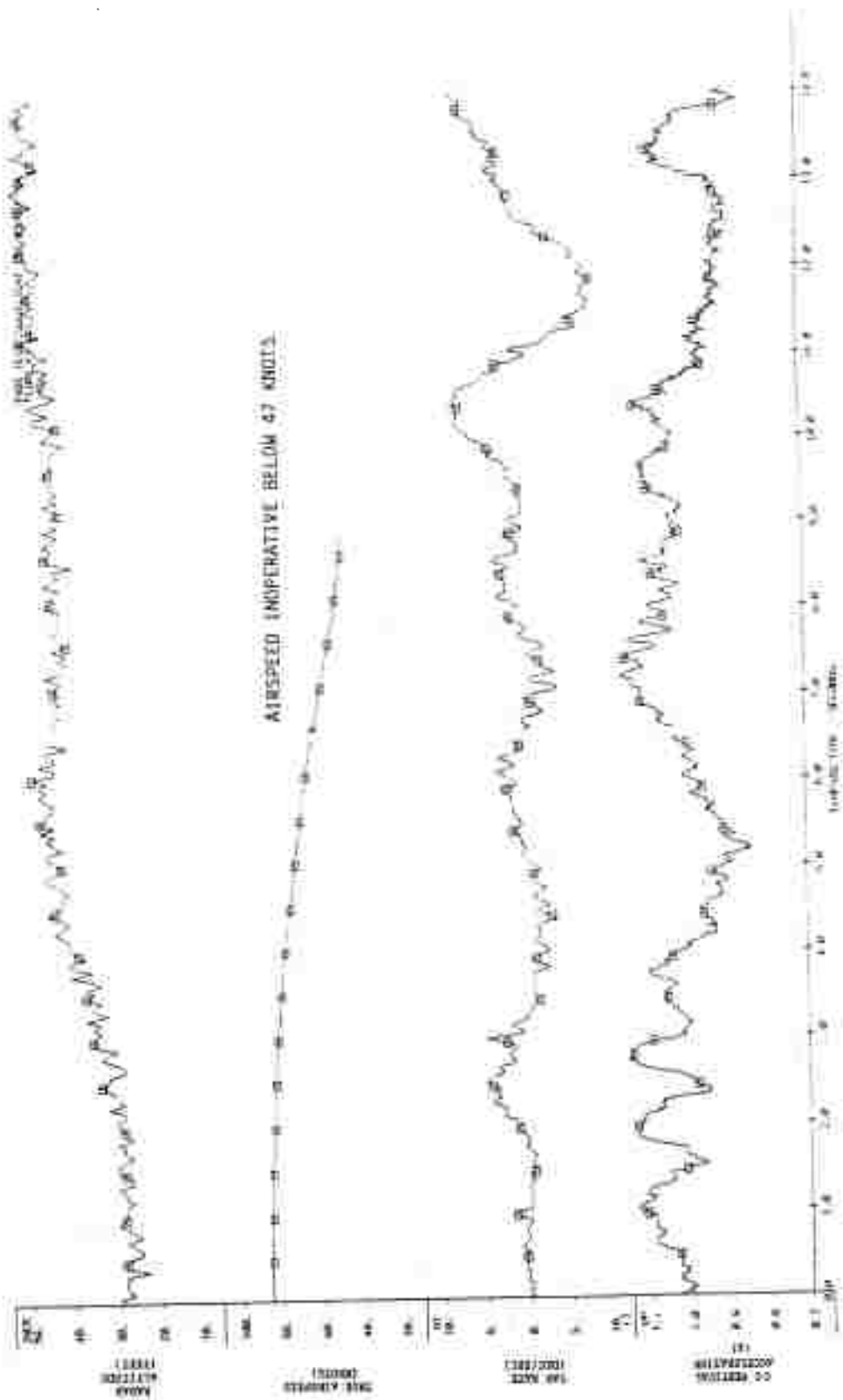


FIGURE 4A
RECOVERY FROM AUTOROTATION
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
15180	205.3(AFT)	3800	16.0

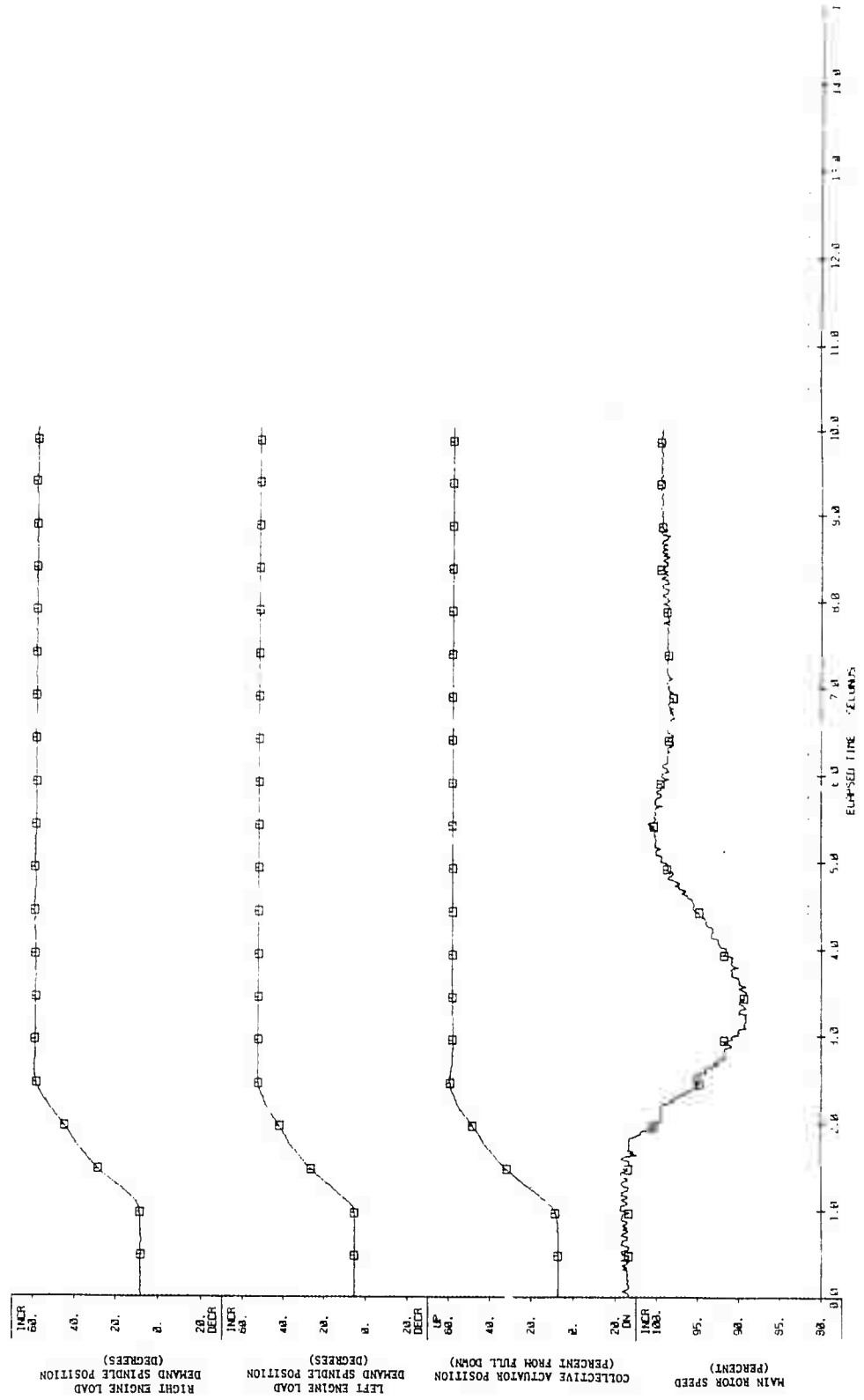


FIGURE 4B
RECOVERY FROM AUTOROTATION
AH-64A USA S/N 82-23355

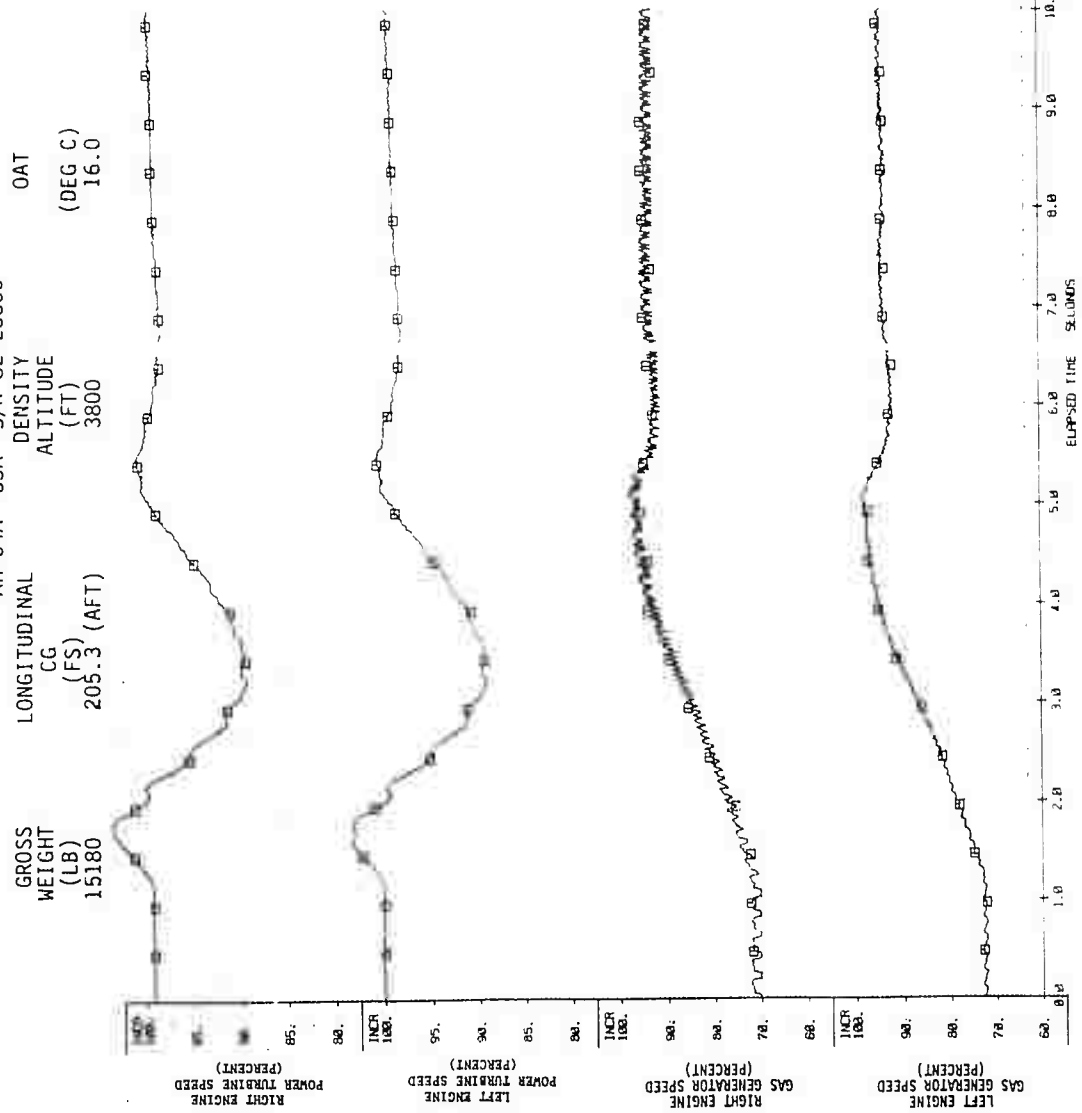


FIGURE 4C
RECOVERY FROM AUTOROTATION
AH-64A USA S/N 82-23355

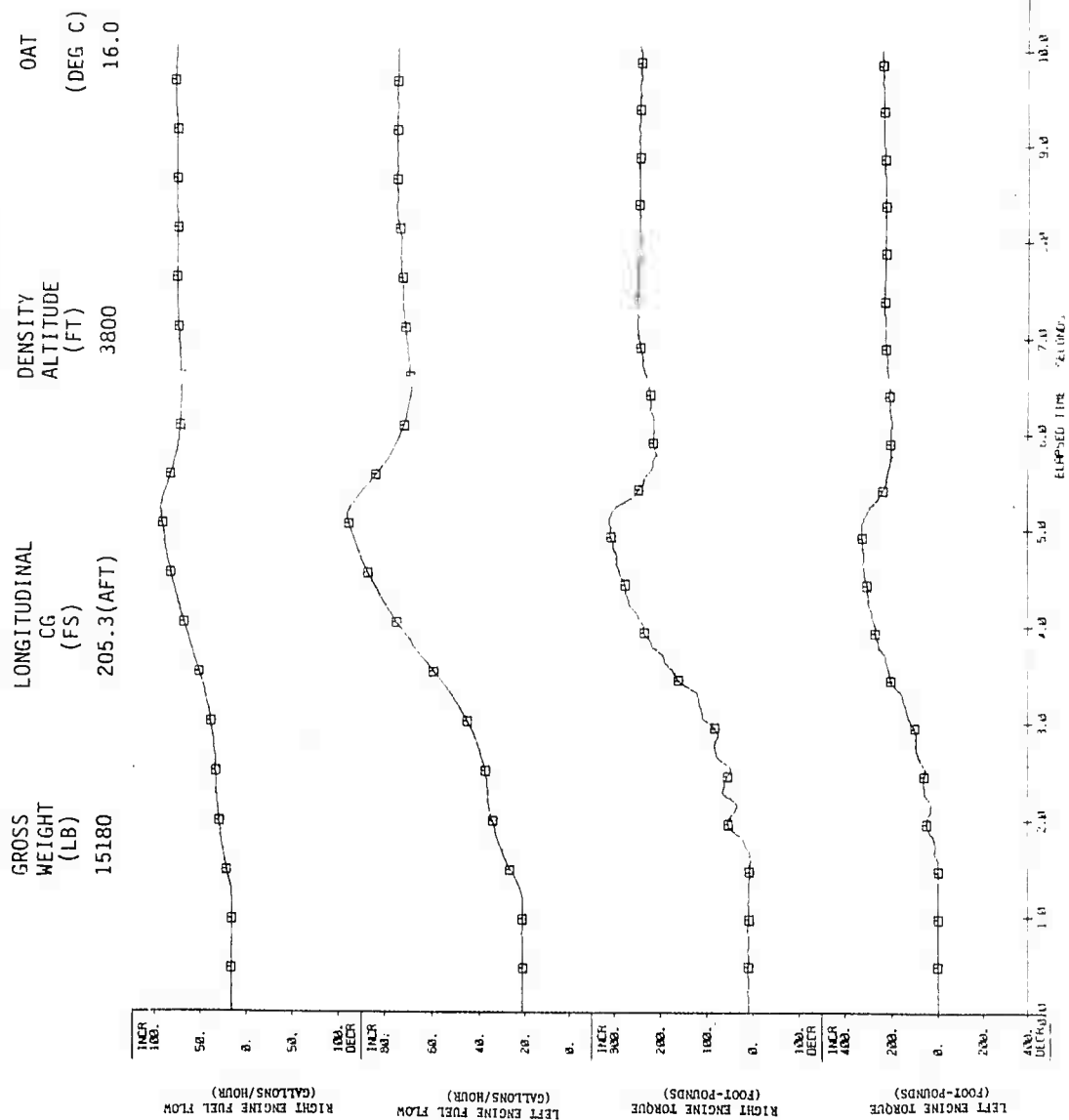


FIGURE 4D
RECOVERY FROM AUTOROTATION
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15180	LONGITUDINAL CG (FS)	205.3(AFT)	DENSITY ALTITUDE (FT)	3800	OAT (DEG C)	16.0
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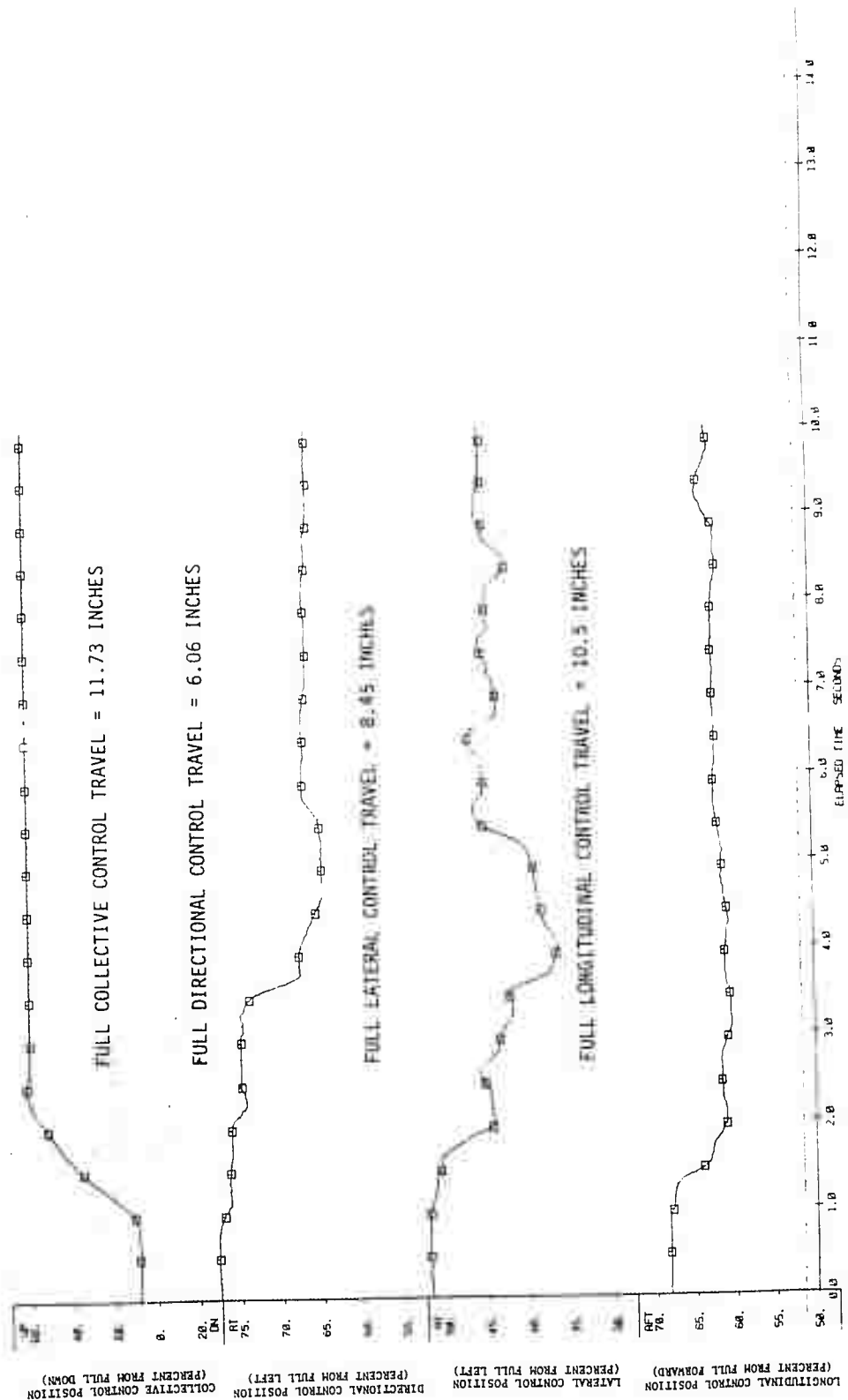


FIGURE 4E
RECOVERY FROM AUTOROTATION
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
15180	205.3(AFT)	3800	16.0

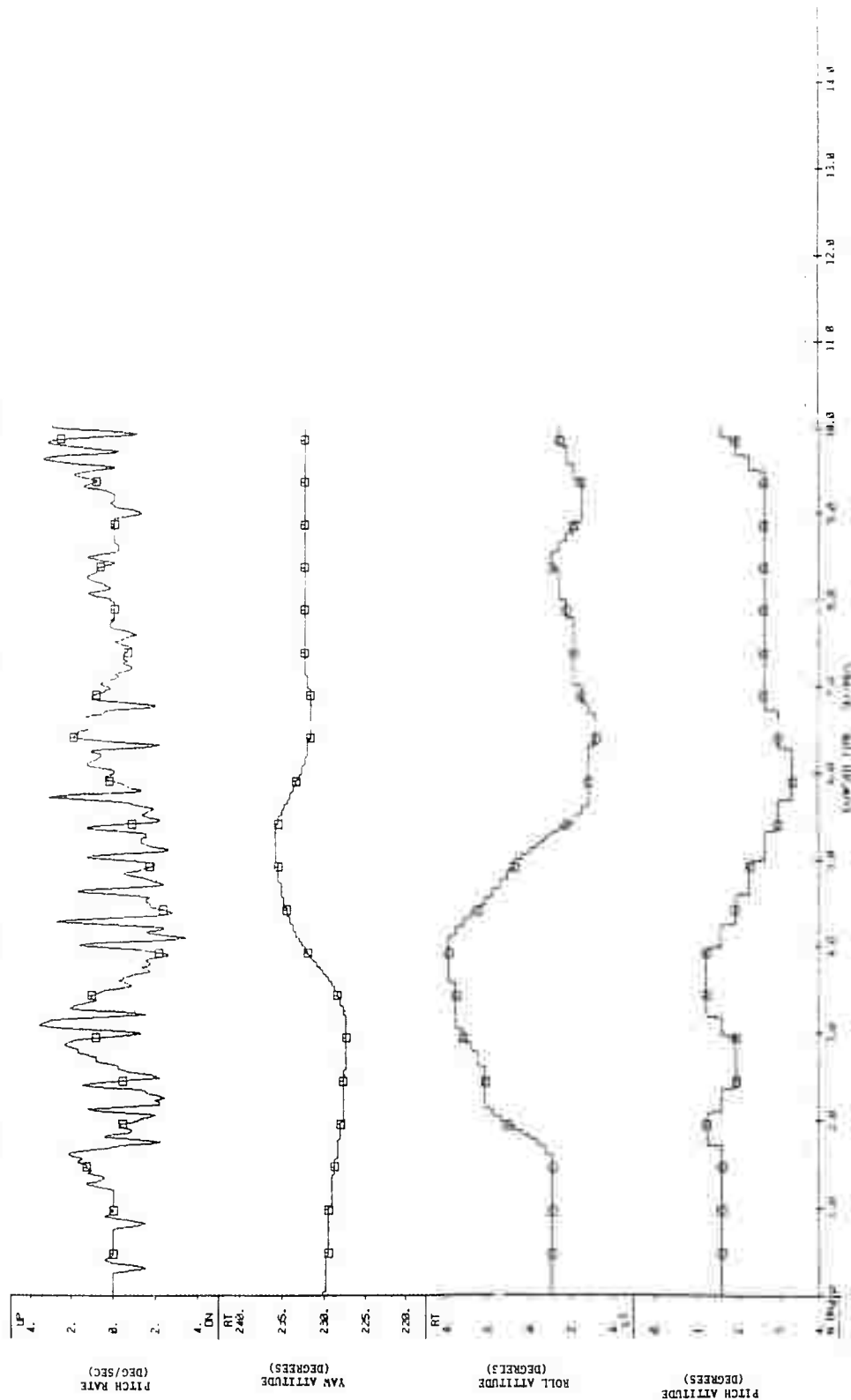


FIGURE 4F
RECOVERY FROM AUTOROTATION
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15180	LONGITUDINAL CG (FS)	205.3(AFT)	DENSITY ALTITUDE (FT)	3800	OAT (DEG C)	16.0
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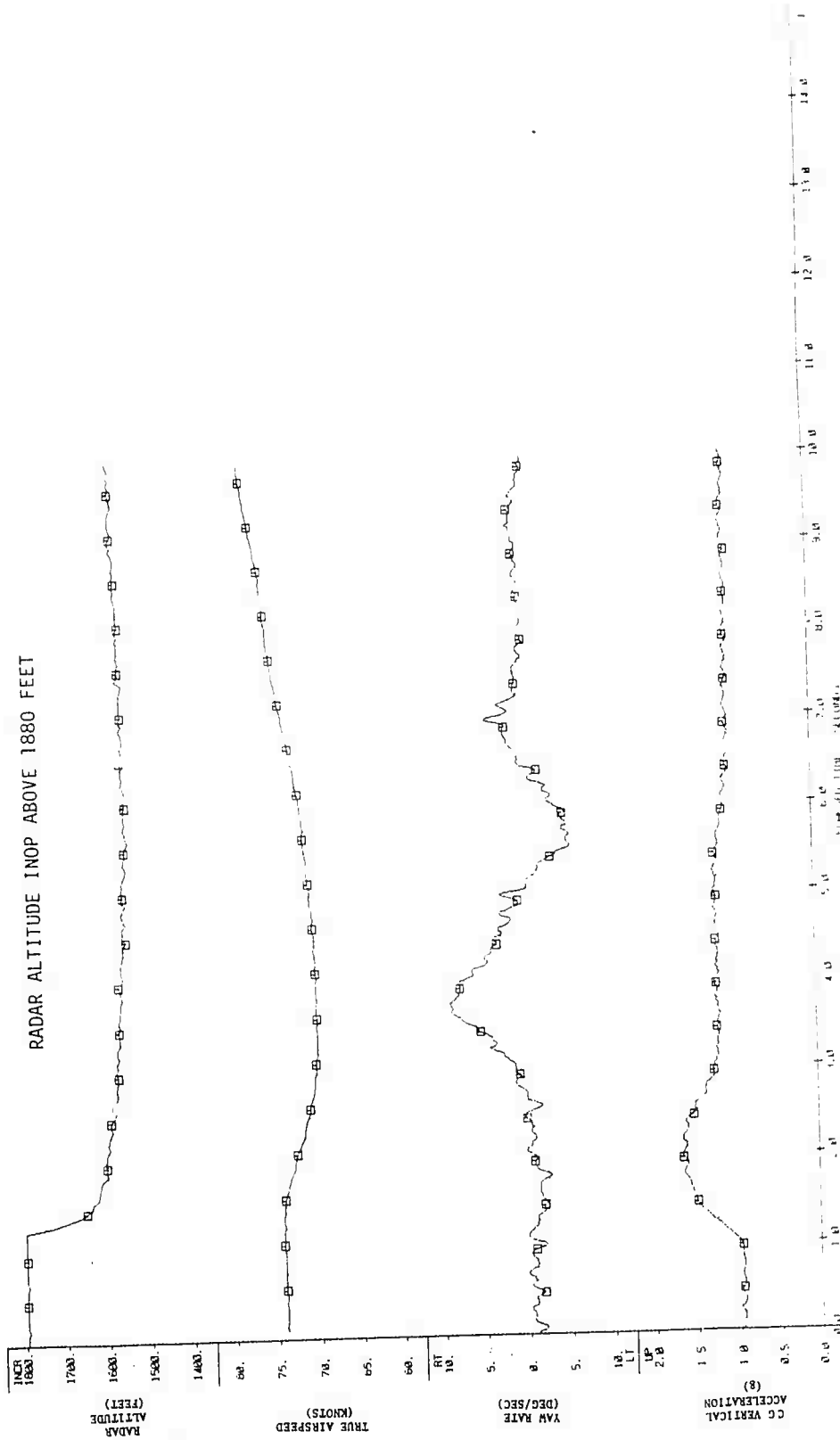


FIGURE 5A
RECOVERY FROM AUTOROTATION
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB) 15340
LONGITUDINAL CG (FS) 105.2 (AFT)
DENSITY ALTITUDE (FT) 5370
OAT (DEG C) 17.5

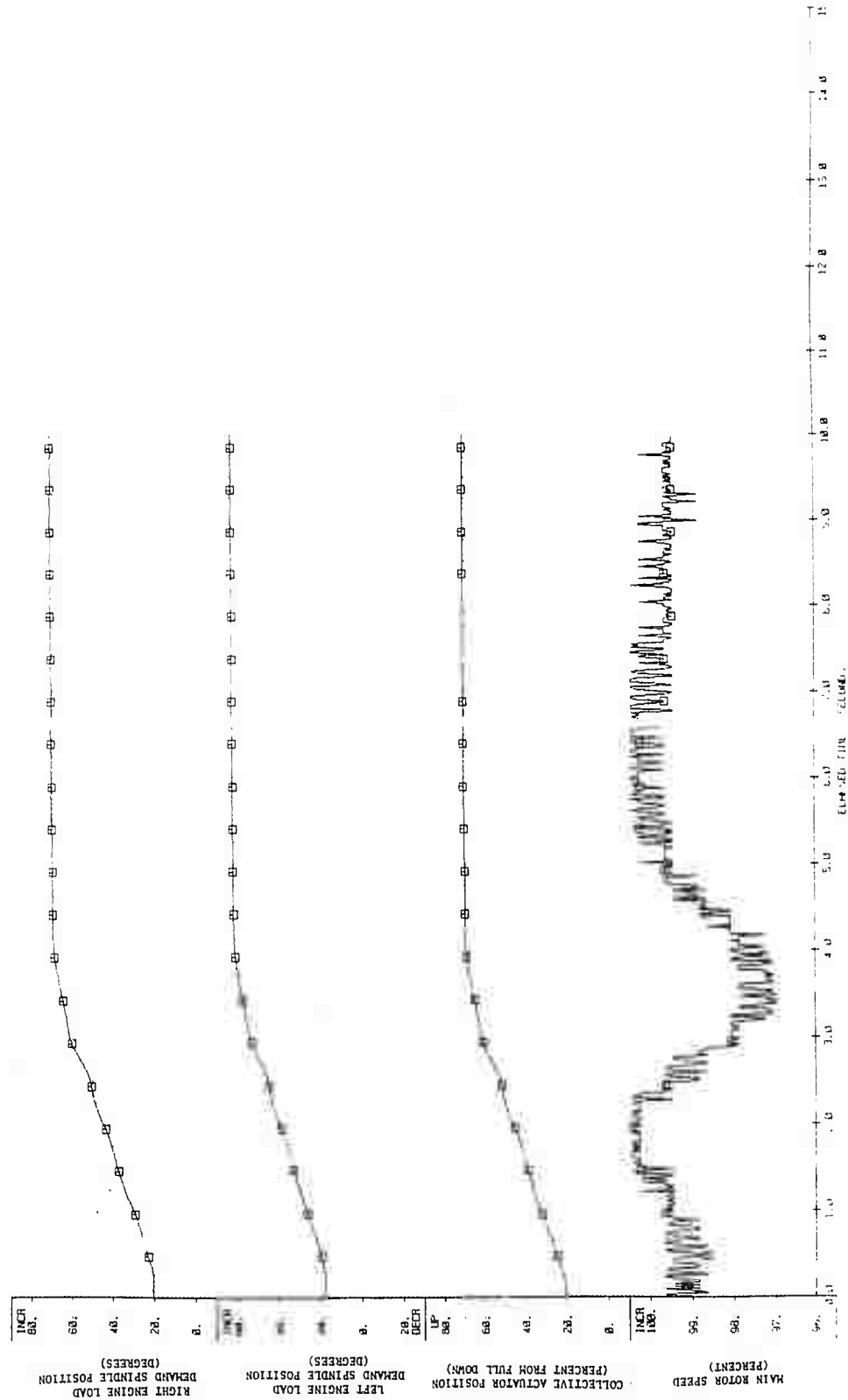


FIGURE 56
RECOVERY FROM AUTOROTATION
AH-64A USA S/N 82-23355

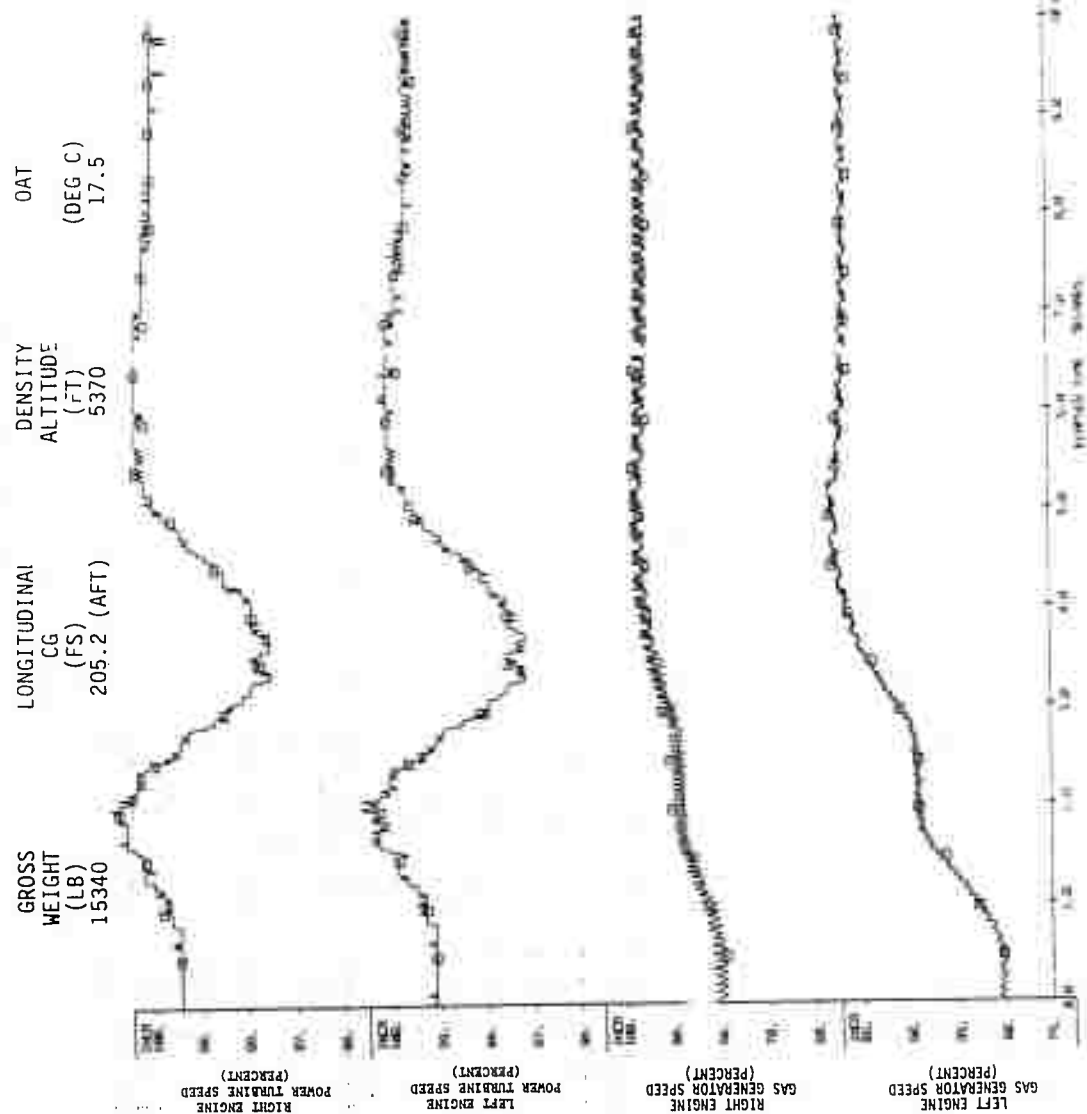


FIGURE 5C
 RECOVERY FROM AUTOROTATION
 AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15340	LONGITUDINAL CG (FS)	205.2(AFT)	DENSITY ALTITUDE (FT)	5370	OAT (DEG C)	17.5
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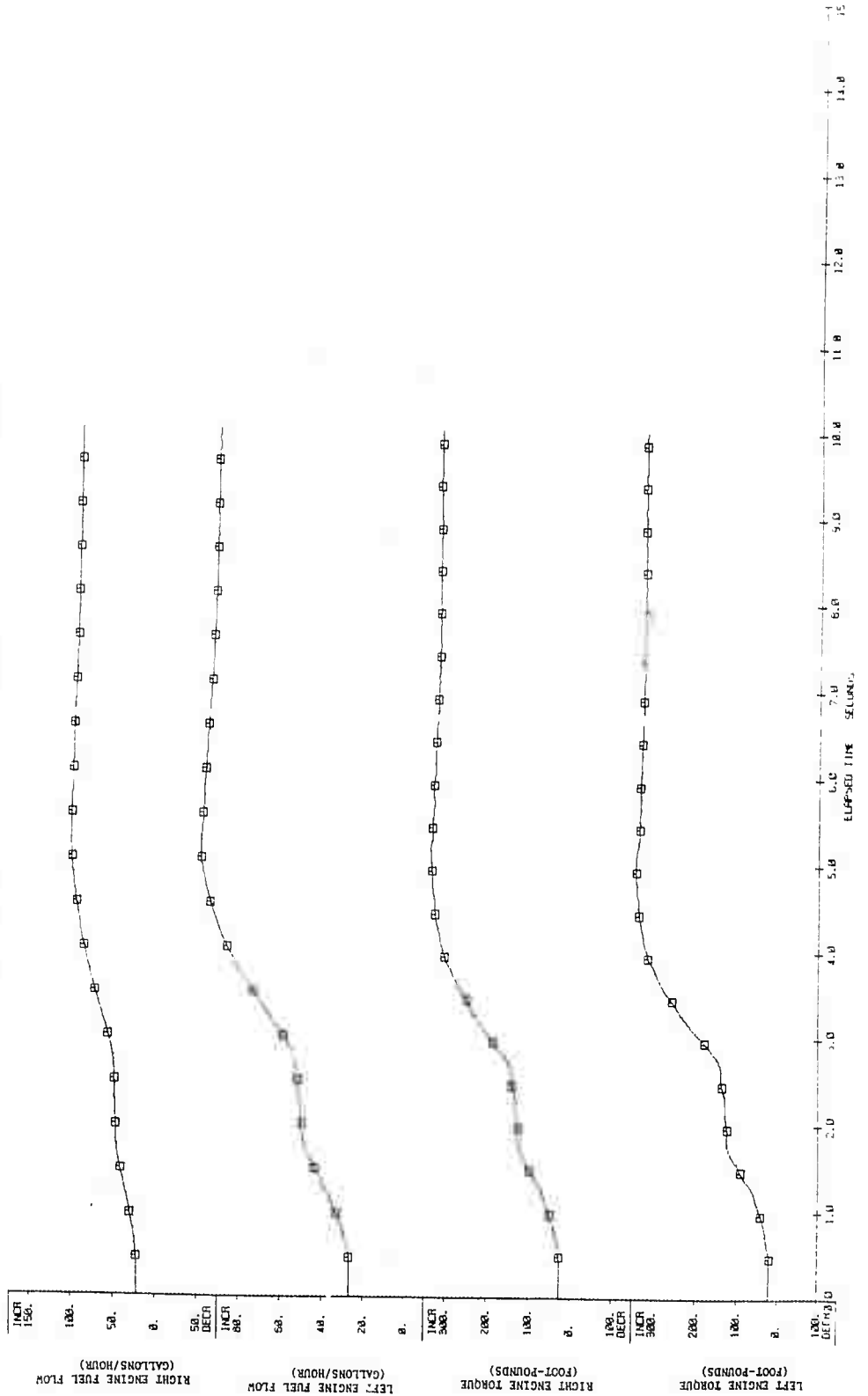


FIGURE 5D
RECOVERY FROM AUTOROTATION
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15340	LONGITUDINAL CG (FS)	205.2(AFT)	DENSITY ALTITUDE (FT)	5370	OAI (DEG C)	17.5
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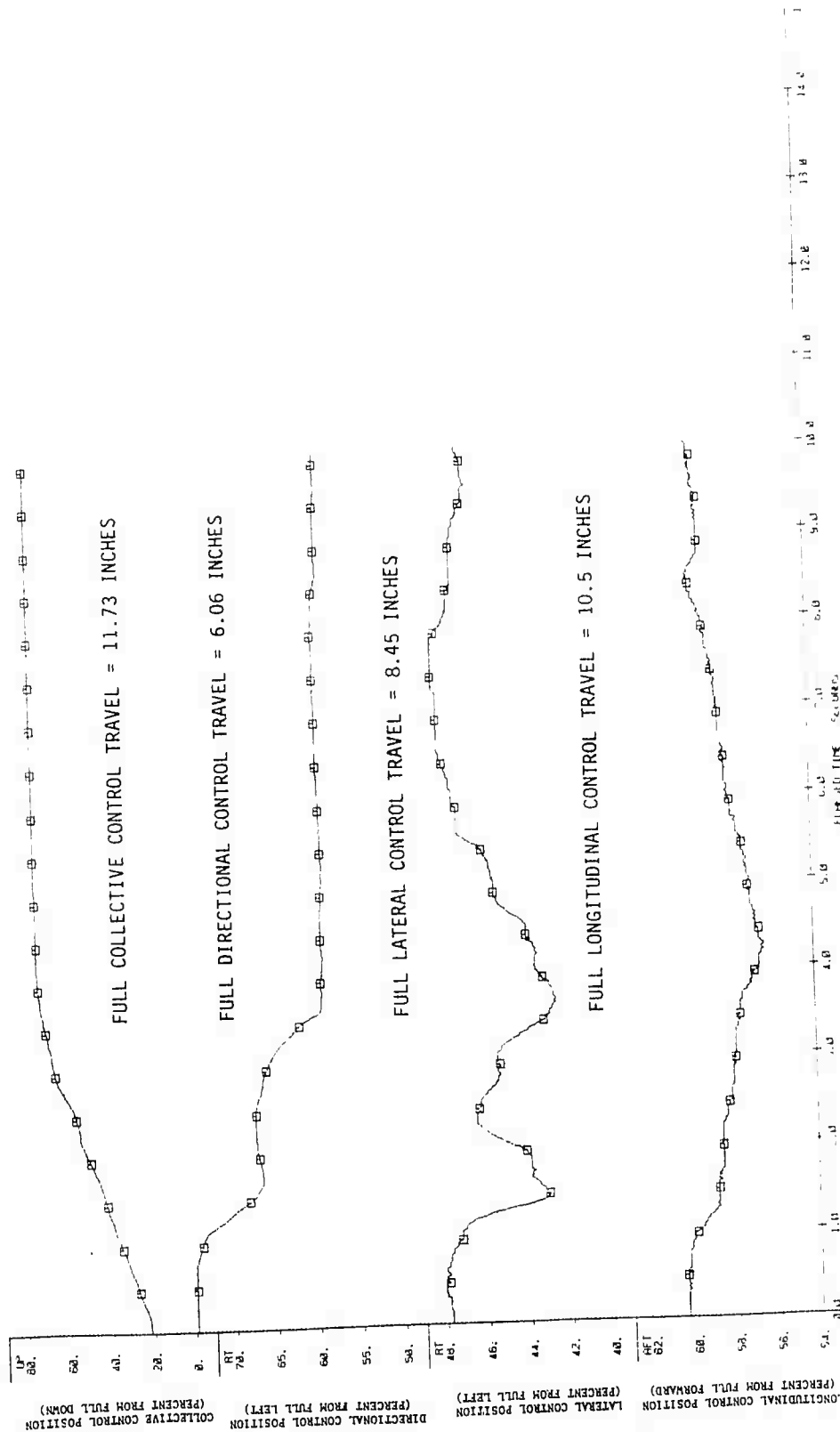


FIGURE 5E
RECOVERY FROM AUTOROTATION
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15340	LONGITUDINAL CG (FS)	205.2 (AFT)	DENSITY ALTITUDE (FT)	5370	OAT (DEG C)	17.5
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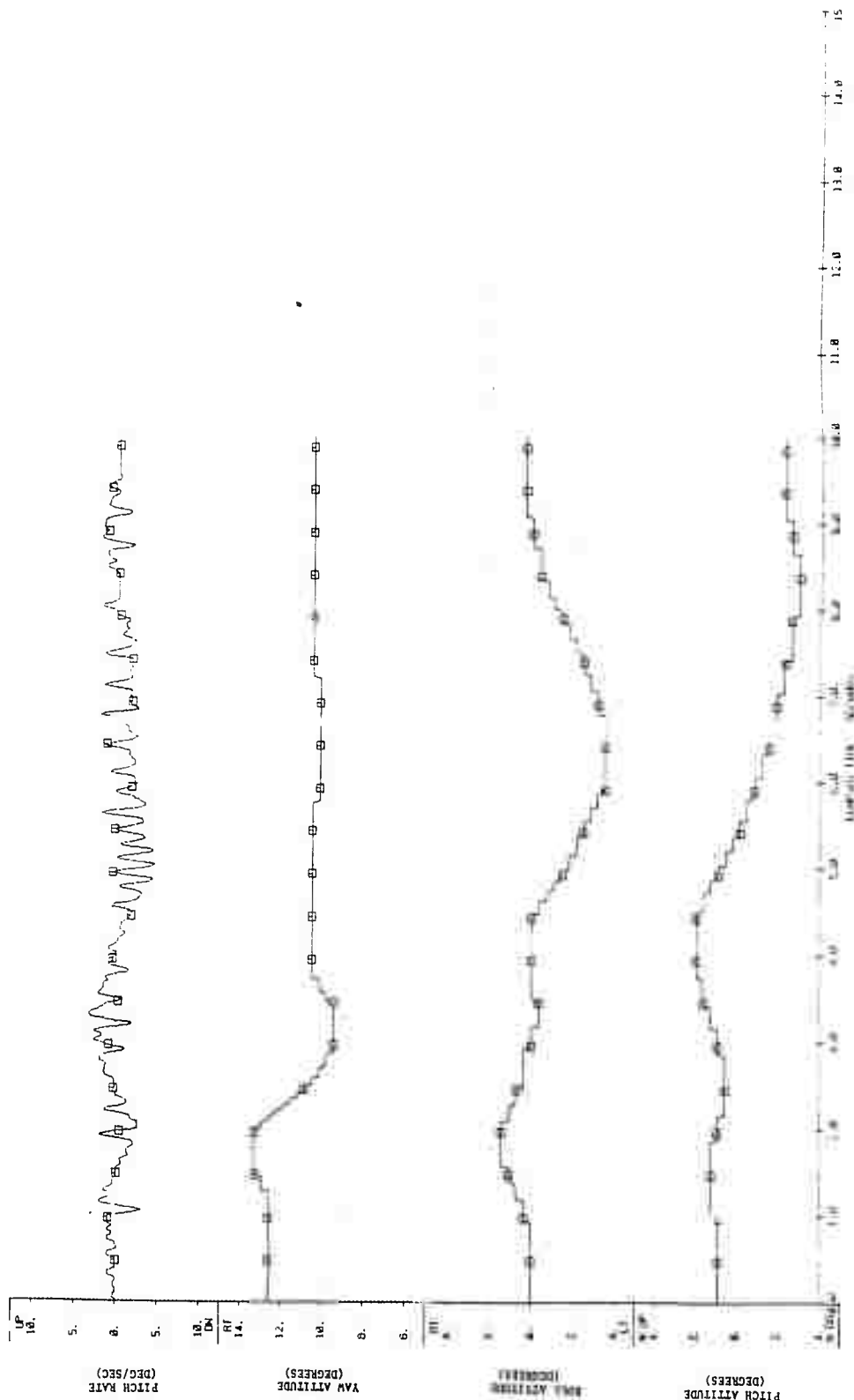


FIGURE 5F
RECOVERY FROM AUTOROTATION
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
15,400	205.2(AFT)	5370	17.5

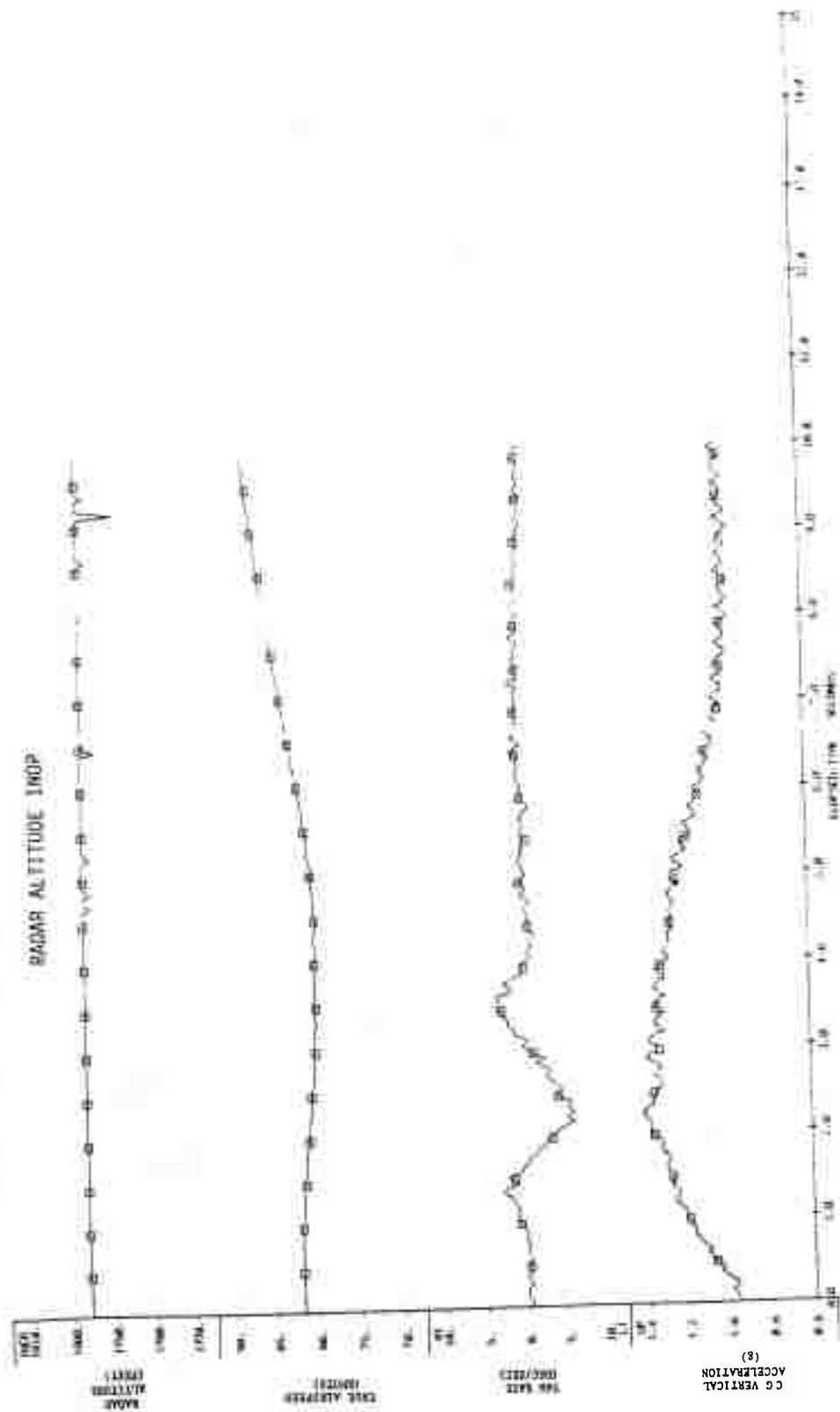


FIGURE 6A
RIDGELINE MANEUVER
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB) 15090
LONGITUDINAL CG (FS) 205.3(AFT)
DENSITY ALTITUDE (FT) 6730
OAT (DEG C) 20.0

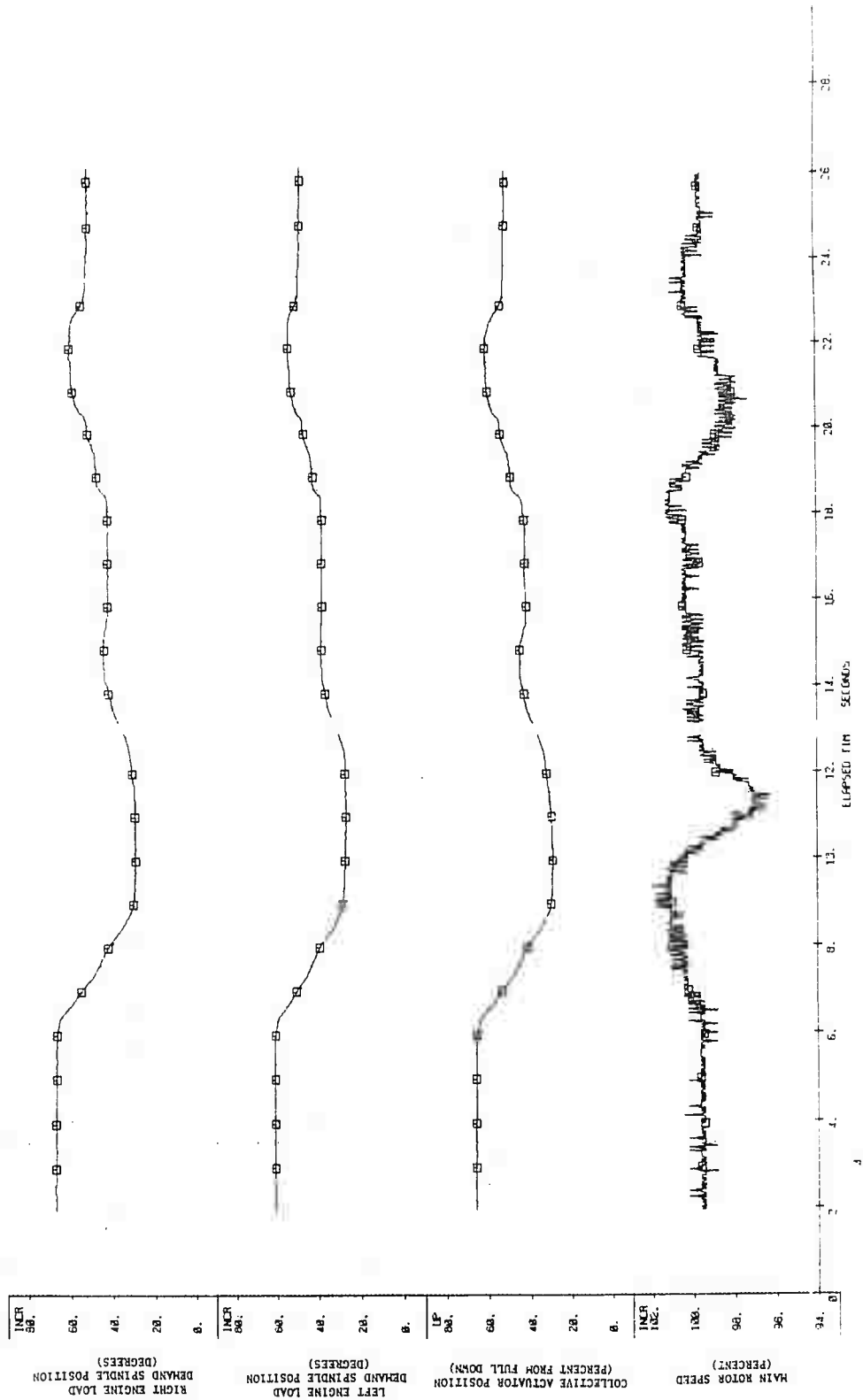


FIGURE 6B
RIDGE LINE MANEUVER
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB) 15090
LONGITUDINAL CG 205.3 (ATT)
DENSITY ALTITUDE (FT) 6730
OAT (DEG C) 20.0

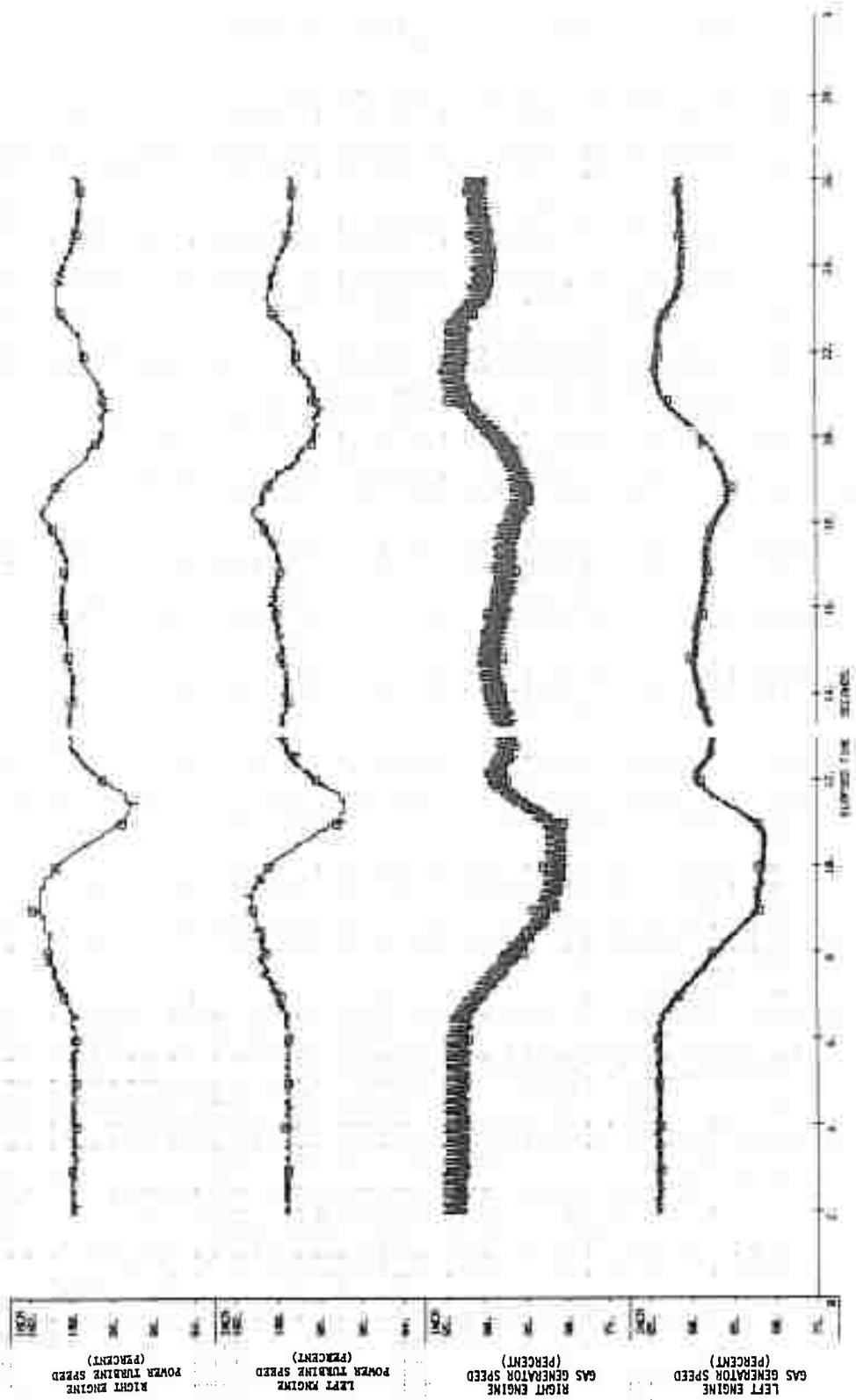


FIGURE 6C
RIDGELINE MANEUVER
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15090	LONGITUDINAL CG (FS)	205.3 (AFT)	DENSITY ALTITUDE (FT)	6730	OAT (DEG C)	20.0
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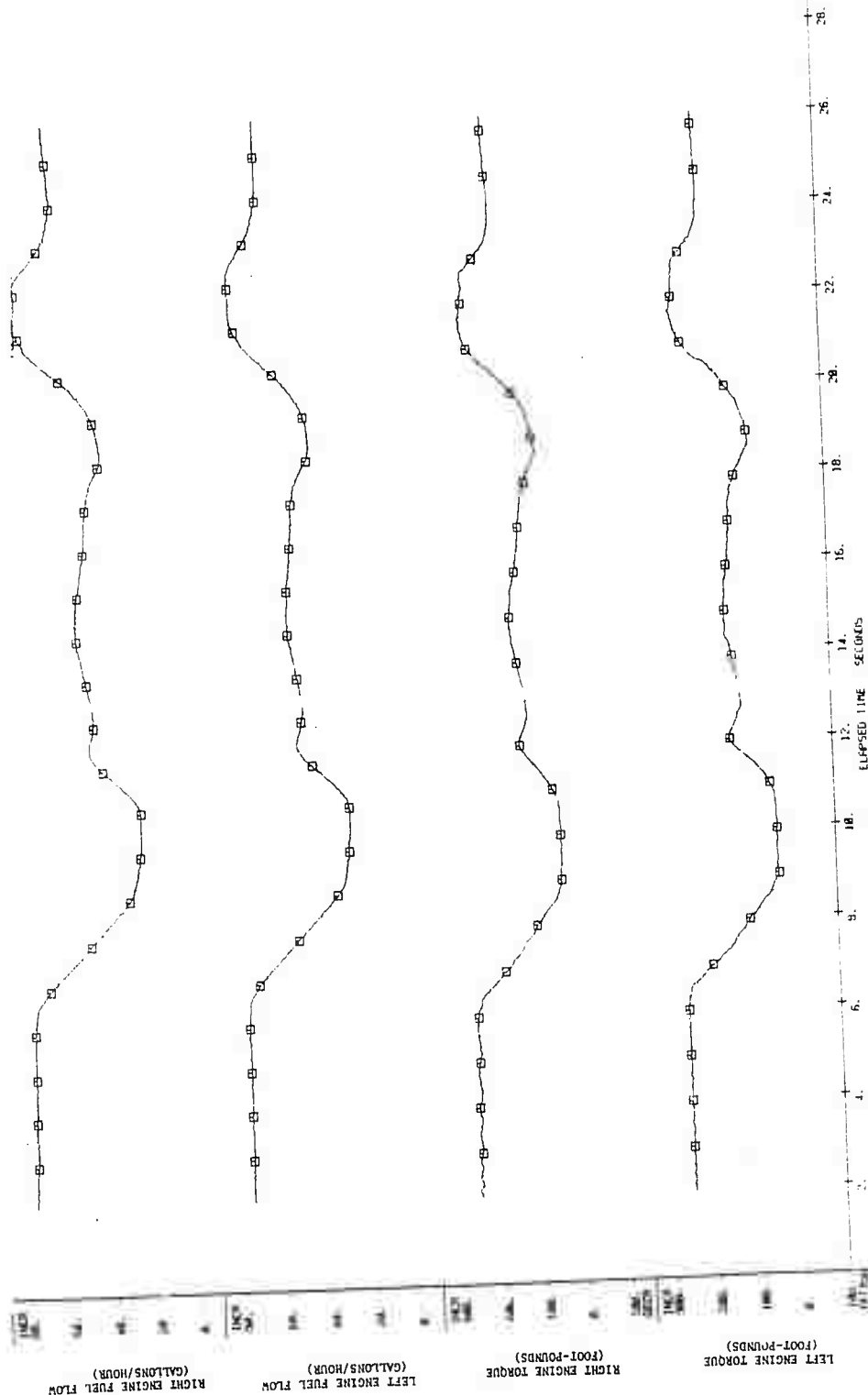


FIGURE 6D
RIDGELINE MANEUVER
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15090	LONGITUDINAL CG (FS)	205.3(AFT)	DENSITY ALTITUDE (FT)	6730	OAT (DEG C)	20.0
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FULL COLLECTIVE CONTROL TRAVEL = 11.73 INCHES



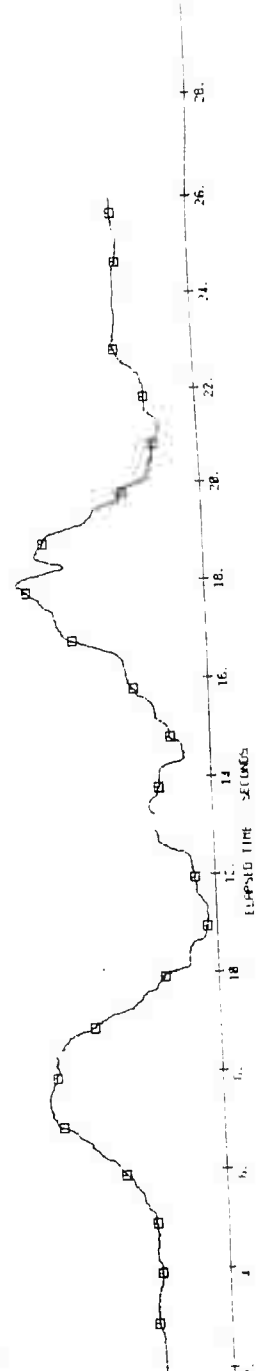
FULL DIRECTIONAL CONTROL TRAVEL = 6.06 INCHES



FULL LATERAL CONTROL TRAVEL = 8.45 INCHES



FULL LONGITUDINAL CONTROL TRAVEL = 10.5 INCHES



LONGITUDINAL CONTROL POSITION (PERCENT FROM FULL FORWARD)
LATERAL CONTROL POSITION (PERCENT FROM FULL LEFT)
DIRECTIONAL CONTROL POSITION (PERCENT FROM FULL LEFT)
COLLECTIVE CONTROL POSITION (PERCENT FROM FULL DOWN)

FIGURE 6E
RIDGELINE MANEUVER
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
15090	205.3(AFT)	6730	20.0

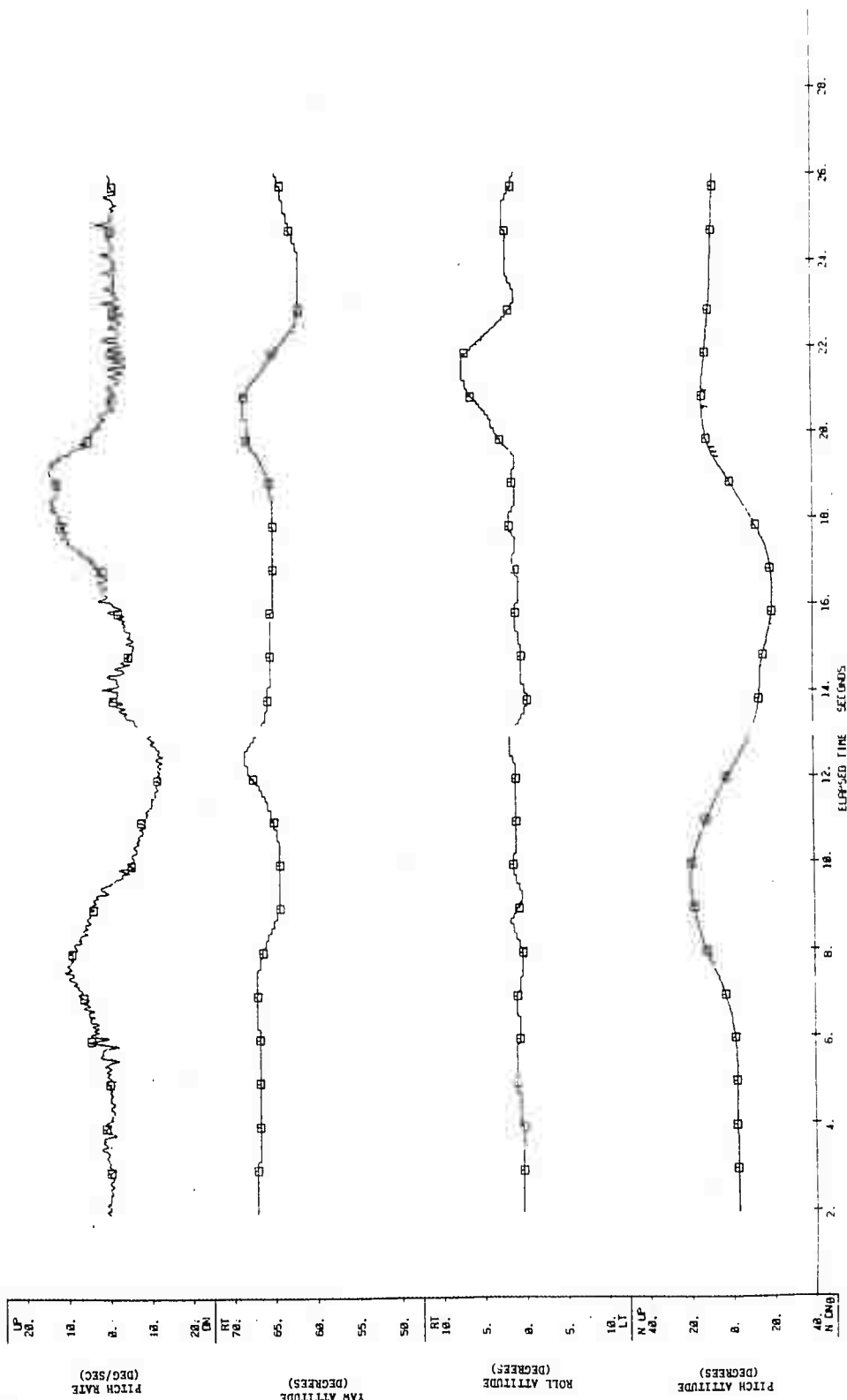
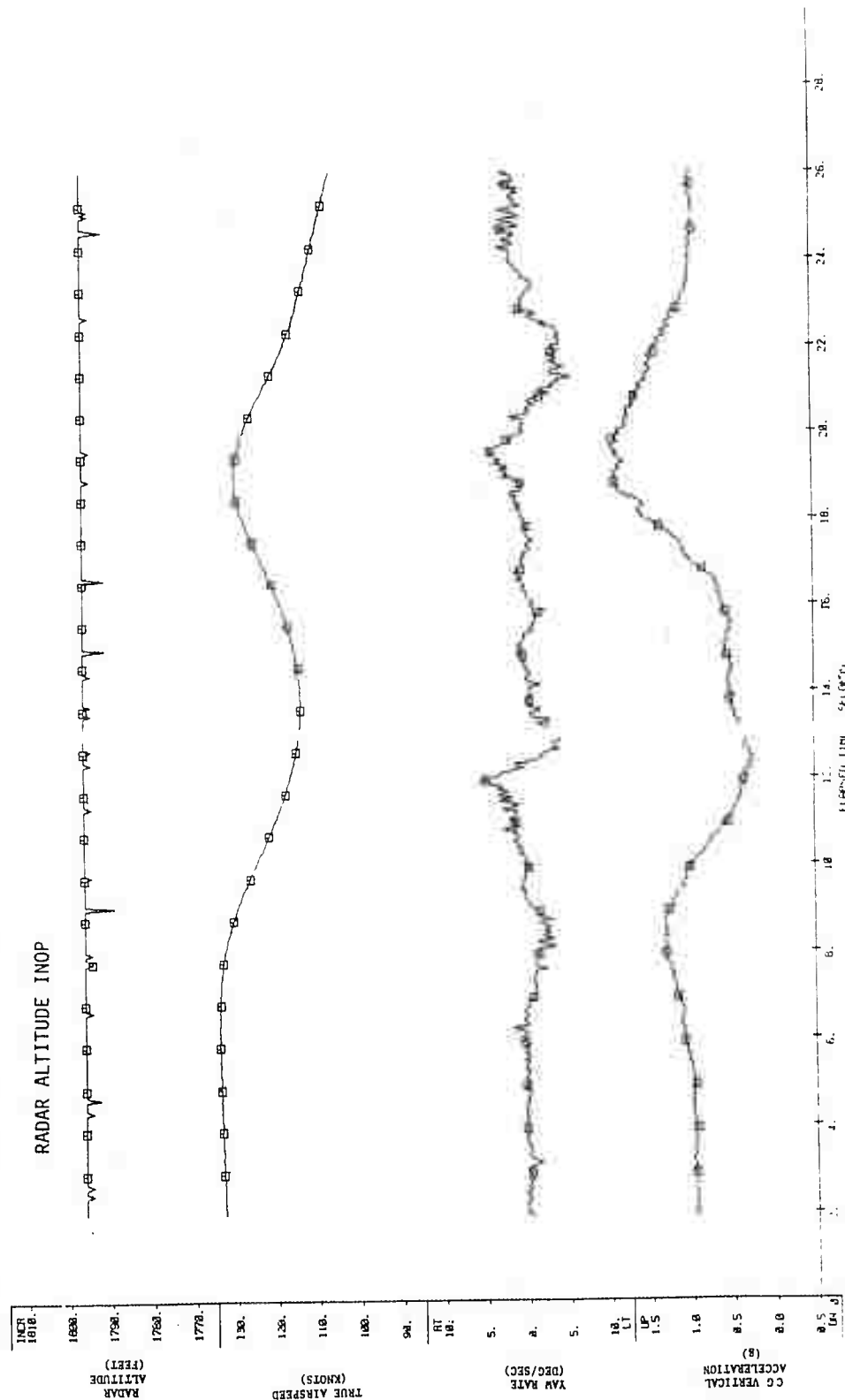


FIGURE 6F
RIDGE LINE MANEUVER
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15090	LONGITUDINAL CG (FS)	205.3 (AFT)	DENSITY ALTITUDE (FT)	6730	OAT (DEG C)	20.0
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