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PRELIMINARY AIRWORTHINESS EVALUATION AH - 1S (MC) HELICOPTER WITH EXTERNAL FUEL TANKS INSTALLED

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FINAL REPORT

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UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
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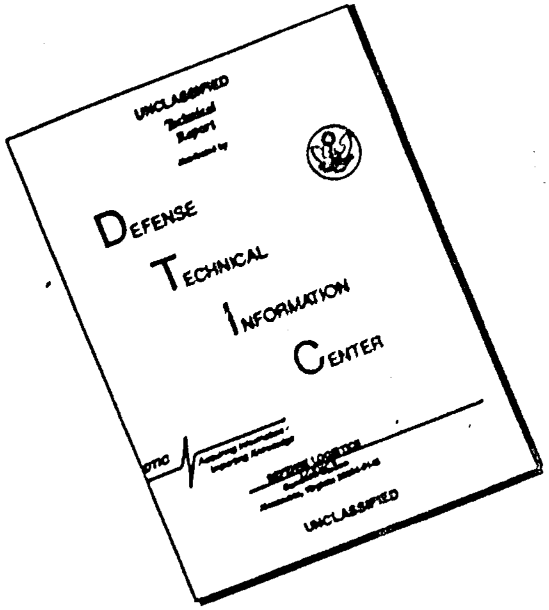

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Preliminary Airworthiness Evaluation of the AH-1S Modernized Cobra, (S/N 69-16423) with the Kellett ferry tanks installed was conducted at Edwards Air Force Base, California (2302 feet) and Bakersfield, California (488 feet). Approximately 19 productive hours were flown during 24 flights between 17 March and 27 April 1984. The Kellett ferry tanks increased the equivalent flat plate area by 2.0 ft^2 sq ft. One deficiency noted during the evaluation was the

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) lack of crashworthiness of the external fuel tanks. Four shortcomings associated with the installation of the external fuel tanks were found.

DEPARTMENT OF THE ARMY
HEADQUARTERS, US ARMY AVIATION SYSTEMS COMMAND
4300 GOODFELLOW BOULEVARD, ST. LOUIS, MO 63120

REPLY TO
ATTENTION OF
AMSAV-ED

SUBJECT: Directorate for Engineering Position of the Final Report of USAAEFA Project No. 84-09, Preliminary Airworthiness Evaluation AH-1S(MC) Helicopter with External Fuel Tanks Installed

SEE DISTRIBUTION

1. The purpose of this letter is to establish the Directorate for Engineering position on the subject report. The ferry tank kit used in this project was prepared in order for an operational unit to conduct a Concept Evaluation (CE). The testing accomplished on the ferry kit was minimal, sufficient to insure a margin of safety commensurate with the CE. Virtually no qualification work was done beyond establishing airworthiness for one mission. The tanks, pumps, and brackets were items provided on loan from the Marine Corps. All plumbing, wiring, gauging and controls were fabricated with a minimum of engineering analysis and sketches, and were not subjected to any testing beyond functional tests. Any attempt to achieve operational status with this ferry tank kit must be preceded by a design effort followed by a thorough ground and flight test program.

2. This Directorate agrees with the report conclusions and recommendations with the exceptions identified herein. Comments are directed to the paragraph of the report as indicated below:

a. Paragraph 30. The lack of adequate crashworthiness protection of the external fuel tank subsystem is a concern. However, the external fuel system will be utilized for ferry flights and not routine flights and the jettison capability has been demonstrated satisfactorily provided they are jettisoned prior to impact. The air compressor motor deficiencies should be corrected.

b. Paragraph 31a. The high vibrations level at airspeeds greater than 100 KIAS at pressure altitudes above 5000 feet in the AH-1S(MC) configuration is a shortcoming. The AH-1S series helicopters commonly exhibit high vibration levels with external stores/weapons when flown at high airspeeds. Unfortunately, the AH-1S(MC) tested was not instrumented for cockpit vibration levels and a quantitative assessment of this shortcoming is not possible.

c. Paragraph 31b. The inability of the pilot to determine fuel remaining in the external tanks is a shortcoming. Although the installation of a fuel gage or flowmeter to record fuel used is a requirements item, it is recommended that a gaging system be installed to help prevent inadequate lateral cyclic control due to center of gravity shifts.

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d. Paragraph 31c. The inability of the pilot to regulate the external flow rate to the main fuel cell is a shortcoming. Pending any design change the pilot will be required to monitor main tank fuel, allow the fuel to deplete 50-75 pounds, turn on the external fuel replenishment and shut off the external fuel when the main tank reads nearly maximum. This procedure would be repeated as necessary until the external tanks are depleted (this method is used with the CH-47C ferry system).

e. Paragraph 31d. The shortcoming due to inadequate illumination of the fuel flow and low fuel lights should be eliminated if the control panel is relocated to the upper righthand corner of the pilot instrument panel.

f. Paragraph 32f. The limited use of the Cobra in the external fuel configuration does not warrant additional testing at 170 KIAS V_{ne}. Limiting V_{ne} to 145 KIAS is adequate in this configuration.

FOR THE COMMANDER:

RONALD E. GORMONT
Acting Director of Engineering

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INTRODUCTION

BACKGROUND

1. A ferry kit was developed by the US Army to extend the range capability of the UH-1 helicopter in the early 1960's. The kit was placed in the supply system until the US Navy modified the kit for use on the AH-1J and AH-1T helicopters. The US Army has renewed interest in being able to deploy the AH-1S Modernized Cobra (MC) helicopter for missions requiring a ferry range greater than the current internal fuel capability. In March 1984, the US Army Aviation Engineering Flight Activity (USAAEFA) was tasked by the US Army Aviation System Command (AVSCOM) to plan and conduct a Preliminary Airworthiness Evaluation (PAE) of the AH-1S (MC) with the 100 gallon Kellett external fuel tanks installed (ref 1,app A).

TEST OBJECTIVES

2. The objectives of the PAE were to obtain sufficient data to enable AVSCOM to establish an Airworthiness Release for the AH-1S (MC) aircraft with the Kellet tanks installed based upon the following:

a. Sufficient performance data to determine the change in power required due to the external fuel tank installation.

b. Changes in handling qualities due to the external fuel tank installation.

c. Limited structural dynamics data to determine critical fuel loading and structural loads on the wing attaching lugs.

d. Demonstration of external tank separation (jettison) capability.

DESCRIPTION

3. The test helicopter, an AH-1S MC, (US Army S/N 69-16423), is a two-place, tandem seat, single engine attack helicopter with two-bladed main and antitorque rotors and skid landing gear, manufactured by Bell Helicopter Textron (BHT). The helicopter is powered by an AVCO Lycoming T53-L-703 turboshaft engine. The normal maximum gross weight of the AH-1S (MC) is 10,000 pounds which was increased to 10,500 for this evaluation. The helicopter is equipped with a crashworthy fuel system which has a total fuel capacity of 262 gallons of which 260 are useable. With the installation of two Kellett external fuel tanks and required

plumbing the fuel capacity is increased to 462 gallons (photos 1 and 2, app B). The installation of the external fuel system increased the empty weight of the AH-1S(MC) by approximately 200 pounds. A more detailed description of the external fuel tank subsystem and installation is contained in appendix B and the US Navy Technical Manual reference 2, appendix A. The external configuration of the test aircraft was modified by the installation of various test equipment which is discussed in appendix C. Additional descriptions of the AH-1S (MC) is contained in the operator's manual (ref 3, app A).

TEST SCOPE

4. The major portion of flight testing was conducted at Edwards Air Force Base, California (2302 feet), with some performance testing conducted at Bakersfield, California (488 feet). A total of 24 flights were conducted between 17 March and 27 April, 1984 for a total of 36.7 flight hours of which 18.9 were productive. USAAEFA installed, calibrated and maintained all test instrumentation. Additionally, USAAEFA installed the Kellett ferry tanks and performed all required maintainance on the ferry system and the test helicopter. Flight restrictions and operating limitations observed during the PAE are contained in the operator's manual (ref 3 , app A) and the airworthiness release (ref 4). Testing was conducted in accordance with the test plan (ref 5) at the conditions shown in tables 1 through 3.

TEST METHODOLOGY

5. Established flight test techniques and data analysis procedures were used (refs 6 and 7), and are described in appendix D. A Handling Qualities Rating Scale (HQRS) (fig. 1, app D) and a Vibration Rating Scale (VRS) (fig. 2) were used to augment pilot comments relative to aircraft handling qualities and vibrations. Flight parameters were recorded utilizing cockpit instruments, inflight magnetic tape recorder, and onboard voice recorder. Parameters which were considered critical were monitored in real time using telemetry. A detailed listing of the test instrumentation is contained in appendix C.

Table 1. Performance Conditions[1]

Test	Configuration	Gross Weight Range (lb)	Density Altitude Range (ft)	Thrust Coefficient Range ($x10^4$)
Level Flight	Clean[2]	8530 to 10,080	1410 to 10,900	45.55 to 64.45
Level Flight	Kellet Fuel Tank[3]	8660 to 9470	890 to 10,990	45.25 to 66.27
Autorotation[4]	Kellet Fuel Tanks	10,000	5000	

NOTES:

[1]Test conducted in zero sideslip flight, at a mid longitudinal and mid lateral center of gravity with a referred rotor speed of 324 rpm.
[2]Clean configuration - no external stores.
[3]100 gallon Kellet fuel tanks installed on outboard store position.
[4]Autorotations conducted in ball-centered flight.

Table 2. Handling Qualities Test Conditions[1]

Test	Gross Weight (lb)	Density Altitude (ft)	Trim Calibrated Airspeed (kt)
Control Positions in Trimmed Forward Flight[2]	8530 to 10,080	890 to 10,990	30 to 135
Static Longitudinal Stability	9830 and 10,080	4400 and 4780	67 and 114
Static Lateral-Directional Stability	9860 and 10,100	7620 and 7800	65 and 110
Maneuvering Stability	10,150	5200	125
Dynamic Stability	8690 to 10,210	7040 to 7170	120 to 127
Simulated Engine Failure	8540 and 8480	7160 and 7320	108 and 120
SCAS Failure	8600 to 10,050	6530 to 6820	65 to 117

NOTES:

[1]Tests conducted in ball-centered flight, where applicable, at a mid longitudinal and mid lateral center of gravity, external fuel tanks installed, with a rotor speed of 100% (324 rpm).
[2]Control positions were obtained during level flight performance, autorotation, and climbing flight.

Table 3. Jettison Conditions[1]

Flight Condtion	Trim Calibrated Airspeed (kt)	Aircraft Trim Position (Ball-Position)
Level Flight	121	1/2 Ball Right
Autorotation	61	1/2 Ball Right
Autorotation	106	Centered
Autorotation	85	Centered
Autorotation	85	1/2 Ball Right

NOTE:

[1]Tests conducted at a gross weight of 9400 pounds, mid longitudinal center of gravity (FS 196), mid lateral center of gravity, 100% rotor speed (324 rpm), empty fuel tanks mounted on outboard store station, right outboard fuel tank was jettisoned.

RESULTS AND DISCUSSION

GENERAL

6. Limited performance and handling qualities data were obtained for the AH-1S(MC) helicopter with the external fuel tanks installed. A baseline level flight performance evaluation was conducted in the clean configuration. The aircraft was flown in zero sideslip for all level flight performance testing and ball-centered flight for all handling qualities and autorotation descent performance. For all level flight performance the rotor speed was varied to maintain a constant referred rotor speed of 324 rpm. The change in equivalent flat plate area caused by the external fuel tank installation was 2.0 ft^2. One deficiency noted during the evaluation was the lack of crashworthiness of the external fuel tanks. The four shortcomings associated with the installation of the external fuel tanks were: (1) high vibrations at airspeeds greater than 100 KIAS; (2) the inability of the pilot to determine fuel remaining in the external tanks; (3) the inability of the pilot to regulate external fuel flow rate to the main fuel cell; and (4) the inadequate illumination of the fuel flow and low fuel lights.

PERFORMANCE

Level Flight Performance

7. Level flight performance tests were conducted to determine the change in equivalent flat plat area of the external fuel tank installation. These tests were conducted at the conditions listed in table 1. Data were obtained for the clean (no external stores) AH-1S (MC) to provide a baseline. Data were also obtained with two 100 gallon Kellett fuel tanks installed on the outboard store positions (photo 1, app B). The nondimensional data for the clean configuration are presented in figures 1 and 2, appendix E and the dimensional data for both configurations are presented in figures 3 through 10. The change in equivalent flat plate area caused by the external fuel tanks and associated external lines was determined to be 2.0 square feet.

Autorotational Descent Performance

8. Tests were conducted to determine the autorotational descent performance characteristics of the AH-1S (MC) helicopter with the external fuel system installed. The airspeeds for minimum rate of descent ($V_{min\ R/D}$) and maximum glide distance were obtained by conducting a series of steady state autorotational descents at a rotor speed of 320 rpm and incrementally varing airspeeds from 52

to 131 knots calibrated airspeed (KCAS). After $V_{min\ R/D}$ was determined, another series of descents was conducted at that airspeed and rotor speed was varied from 293 to 335 rpm to determine the effect of rotor speed on rate of descent. The results of these tests are presented in figures 11 and 12, appendix E.

9. The minimum R/D was 1920 ft/min at 65 KCAS. Airspeed could be varied ±10 knots with only a slight change in the R/D (±30 ft/min). The airspeed for maximum glide distance at an altitude of 5000 feet was 99 KCAS with a R/D of 2330 ft/min. Varying airspeeds ±3 knots from the maximum glide airspeed resulted in the distance traveled changing approximately ±3%. The $V_{min\ R/D}$ of 65 KCAS corresponds to 61 knots indicated airspeed (KIAS) and maximum glide speed of 99 KCAS corresponds to 94 KIAS. The airspeeds published in the operator's manual (ref 3, app A) for autorotational flight with wing stores should be used for the external fuel tank configuration (60 KIAS $V_{min\ R/D}$ and 90 KIAS for maximum glide distance).

10. As shown in figure 12, appendix E the R/D varied only 180 ft/min through the range of rotor speeds tested (293 to 335 rpm) Precise control of rotor speed during autorotation is not feasible, since any control input will result in relatively large changes in rotor speed. Since small variations of rotor speed from the optimum does not result in significant increases in R/D, 100% (324 rpm) should be maintained during autorotation, as described in the operator's manual.

HANDLING QUALITIES

General

11. Stability and control, jettision, system failure, and limited systems tests were conducted qualitatively and quantitatively to evaluate the handling qualities of the AH-1S (MC) with the external fuel tanks installed. The handling qualities and the reactions to system failures of the AH-1S (MC) were essentially unchanged by the installation of the external fuel tank subsystem. During the jettision evaluation it was determined that the maximum autorotational airspeed for jettisons should be to 85 KCAS.

Control Positions in Trimmed Forward Flight

12. Control positions in zero sideslip forward flight were obtained in conjunction with level flight performance testing at the conditions listed in table 2. The test results are presented in figures 13 through 16, appendix E. The control positions in

trimmed forward flight were essentially unchanged with the external fuel subsystem installed and are satisfactory.

13. The variation in flight control positions were also evaluated in climbing flight at the conditions listed in table 2. The data are presented in figure 17, appendix E. During military rated power (MRP) climbs, the variation of longitudinal control position with airspeed was slightly nonlinear, with increased forward longitudinal control required for increased airspeed. The pitch attitude did not change from that observed in trimmed level flight. The control positions in trimmed MRP climbs were essentially unchanged from previous evaluations (ref 8, app A) and are satisfactory.

14. Control positions in autrotational flight were evaluated at the conditions listed in table 2 and the data are presented in figure 18, appendix E. The longitudinal control position trend in autorotation was essentially linear and as airspeed was increased more forward longitudinal cyclic control was required. The significant longitudinal and lateral cyclic trim change in autorotative flight were similar to those previously reported for the standard AH-1S aircraft and are satisfactory.

Static Longitudinal Stability

15. The static longitudinal stability chatacteristics of the test aircraft with the external fuel tanks installed were evaluated at the conditions shown in table 2. Tests were conducted by trimming the aircraft in level flight at 67 and 115 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 airspeed, and are presented in figures 19 and 20, appendix E. At both airspeeds, the static longitudinal stability, as indicated by the variation of longitudinal cyclic control position with airspeed, was stable (increasing forward longitudinal control with increasing airspeed). The gradient of longitudinal cyclic position versus airspeed was very shallow at 67 KCAS (approximately 0.017 inch/knot) with the gradient further reduced with increasing airspeed (approximately 0.015 inch/knot at 115 KCAS). The static longitudinal stability characteristics were compared with a previous evaluation (ref 9, app A) and were essentially unchanged. The static longitudinal stability characteristics of the AH-1S(MC) with the external fuel tank subsystem installed are satisfactory.

Static Lateral-Directional Stability

16. The static lateral-directional stability characteristics of the test aircraft were evaluated at the conditions shown in table 2. Tests were conducted by first trimming the aircraft at ball-centered level flight at 65 and 110 KCAS and then stabilizing at incrementally increasing left and right sideslip angles. Data were recorded at zero turn rate with airspeed, collective control, and sideslip angle held constant. Test data are presented in figures 21 and 22, appendix E. Static directional stability was positive (increasing left directional control with increasing right sideslip) throughout the sideslip envelope for both trim airspeeds and is satisfactory. Dihedral effect was also positive (increasing right lateral cyclic control with increasing right sideslip) for both trim airspeeds and is satisfactory. The sideforce cues (as indicated by bank angle variation with sideslip) at 65 KCAS were weak. At this airspeed the lack of sideforce cues increased the pilot workload to maintain aircraft trim. At 110 KCAS the sideforce cues were stronger and the pilot workload to maintain trimmed flight was reduced. A comparison of the static lateral-directional characteristics with those previously reported (ref 9, app A) indicated the characteristics were essentially uneffected by the installation of the external fuel tank subsystem.

Maneuvering Stability

17. The maneuvering stability characteristics of the AH-1S (MC) with the external fuel tanks installed were qualitatively evaluated in steady-state turns at the conditions shown in table 2. The steady-state turns were conducted by trimming at 125 KCAS and then stabilizing in coordinated flight at incrementally increasing roll attitudes while maintaining collective control and airspeed constant. The variation of longitudinal control position with normal load factor (g) was positive (aft cyclic control with increasing g) up to 1.4 gs and neutral (no change in longitudinal control postion with increasing g) between 1.4 and 1.8 gs. Below 1.4 gs the maneuvering stability characteristics were essentially unchanged from those exhibited in a previous evaluation (ref 9, app A). At g levels greater than 1.4 small longitudinal cyclic control inputs resulted in large airspeed changes so that the pilot tended to "chase" the desired airspeed. This required considerable pilot compensation to maintain airspeed within ±5 knots (HQRS 5). The undesirable maneuvering stability characteristics above 1.4 gs significantly increased pilot workload and remain an uncorrected shortcoming for the attack helicopter mission (ref 9). For the ferry mission it is not significant and is satisfactory.

Dynamic Stability

18. The short-term dynamic stability characteristics were evaluated with empty and full external fuel tanks at the conditions listed in table 2. The evaluation was conducted by utilizing control pulses in both directions in all axes. The pulse was made by rapidly displacing the appropriate control up to 1 inch for 0.5 second, then rapidly returning to the trim position. The flight controls were then held fixed until corrective recovery became necessary or the aircraft motions were damped. Representative data for both configurations (empty and full tanks) are presented in figures 23 through 28, appendix E. The lateral and longitudinal inputs resulted in a similar aircraft response when compared to a previous Cobra evaluation (ref 10, app A). The directional control pulses resulted in high roll and yaw rates, but the aircraft response after the controls were returned to trim was heavily damped. The short-term dynamic stability characteristics of the AH-1S(MC) with the external fuel tanks subsystem installed were essentially unchanged from those seen during previous evaluations.

Stores Jettison Capability

19. A total of 5 external fuel tank jettison tests were accomplished at the conditions listed in table 3. The tanks used during the jettisons were approximately 30 pounds lighter then the operational external fuel tanks since no "EXPLOSAFE" was installed. Since the "EXPLOSAFE" is evenly distributed in the operational tanks, the moments of interia about all axes of these tanks will be higher than that of the empty tanks. Therefore, the angular rates and accelerations of the empty tanks observed during the jettison tests should be higher than those of the operational tanks. During the jettisons in level flight at 121 KCAS (approximate cruise airspeed) and in autorotation at 61 KCAS (approximate minumum rate of descent airspeed) the separations were very clean with no observable attitude changes to the tank until it was well clear of the aircraft. At 106 KCAS, in ball-centered autorotation, the jettison characteristics of the tank degraded significantly. The tank started to pitch up 0.08 seconds after jettsion initiation, approximately 18 inches below the wings, and the nose started a right yaw 0.05 seconds later. The tank reached a 90 degree pitch up approximately 0.3 seconds after jettsion initiation and the nose of the tank cleared the wing pylon mounts by approximately 1 foot. The tank then continued its pitching motion but continued to drop away from the aircraft and did not impact with the aircraft. The jettison sequence is shown in photos 1 through 5, appendix E. Jettison at

a lower airspeed was conducted so that a safe jettision envelope in autorotation could be established. These two jettisions were done at 85 KCAS ball-centered and 1/2 right ball out of trim and were accomplished with no further problems. No adverse aircraft handling qualities were experienced as a result of the jettisons. The following statement should be incorporated in the operator's manual: Prior to jettision of the external fuel tanks, the airspeed should be below 120 KIAS in level flight and between 50 and 85 KIAS in autorotation.

Aircraft System Failures

Simulated Engine Failures:

20. The response of the AH-1S(MC) to simulated sudden engine failures (with the external fuel tanks installed) were evaluated in forward level flight at the conditions listed in table 2. Engine failure was simulated by rapidly rolling the throttle to flight-idle. Flight controls were held fixed until one of the following occurred: (1) 2 seconds following the simulated power loss, (2) the minimum transient rotor speed was reached, or (3) the pilot deemed recovery necessary. Representative time history plots are presented in figures 29 and 30, appendix E. The test results indicate flight control delay times were approximately 0.5 seconds for entries at airspeeds greater than 100 KCAS. The high roll and yaw rates following the loss of power provided immediate cues to the pilot and the low rotor rpm warning system provided an audio cue approximately 1 second following the power loss at which time collective was reduced. Due to the high roll acceleration generated by the simulated engine failure very large lateral cyclic control inputs were required (approximately 1.5 inches to the right). The 2-second collective delay requirement of paragraph 3.5.5 of MIL-H-8501A (ref 11, app A) could not be attained at airspeeds greater than 100 KCAS. The delay times are consistent with those observed in USAAEFA Project No. 75-18, reference 12. The installation of the external fuel tank subsystem did not affect the aircraft reaction following the simulated engine failures.

Stabilty and Control Augmentation System Failures:

21. Simultaneous three-axis Stability and Control Augmentation System (SCAS) failures were evaluated in the external fuel tank configuration (empty and full tanks) at the conditions listed in table 2. Representative data are presented in figures 31 through 34, appendix E. The failures were evaluated at airspeeds from 65 to 117 KCAS. The tests were accomplished by stabilizing the aircraft at the appropriate trim speed, then simultaneously

failing all three channels of SCAS utilizing the pilot's SCAS release switch. The flight controls were held fixed for a minimum of 3 seconds following the failures. Recovery consisted of returning the aircraft to straight and level flight and re-engaging the SCAS when the airspeed was less than 100 KIAS. There was no noticable difference in aircraft reaction to SCAS failures in either configuration. With full external tanks, the highest airspeed without a divergent response was 65 KCAS where the roll oscillation was 2 degrees/second in response to the SCAS failure. With empty external tanks the nondivergent response occurred at up to 87 KCAS but the roll rate oscillation increased in amplitude to ±4 degrees/second. At 117 KCAS the roll rate was 14 degrees/second and roll acceleration was 15 degree/second/second after 1 cycle of the oscillation (approximately 6 seconds following the failure). During the recovery at airspeeds greater than 100 KIAS, pilot workload increased when attempting to maintain roll attitude within ±2 degrees (HQRS 5). The response following the SCAS failures were similar to the SCAS OFF dutch roll investigation performed during USAAEFA Project No. 78-03 (ref 9, app A) but appeared to be slightly degraded from that seen during the Skid Cross-Tube Fairings Removed evaluation (ref 10, app A), however, it was not a problem. The SCAS OFF characteristics below 100 KIAS are similar to the standard AH-1S and the 100 KIAS limit for SCAS OFF flights as referenced in the -10 should be retained.

STUCTURAL DYNAMICS

Vibration

22. During all testing, the aircraft vibration levels were evaluated qualitatively utilizing a VRS. At gross weights, altitudes and airspeed combinations associated with the ferry missions, abnormal vibrations were noted at airspeeds greater than 100 KIAS. For example, at a gross weight of 8600 pounds and a pressure altitude of 5350 feet, high vibrations were encountered at airspeeds above 100 KIAS. The vibration was very apparent to the crewmembers and was severe enough that notes could not be written and airspeed could be read to only ±2 knots (VRS 7). To further analyze the vibration, the collective was reduced and the aircraft was placed in a shallow dive so that airspeed could be maintained. The level of vibration decreased to a VRS of 4. The high vibration level at airspeeds greater than 100 KIAS when operating at gross weights greater than 8500 pounds and pressure altitudes above 5000 feet is a shortcoming.

Structural Loads

23. A limited structural evaluation was performed in an attempt to determine the critical fuel loading which would result in maximum loads at the wing attaching lugs. During the structural evaluation, axial loads on the left wing upper forward and center attaching lugs were monitored in real time. The loads were characterized as an oscillatory 2 per revolution (10.8 hertz) with the load amplitude increasing as bank angle or airspeed was increased (figs. 35 and 36, app E). In level flight the endurance limit of ±2200 pounds was reached on the center attaching lug at airspeeds above approximately 150 KCAS. The airworthiness release (ref 4, app A) set velocity never exceed (V_{NE}) at 170 KIAS, but due to the higher loads seen at 145 KIAS the 170 KIAS V_{NE} should be reevaluated. A critical fuel load evaluation was conducted by measuring the wing lug loads at various airspeeds and external fuel loads. At all airspeeds tested, the fuel load in the external fuel tanks had little effect on the lug loads.

FUEL TRANSFER SYSTEM AND FUEL MANAGEMENT

24. The fuel transfer control panel for the external fuel tank subsystem was located on the pilot's right console. The control panel contained two ON/OFF switches to control tank mounted air compressors, two green cat eye lights to indicate external tank fuel flow, two yellow cat eye lights to indicate low fuel in the external fuel tanks and two circuit breakers to protect the air compressors. Due to the low intensity of both sets of lights it was difficult for the pilot to determine the mode of operation in normal daylight lighting conditions. Several times during the evaluation the lights illuminated, indicating fuel flow or low fuel, and the illumination was not noted by the pilot. Due to the nature of this particular test the pilot was attempting to monitor the lights much closer than a normal mission pilot would. The inadequate illumination of the fuel flow and low fuel lights is a shortcoming.

25. In the present configuration, the pilot cannot determine the amount of fuel remaining in the external tanks. As a result, the pilot could transfer fuel asymmetrically due to either pilot error or a system malfunction. In either case, large lateral center of gravity shifts (as large as 4.3 inches) could occur which may result in inadequate lateral cyclic control margins. The inability of the pilot to determine fuel remaining in the external tanks is a shortcoming.

26. Fuel flow rates for the external fuel tank subsystem were determined by measuring the amount of fuel pumped out of the tanks during a specified time period. This test was done at Edwards AFB, California (2303 feet) at an ambient temperature of approximately 15 degrees celcius utilizing external electrical power. The tanks were mounted so that they were 4 degrees nose-up when the aircraft was level (wing pylons in the stowed position). The fuel flow averaged 20 lb/min per tank for the first 90 gallons transferred and decreased to approximately 8 lb/min per tank for the remaining 10 gallons. The fuel transfer lights on the pilot's control panel would not always remain illuminated during the transfer of the last 10 gallons, (all but one gallon/tank was usable during level flight). Since the rate of fuel transfer from the external tanks is greater than the rate of fuel consumption by the engine, it is possible to overfill the main tank, resulting in fuel venting overboard. The inability of the pilot to regulate the external fuel flow rate to the main fuel cell is a shortcoming.

EXTERNAL FUEL TANK SUBSYSTEM

27. The installation of the external fuel tanks subsystem was accomplished with only two permanent modifications, a cutout in the leading edge of the wing store pylon fairings (photo 3, app B) and a cutout in the access panels in the area beneath the transmission (photo 4, app B). The installation of the various fuel lines and check valves in the area beneath the transmission was difficult due to limited space. Photos 5 and 6 show the limited space in this compartment. The external plumbing should be rerouted so that the fuel and electrical lines are not routed through the area under the transmission. Consideration should be given to routing the various lines to enter the aircraft belly externally in the vicinity of the forward fuel sump drain.

28. The internal fuel system in the AH-1 series have a crashworthy fuel system (self-sealing break-away fuel lines and self-sealing fuel tanks). The external fuel tanks and lines operate utilizing air pressure and the only crashworthy design in the entire system was the addition of "EXPLOSAFE". Additionally, the motor which drove the air compressor (mounted just aft of the fuel filler cap) appeared not to be explosion proof (no "explosion proof" markings and no spark protection for motor brushes). The lack of adequate crashworthiness protection of the external fuel tank subsystem significantly degrades the overall system safety of the AH-1 series when installed and is a deficiency.

CONCLUSIONS

GENERAL

29. Based on the Preliminary Airworthiness Evaluation of the AH-1S (MC) helicopter with the external fuel tanks installed, the following conclusions were reached:

a. The handling qualities of the AH-1S (MC) were essentially unchanged with the installation of the external fuel tank subsystem.

b. One deficiency and four shortcomings were noted.

DEFICIENCY

30. The deficiency identified during this evaluation was the lack of adequate crashworthiness protection of the external fuel tank subsystem (para 28).

SHORTCOMINGS

31. The following shortcomings (in decreasing order of relative importance) were identified:

a. The high vibration level at airspeeds greater than 100 KIAS when operating at gross weights greater than 8500 pounds and pressure altitude above 5000 feet (para 22).

b. The inability of the pilot to determine fuel remaining in the external fuel tanks (para 25)

c. The inability of the pilot to regulate external fuel flow rate to the main fuel cell (para 26).

d. The inadequate illumination of the fuel flow and low fuel lights (para 24)

RECOMMENDATIONS

32. The following recommendations are made:

a. The deficiency reported in paragraph 30 must be corrected.

b. The shortcomings reported in paragraph 31 should be corrected.

c. The airspeeds published in the operator's manual (ref 3, app A) for autorotational flight with wing stores should be used for the external fuel tank configuration (para 9).

d. The rotor speed should be maintained at 100% (324 rpm) during autorotations (para 10).

e. The following jettision envelope should be incorporated in the operator's manual: Prior to the jettision of the external fuel tanks, the airspeed should be below 120 KIAS in level flight and between 50 and 85 KIAS in autorotation (para 19).

f. The 170 KIAS V_{NE} should be reevaluated (para 23).

h. The external plumbing should be rerouted so that the fuel and electrical lines are not routed through the area under the transmission (para 26).

APPENDIX A. REFERENCES

1. Letter, AVRADCOM, DRDAV-ED, 14 March 1984, subject: Preliminary Airworthiness Evaluation of the AH-1S(MC) with Ferry Tanks Installed, USAAEFA Project No. 84-09.

2. Technical Manual, NAVAIR 03-10JL-13, *Fuel Tank 100 gallon and Adapter, Auxiliary Fuel Part Number 382-68550-1 and 382-68500-1*, Naval Air Systems Command, 30 October 1981.

3. Technical Manual, TM55-1520-236-10, *Operator's Manual, Army Model AH-1S (Modernized Cobra)*, Headquarters, Department of the Army, 11 January 1980, with change 8 dated 16 January 1984.

4. Letter, AVRADCOM, DRSAV-E, 21 March 1984, Revisions 2 and 5 April 1984, subject: Airworthiness Release for AH-1S (MC) with External Fuel Tanks Installed.

5. Letter, USAAEFA, SAVTE-TB, 15 March 1984, subject: Test Plan, Preliminary Airworthiness Evaluation of the AH-1S (MC) Helicopter with Ferry Tanks Installed, USAAEFA Project No. 84-09.

6. Engineering Design Handbook, Army Material Command, AMC Pamphlet 706-204, *Helicopter Performance Testing*, 1 August 1974.

7. Flight Test Manual, Naval Air Test Center, FTM No. 101, *Stability and Control*, 10 June 1968.

8. Final Report, USAAEFA Project No. 77-04, *Army Preliminary Evaluation YAH-1S Helicopter with Modified Flat Plate Canopy Installed*, August 1977.

9. Final Report, USAAEFA Project No. 78-03, *Preliminary Airworthiness Evaluation AH-1S Helicopter Installed with Enhanced Cobra Armament System (AH-1S/ECAS)*, February 1979.

10. Letter, USAAEFA, DAVTE-TA, March 1984, subject: Report, Airworthiness Evaluation of the AH-1S (Modernized Cobra) with Skid Cross-Tube Fairings Removed, USAAEFA Project No. 83-14.

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

12. Final Report, USAAEFA Project No. 75-18, *Army Preliminary Evaluation YAH-1Q Helicopter with A Flat Plate Canopy*, August 1975.

APPENDIX B. DESCRIPTION

GENERAL

1. The AH-1S (Modernized Cobra (MC)) helicopter is a tandem seat, two place, single engine aerial weapon platform. A three-axis Stability and Control Augmentation System (SCAS) is provided with actuators limited to ± 12.5 percent authority. The fuselage (forward section) employs aluminum alloy skin and aluminum, titanium and fiberglass honeycomb panel construction. Honeycomb deck panels and bulkheads attached to main beams produce a box-beam structure. These beams make up the primary structure and provide support for the cockpit, landing gear, wings, engine, pylon assembly, fuel cells, and tailboom. The nose section incorporates a 20 MM cannon mounted on a universal turret and a gyro stablized telescopic sight unit. The tailboom is a tapered semi-monocoque structure and supports the cambered vertical stabilizer tail skid, elevators, and tail rotor drive system. The AH-1S(MC) incorporates two fixed cantilever wings which have a span of 129 inches (wing tip to wing tip) and a mean chord of 30 inches. The primary function of the wings are to provide support for wing store pylons. Each wing has two pylons. The inboard pylons are fixed and the outboard pylons are articulated (pitch axis only). The outboard pylons are limited by the operator's manual (ref 3, app A) to approximately 500 pounds. Additional description of the AH-1S (MC) is contained in the operator's manual.

POWER PLANT

2. The T53-L-703 turboshaft engine is installed in the AH-1S(MC) helicopter. This engine employs a two-stage, axial-flow free power turbine; a two-stage, axial flow turbine driving a five-stage axial and one-stage centrifugal compressor; variable inlet guide vanes; and an external annular combustor. A 3.2105:1 reduction gear located in the air inlet housing reduces power turbine speed to a nominal output shaft speed of 6604.3 rpm at 100 percent N2. Maximum uninstalled engine shaft horsepower (shp) is 1800 shp on a sea level standard day condition. Installed in the AH-1S aircraft the engine is transmission limited to 1294 shp for 30 minutes at less than 100 knots indicated airspeed.

INTERNAL FUEL SYSTEM

3. The AH-1S(MC) is equipped with a crashworthy fuel system. This system is designed to contain fuel during a severe, but survivable, crash impact to reduce the possibility of fire. The

fuel system consists of two fuel cells which when full contain 260 useable gallons, a fuel quantity gauge, a separate low fuel warning system, a fuel boost pump in each tank, and assorted plumbing and electrical lines. There are no provisions for fuel jettision or measurement of fuel flow. Additionally, all fuel lines are configured with self-sealing break-away connectors.

EXTERNAL FUEL TANK SUBSYSTEM

4. The auxiliary fuel system (photos 1 through 7) consists of two 100-gallon Kellet fuel tanks (fig. 1), two pump assemblies and brackets which have been qualified for use on US Navy's AH-1T helicopters. The fuel transfer lines, electrical power lines, fittings, control panel and circuit breaker panel were prototypes designed for a short term mission. The inadequate crashworthiness in that the tanks are filled with "EXPLOSAFE" material. None of the lines or connectors are self sealing and the entire system is pressurized. The system is manually operated through switches mounted at the pilot's station. These switches control air pumps mounted on the outboard pylons (photo 3). The pumps are designed to pressurize the tanks and force fuel by air pressure through the fuel transfer lines (photo 7) to the main tanks. Check valves located in the area under the transmission (photo 6) prevent reverse flow of the fuel from the main tank back into the external tanks. Actual fuel flow is indicated to the pilot through the use of two fuel flow lights (one for each tank) located on the control panel. A second set of lights on the control panel indicate low fuel level (approximately 10 gallons remaining) in each external tank. The weight of each 100 gallon kellet tank is 84 pounds.

PRINCIPAL DIMENSIONS

5. The principal and general data concerning the AH-1S (MC) helicopter (photo 2) are as follows:

Overall Dimensions

Length, rotor turning	53 ft, 1 in.
Width, rotor turning	44 ft.
Height, tail rotor turning	13 ft, 9 in.

Main Rotor (K747 IMRB)

Diameter	44 ft
Disc area	1520.53 ft2
Solidity	0.0625

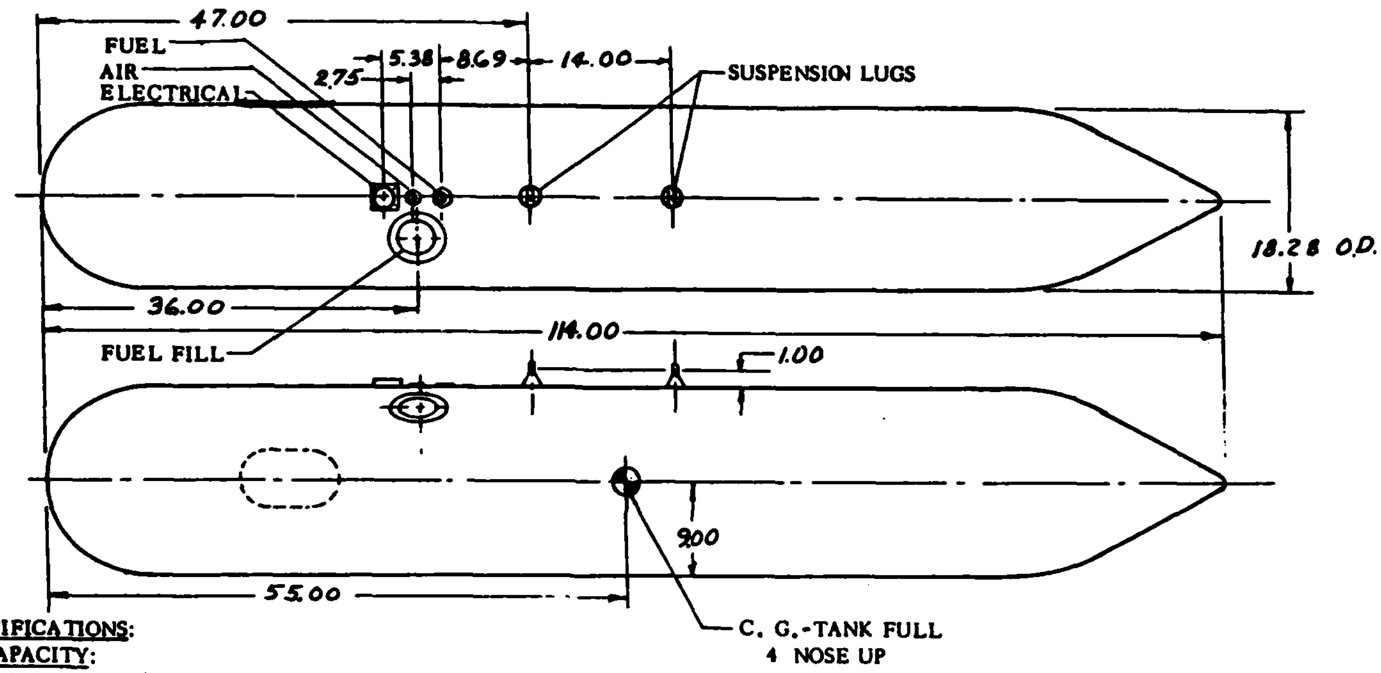
Planform	Trapezoidal chord 30.0" tapering to 10.0" at tip.
Blade twist	-0.556 deg/ft
Normal main rotor speed	324 RPM (100%)

<u>Tail Rotor</u>

Diameter	8 ft, 6 in.
Disc area	56.75 ft^2
Solidity	0.1436
Number of blades	2
Blade chord, constant	11.5 in.
Blade twist	0.0 deg/ft
Airfoil	NACA 0018 at the blade root changing linearly to a special cambered section at 8.27 percent of the tip
Tail rotor speed	1655.1 RPM (100%)

<u>Fuselage</u>

Length, rotor removed	44 ft, 7 in.
Height:	
To tip of tail fin	10 ft, 8 in.
Ground to top of mast	12 ft, 3 in.
Ground to top of transmission fairing	10 ft, 2 in.
Width:	
Fuselage only	3 ft
Wing span	10 ft, 9 in.
Skid gear tread	7 ft
Elevator:	
Span	6 ft, 11 in.
Airfoil	Inverted Clark Y
Vertical Fin:	
Area	18.5 ft^2
Airfoil	Special cambered
Height	5 ft, 6 in.
Wing:	
Span	10 ft, 9 in.
Incidence	17.0 deg
Airfoil (root)	NACA 0030
Airfoil (tip)	NACA 0024



SPECIFICATIONS:

CAPACITY:

GROSS	108 GAL.
EXPANSION	6.5 GAL.
EXPLOSAFE	1.5 GAL.
NET	100 GAL.

WEIGHT:

100 GAL. TANK	51 LB.
EXPLOSAFE	33 LB.
100 GAL. JP4	681 LB.
GROSS	765 LB.

Figure 1. Kellett Auxiliary Fuel Tanks

Photo 1. Kellett External Fuel Tanks Configuration
Front View

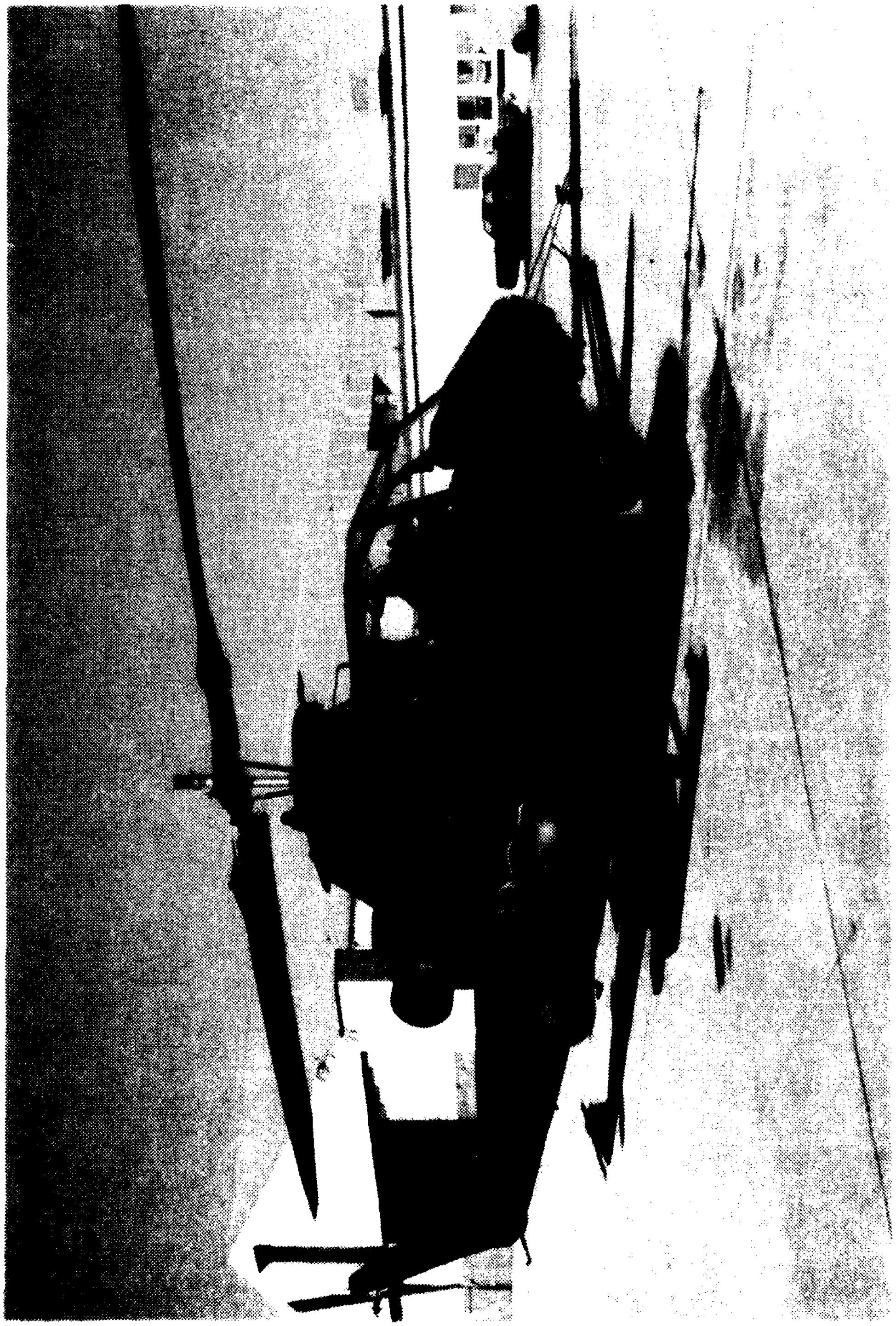


Photo 2. Kellett External Fuel Tanks Configuration
Right Quartering View

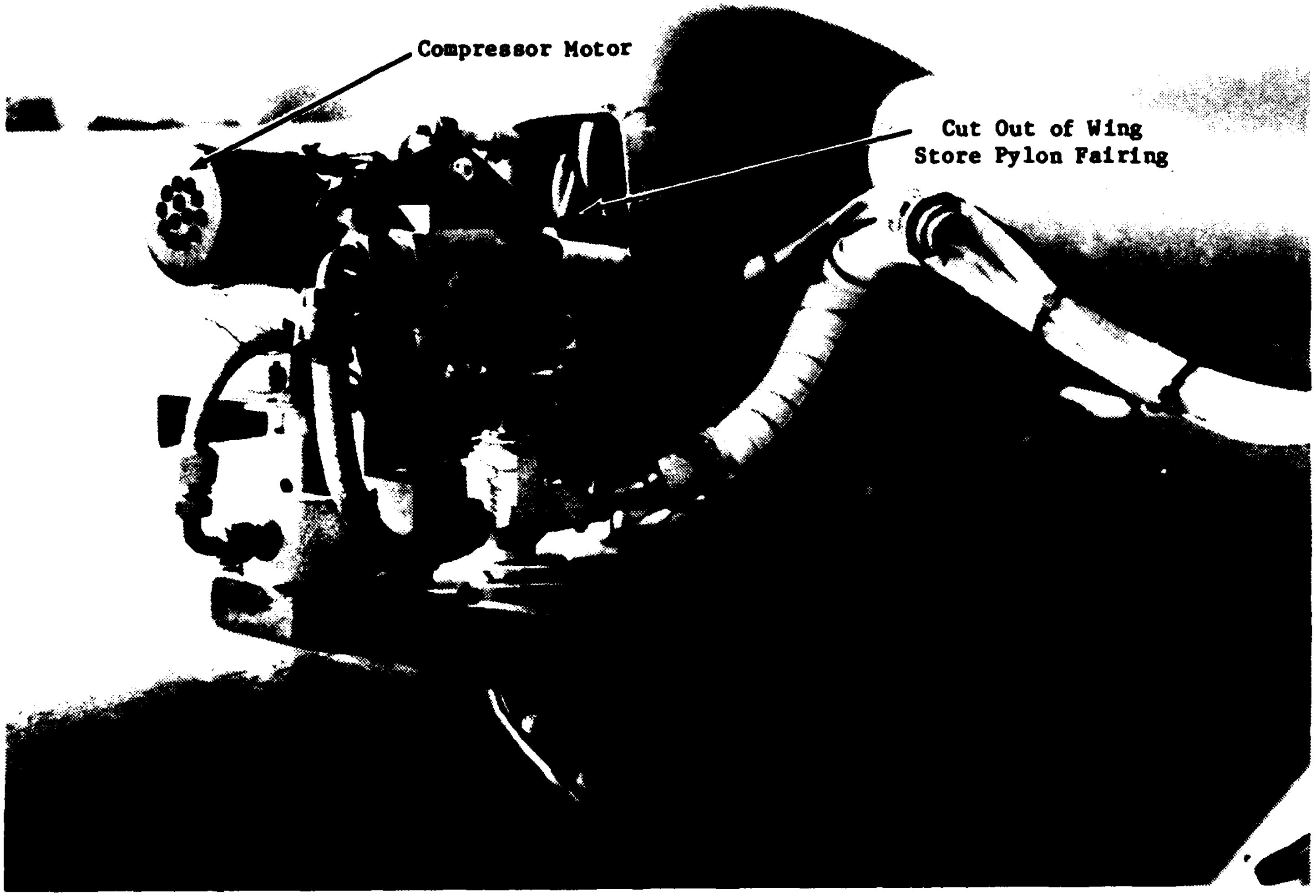


Photo 3. Wing Stores Pylon Fairing Cutout

Photo 4. Transmission Access Panel Cutout

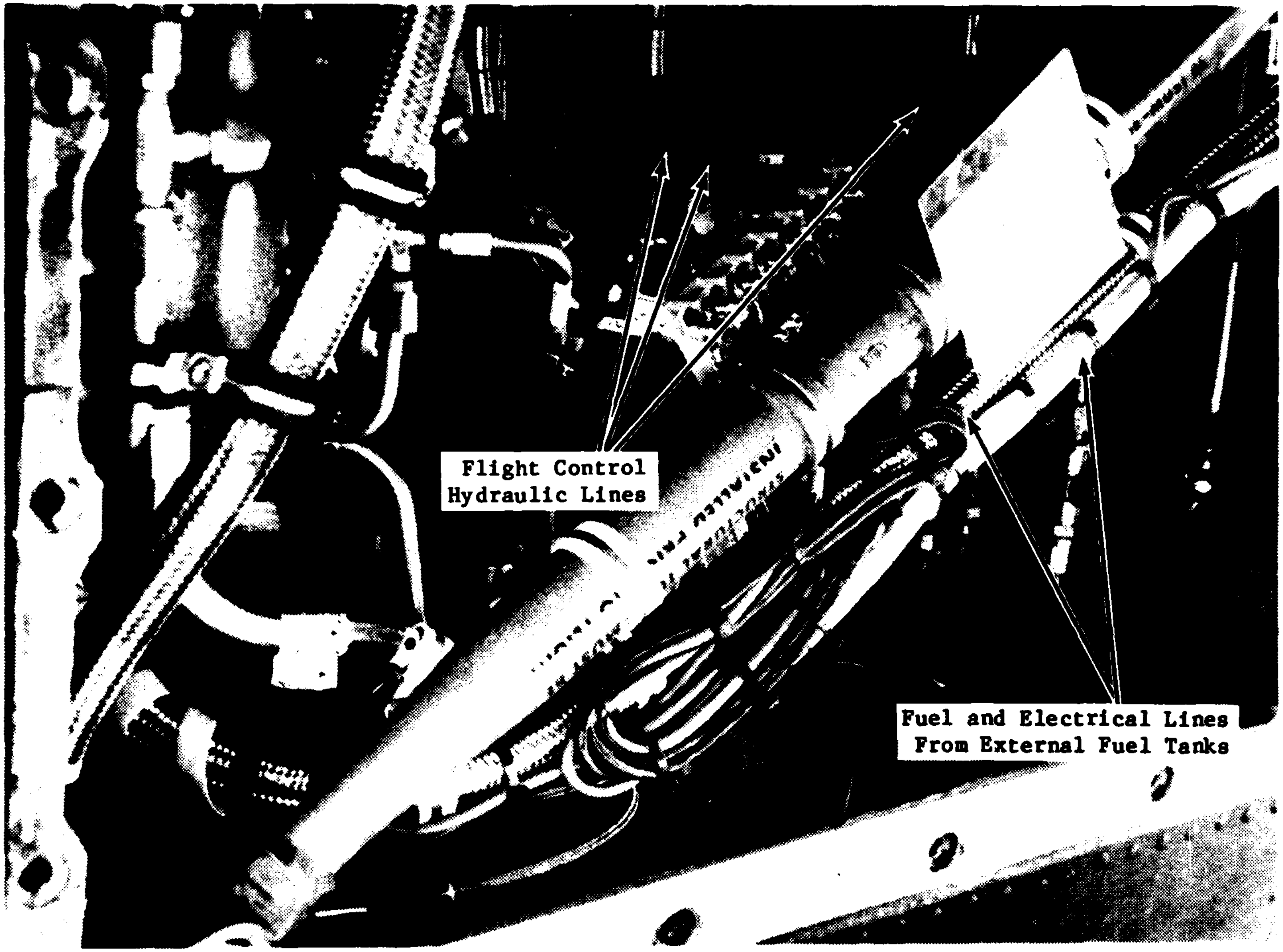


Photo 5. Compartment Beneath Transmission - Right Side

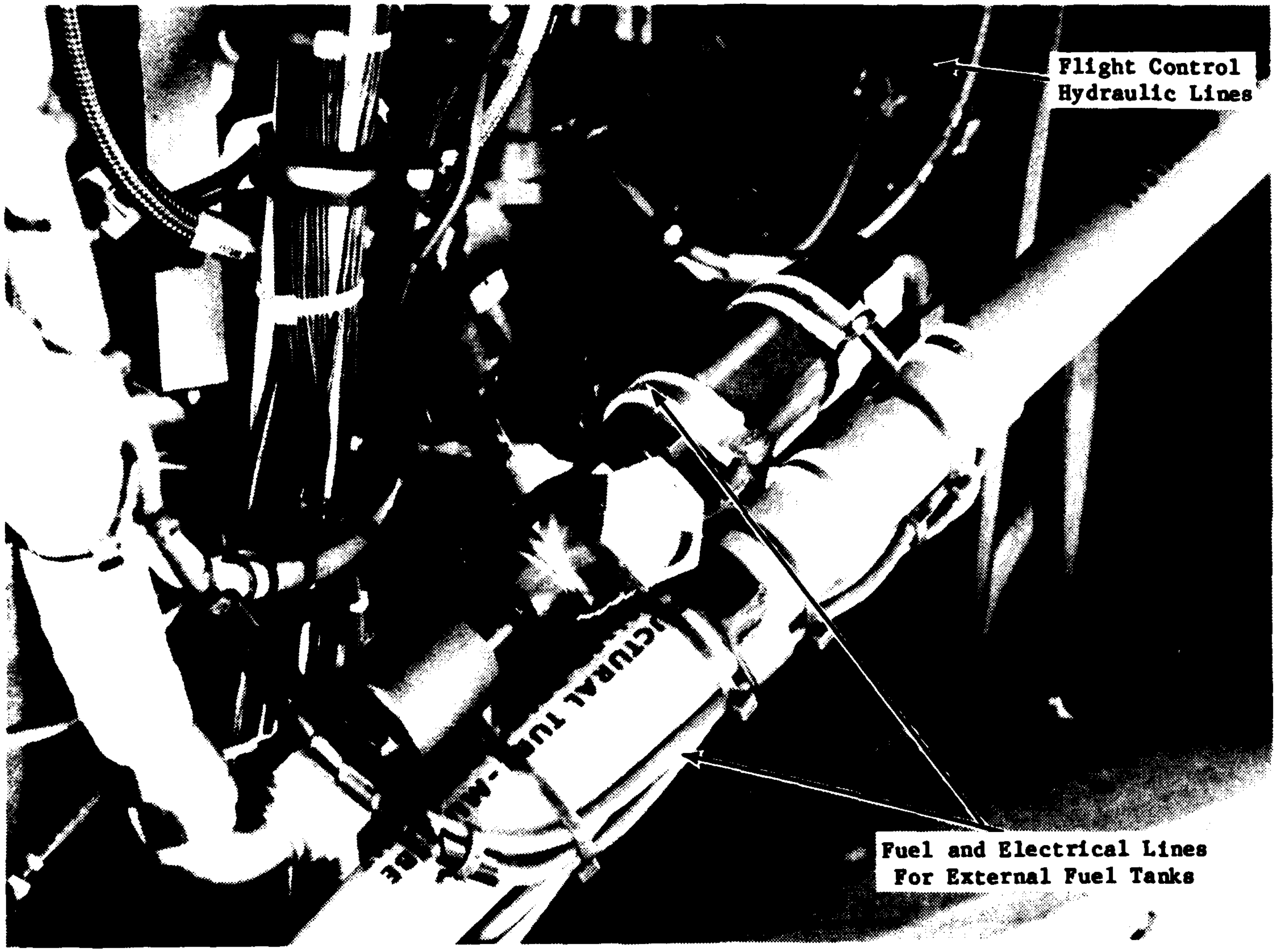


Photo 6. Compartment Beneath Transmission - Left Side

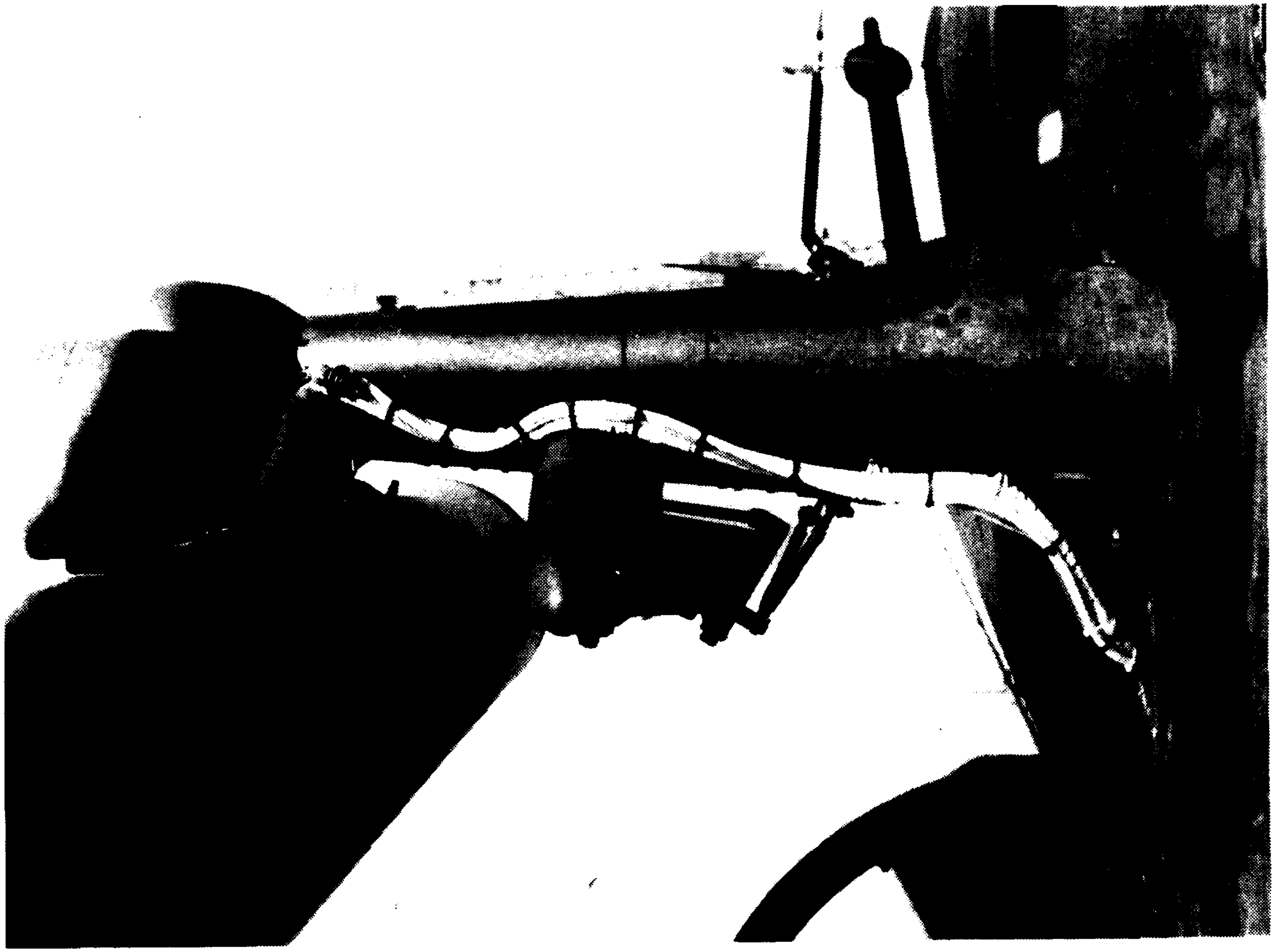


Photo 7. External Fuel Tank Electrical and Fuel Transfer Lines

APPENDIX C. INSTRUMENTATION

1. The test instrumentation system was designed, calibrated, installed, and maintained by USAAEFA. Data were obtained from calibrated instrumentation and were recorded on magnetic tape and/or displayed in the cockpit. The digital instrumentation system consisted of various transducers, signal conditioning units, a ten-bit pulse coded modulation (PCM) encoder, and an Ampex AR 700 tape recorder. Strain gages were mounted on the left wing at the upper forward-wing lug and the upper mid-wing lug to measure axial loads (photo 1). The digital data were telemetered to a ground station for in-flight monitoring. External tank jettision tests were recorded on high speed video tape. A boom with the following sensors was mounted on the nose of the aircraft: swiveling pitot-static head, sideslip vane, angle-of-attack vane, and total-temperature sensor (photo 2, app B). Boom airspeed system calibration is shown in figure 1, and engine torque sensor system calibration is shown in figure 2.

2. Calibrated cockpit monitored parameters and special equipment are listed below.

<u>Pilot Station</u>

Airspeed (boom)
Airspeed (ship's system)
Altitude (boom)
Altitude (ship's system)
Rate of climb (ship's system)
Rotor speed (sensitive)
Engine torque
Gas generated speed (N_1)
Power turbine speed (N_2)
Measured gas temperature (TGT)
Angle-of-sideslip
Outside air temperature (ship's system)
Event switch
External fuel transfer controls and displays

<u>Copilot/Engineer Station</u>

Airspeed (ship's system)
Altitude (ship's system)
Rotor speed (sensitive)
Engine torque (sensitive)
Fuel used (totalizer)
Fuel flow
Gas generator, speed (N_1) (ship's system)
Measured gas temperature
Time of day

Total air temperature (boom)
Event switch
Instrumentation controls and displays

3. Parameters recorded on magnetic tape were as follows:

PCM Parameters

Airspeed (boom)
Airspeed (ship's system)
Altitude (boom)
Altitude (ship's system)
Rotor speed
Engine torque
Fuel used
Fuel flow
Gas generator speed (N_1)
Power turbine speed (N_2)
Measured gas temperature
Control position
    Longitudinal
    Lateral
    Directional
    Collective
Longitduinal, lateral and directional SCAS actuator positions
Pitch, roll and yaw attitudes
Pitch, roll and yaw rates
Longitudinal, lateral and directional linear accelerations
Angle-of-sideslip
Main rotor flapping angle
Left wing upper forward lug axial load
Left wing upper mid lug axial load
Pilot/engineer event
Time of day

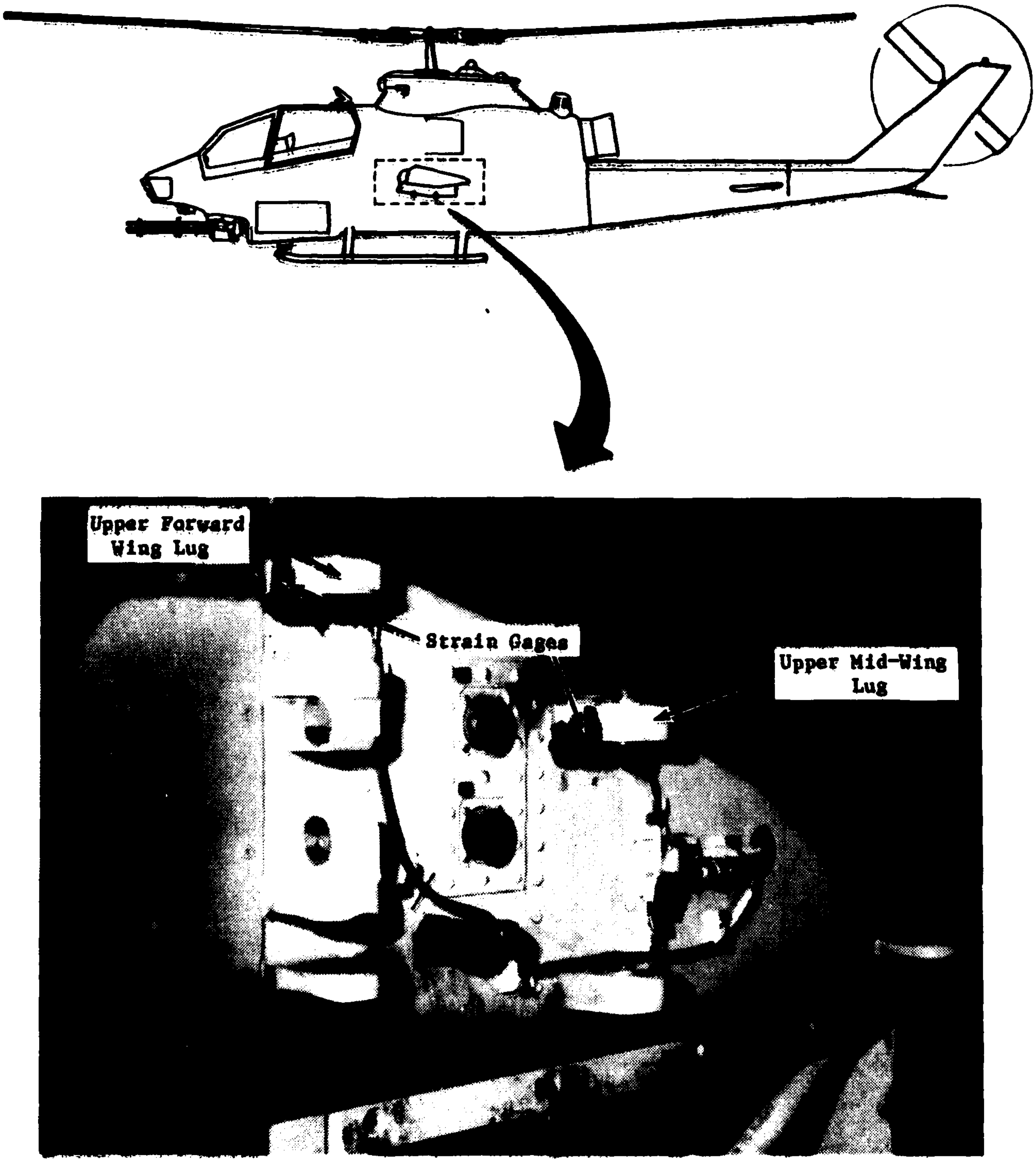
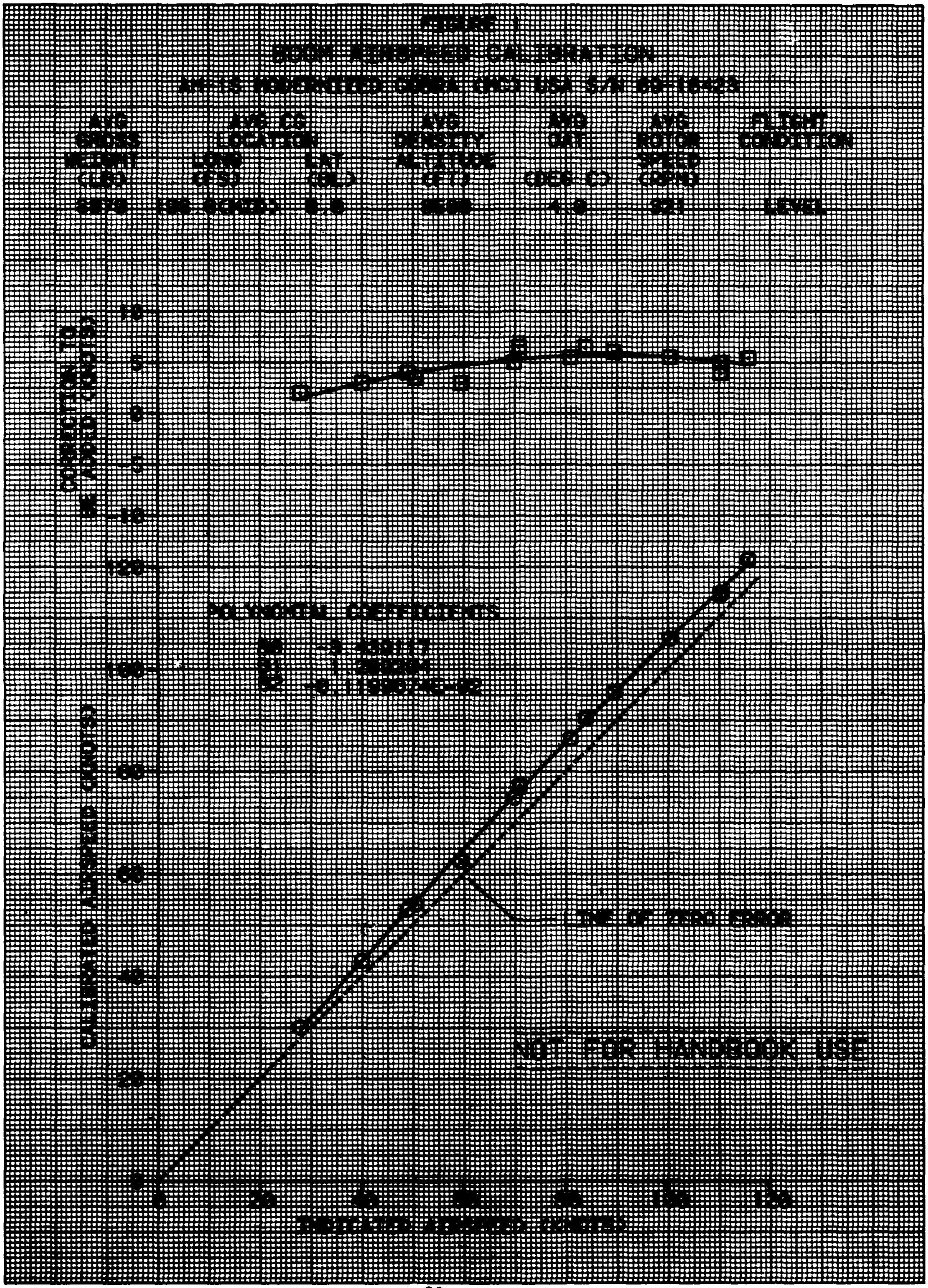


Photo 1. Wing Lug Strain Gage Locations


BOOM AIRSPEED CALIBRATION
AVG GROSS WEIGHT (LB)
AVG CG LOCATION
LONG (FS)
LAT (BL)
AVG DENSITY ALTITUDE (FT)
AVG OAT (DEG C)
AVG ROTOR SPEED (RPM)
FLIGHT CONDITION
LEVEL
CORRECTION TO BE ADDED (KNOTS)
POLYNOMIAL COEFFICIENTS
LINE OF ZERO ERROR
NOT FOR HANDBOOK USE
CALIBRATED AIRSPEED (KNOTS)
INDICATED AIRSPEED (KNOTS)

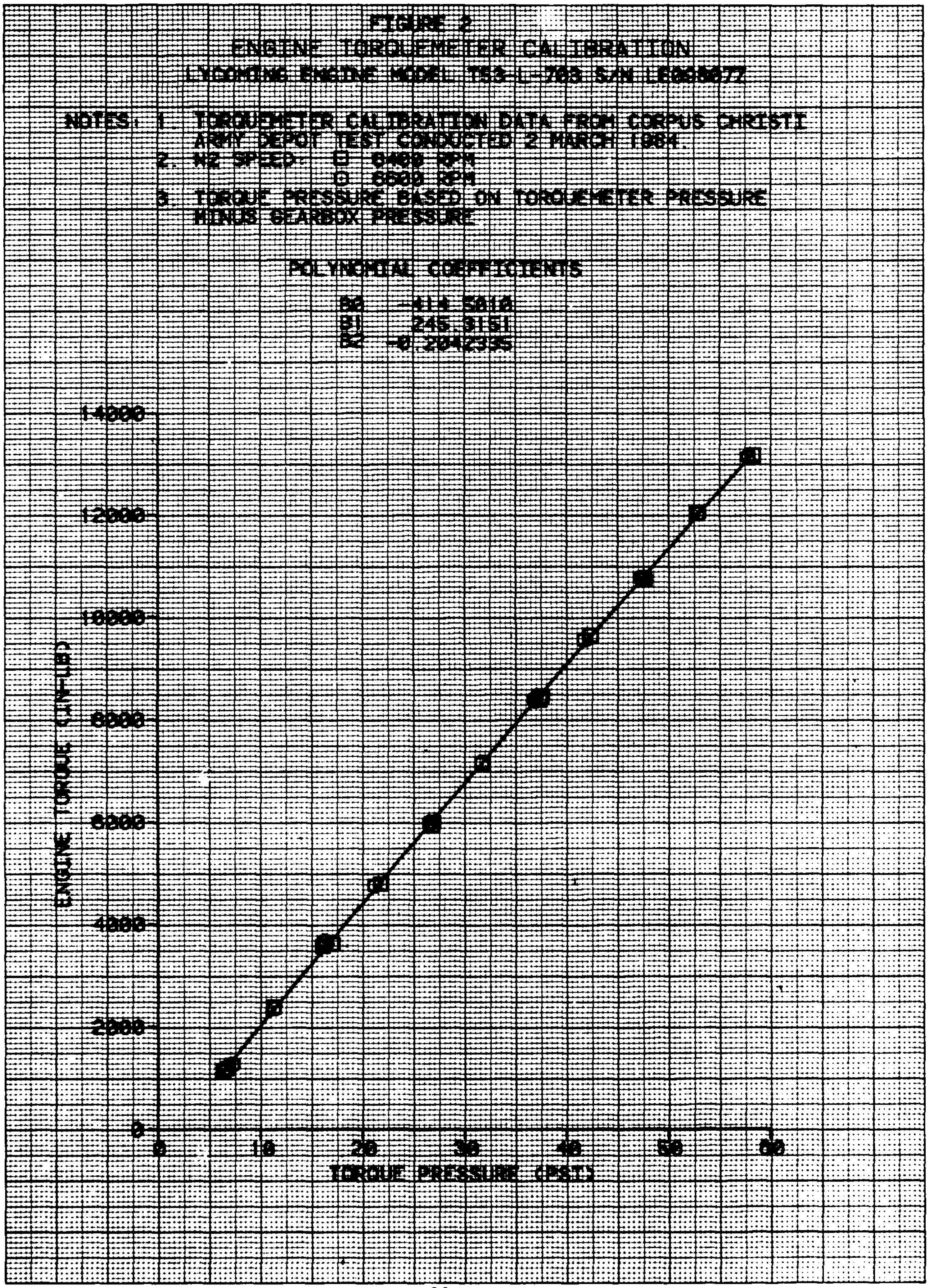


FIGURE 2
ENGINE TORQUEMETER CALIBRATION
LYCOMING ENGINE MODEL T53-L-703 S/N LE090077
NOTES: 1. TORQUEMETER CALIBRATION DATA FROM CORPUS CHRISTI ARMY DEPOT TEST CONDUCTED 2 MARCH 1984.
2. N2 SPEED: 6400 RPM
6600 RPM
3. TORQUE PRESSURE BASED ON TORQUEMETER PRESSURE MINUS GEARBOX PRESSURE
POLYNOMIAL COEFFICIENTS
B0 -414.5810
B1 245.3151
B2 -0.2042335
ENGINE TORQUE (IN-LB)
14000
12000
10000
8000
6000
4000
2000
0
0
10
20
30
40
50
60
TORQUE PRESSURE (PSI)

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. Performance data were obtained using the basic methods described in Army Material Command Pamphlet AMCP 706-204 (ref 6, app A). Performance testing was conducted in zero sideslip flight. Handling qualities data were evaluated using standard test methods described in Naval Air Test Center Flight Test Manual FTM No. 101 (ref 7, app A).

AIRCRAFT WEIGHT AND BALANCE

2. The aircraft was weighed in the instrumented configuration with full oil and all fuel drained prior to the start of the Preliminary Airworthiness Evaluation program. The initial weight of the aircraft was 7468 pounds with the longitudinal center of gravity (cg) located at (FS) 200.9. The aircraft was periodically weighed during the program as items necessary for various tests were added or deleted. The aircraft gross weight was adjusted for the external fuel tanks installation. This increased the gross weight of the aircraft by 200 pounds. The fuel cells and an external sight gage were also calibrated. The measured internal fuel capacity using the gravity fueling method was 254.4 gallons. The fuel weight for each test flight was determined prior to engine start and after engine shutdown by using the external sight gage to determine the volume and measuring the specific gravity of the fuel. The calibrated cockpit fuel totalizer indicator was used during the test and at the end of each test was compared with the sight gage readings.

PERFORMANCE

General

3. Helicopter performance was generalized through the use of nondimensional coefficients as follows using the 1968 US Standard Atmosphere:

a. Coefficient of Power (C_P):

$$C_P = \frac{SHP\ (550)}{\rho A(\Omega R)^3} \qquad (1)$$

b. Coefficient of Thrust (C_T):

$$C_T = \frac{GW}{\rho A(\Omega R)^2} \tag{2}$$

c. Advance Ratio (μ):

$$\mu = \frac{V_T(1.6878)}{\Omega R} \tag{3}$$

Where:

SHP = Engine output shaft horsepower

ρ = Ambient air density ($lb\text{-}sec^2/ft^4$)

A = Main rotor disc area = 1520.53 ft^2

Ω = Main rotor angular velocity (radians/sec) = $\frac{2\pi}{60}$ x RPM

R = Main rotor radius = 22.0 ft

GW = Gross weight (lb)

V_T = True airspeed (kt) = $\frac{V_E}{1.6878\sqrt{\rho/\rho_o}}$

1.6878 = Conversion factor (ft/sec-kt)

ρ_o = 0.0023769 ($lb\text{-}sec^2/ft^4$)

V_E = Equivalent airspeed (ft/sec) =

$$\left\{\frac{7\ (70.7262\ P_a)}{\rho_o}\left[\left(\frac{Q_c}{P_a} + 1\right)^{2/7} - 1\right]\right\}^{1/2}$$

70.7262 = Conversion factor (lb/ft^2 -in. -Hg)

Q_c = Dynamic pressure (in. -Hg)

P_a = Ambient air pressure (in. -Hg)

At the nominal operating rotor speed of 324 RPM (100%) the following constants may be used to calculate C_P and C_T:

ΩR = 746.44 ft/sec

$A(\Omega R)^2$ = 847203716.6 ft^4/sec^2

$\frac{A(\Omega R)^3}{550}$ = 1149797798 $\frac{SHP\ ft^4}{lb\ sec^2}$

4. The engine output shaft torque was determined by use of the engine manufacturer's torque system and using the calibration obtained at Corpus Christi Army Depot on 2 March 1984 (fig 1, app C). The output shaft horsepower (SHP) was determined from the engine shaft torque and rotational speed by equation (4).

$$SHP = \frac{Q(N_p)}{5252.113} \qquad (4)$$

Where:

Q = Engine output shaft torque (ft-lb)

N_P = Engine output shaft rotational speed (rpm)

5252.113 = Conversion factor (ft-lb-rev/min-SHP)

Level Flight Performance

5. Level flight performance was determined by using equations 1 through 3, rewritten in the following format.

$$C_P = \frac{SHP\ (478935.3)}{\delta\sqrt{\theta}\left[\frac{N_R}{\sqrt{\theta}}\right]^3 (\rho_o A R^3)} \qquad (5)$$

$$C_T = \frac{GW\ (91.19)}{\delta\left[\frac{N_R}{\sqrt{\theta}}\right]^2 (\rho_o A R^2)} \qquad (6)$$

$$\mu = \frac{V_T \quad (16.12)}{(R\sqrt{\theta}\,) \quad \frac{N_R}{\sqrt{\theta}}} \qquad (7)$$

Changes in horsepower due to changes in flat plate area were determined from the following equation:

$$\Delta SHP = \frac{(\Delta F_e)(\sigma)(V_T{}^3)}{96254} \qquad (8)$$

Where:

δ = Pressure ratio = $\frac{P_a}{P_{a_o}}$

P_{a_o} = 29.92126 in. -Hg

θ = Temperature ratio = $\frac{OAT + 273.15}{288.15}$

OAT = Ambient air temperature (°C)

N_R = Main rotor speed (rev/min)

$\sigma = \delta/\theta$

478935.3 = Conversion factor (ft-lb-sec^2 -rev^3/min^3-SHP)

91.19 = Conversion factor (sec^2-rev^2/min^2)

16.12 = Conversion factor (ft-rev/min-kt)

ΔF_e = Change in equivalent flat plate area (ft^2)

96254 = Conversion factor (ft^2-kt^3/SHP)

6. Each speed power was flown in zero sideslip flight by reference to an angle of sideslip indicator at a predetermined coefficient of thrust (C_T) and referred rotor speed ($N_R/\sqrt{\theta}$). To maintain the ratio of gross weight to pressure ratio (W/δ) constant, altitude was increased as fuel was consumed. To maintain $N_R/\sqrt{\theta}$ constant rotor speed was changed as temperature changed.

7. Test-day level flight data was corrected to a referred rotor speed of 324 rpm and to standard day conditions by the following equations:

$$SHP_s = SHP_t \frac{(\delta_s \sqrt{\theta_s}) \left[\frac{N_R}{\sqrt{\theta}} \right]_s^3}{(\delta_t \sqrt{\theta_t}) \left[\frac{N_R}{\sqrt{\theta}} \right]_s^3} \qquad (9)$$

$$V_{T_s} = V_{T_t} \frac{\left. \frac{N_R}{\sqrt{\theta}} \right|_s}{\left. \frac{N_R}{\sqrt{\theta}} \right|_t} \qquad (10)$$

where:

subscript s = standard day conditions
subscript t = test day conditions

8. The data obtained with and without external fuel tanks installed were analyzed by use of a three dimensional plot (C_T and μ versus C_P) for each configuration. The reduction of this simulated three dimensional plot to a family of curves of C_T versus C_P, for a constant μ value, allows determination of the power required as a function of airspeed for any value of C_T. The data obtained with the external fuel tanks installed were compared with data obtained with the basic aircraft for determining the equivalent flat plate area of the external fuel tanks.

Autorotational Descent Performance

9. Autorotational descent performance data were obtained at various airspeeds with constant rotor speed and at various rotor speeds with constant airspeed. The tapeline rates of descent were calculated by the following equation.

$$R/D_{tapeline} = \left(\frac{dH_P}{dt} \right) \left(\frac{T_t}{T_s} \right) \quad (11)$$

where:

T = ambient temperature (K)

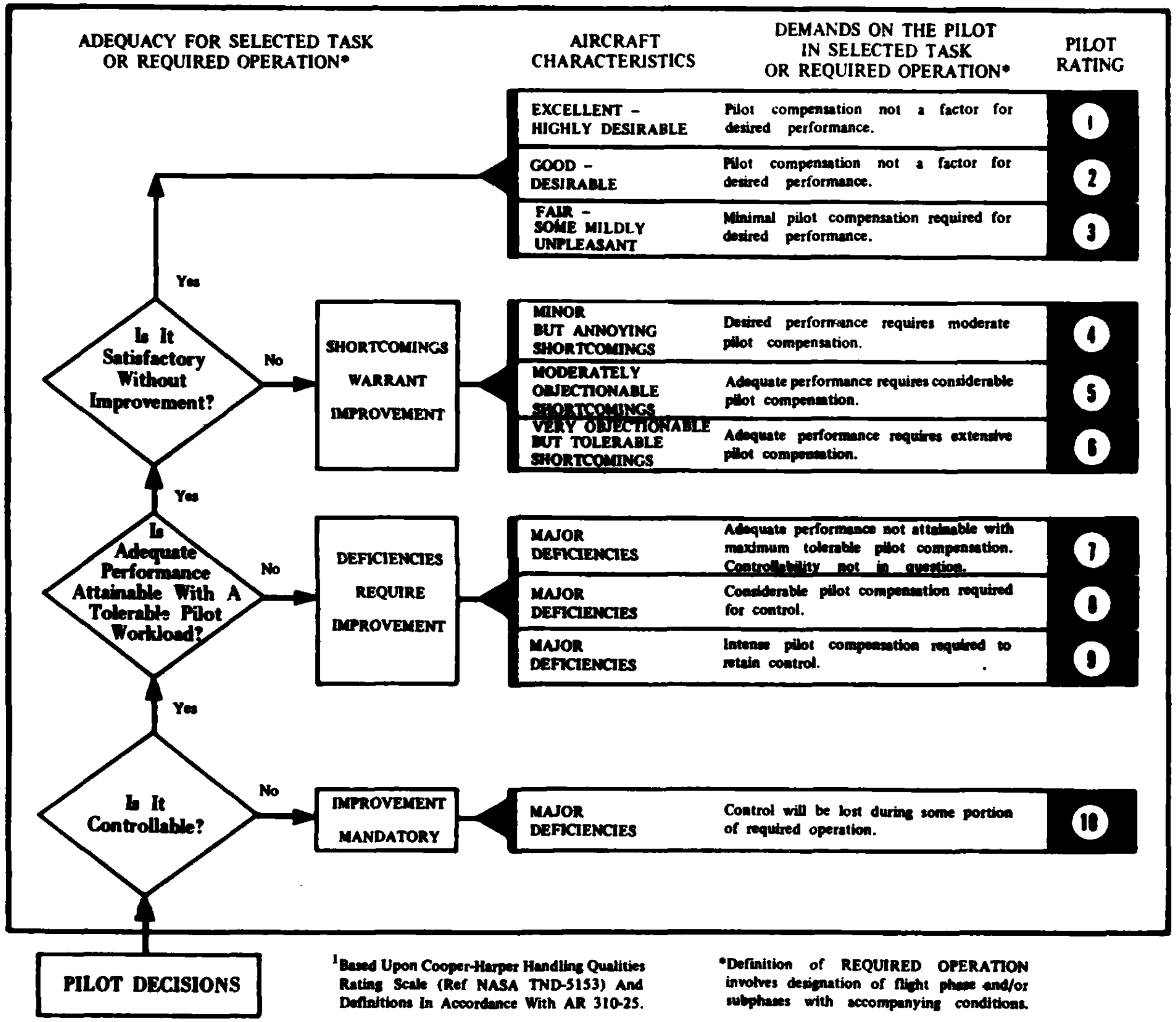
The tapeline rate of descent was plotted versus test pressure altitude. These plots were entered at the desired pressure altitude to obtain data for presentation in figures 11 and 12, appendix E.

HANDLING QUALITIES

10. Stability and control data were collected and evaluated using standard test methods described in reference 7, appendix A. The Handling Qualities Rating Scale (HQRS) presented in figure 1 was used to augment pilot comments relative to handling qualities.

Vibration

11. Vibration was qualitatively evaluated and the Vibration Rating Scale (VRS) presented in figure 2 was used to augment crew comments on aircraft vibration levels.



[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

DEGREE OF VIBRATION	DESCRIPTION[1]	PILOT RATING
No vibration		0
Slight	Not apparent to experienced aircrew fully occupied by their tasks, but noticeable if their attention is directed to it or if not otherwise occupied.	1 2 3
Moderate	Experienced aircrew are aware of the vibration but it does not affect their work, at least over a short period.	4 5 6
Severe	Vibration is immediately apparent to experienced aircrew even when fully occupied. Performance of primary task is affected or tasks can only be done with difficulty.	7 8 9
Intolerable	Sole preoccupation of aircrew is to reduce vibration level.	10

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

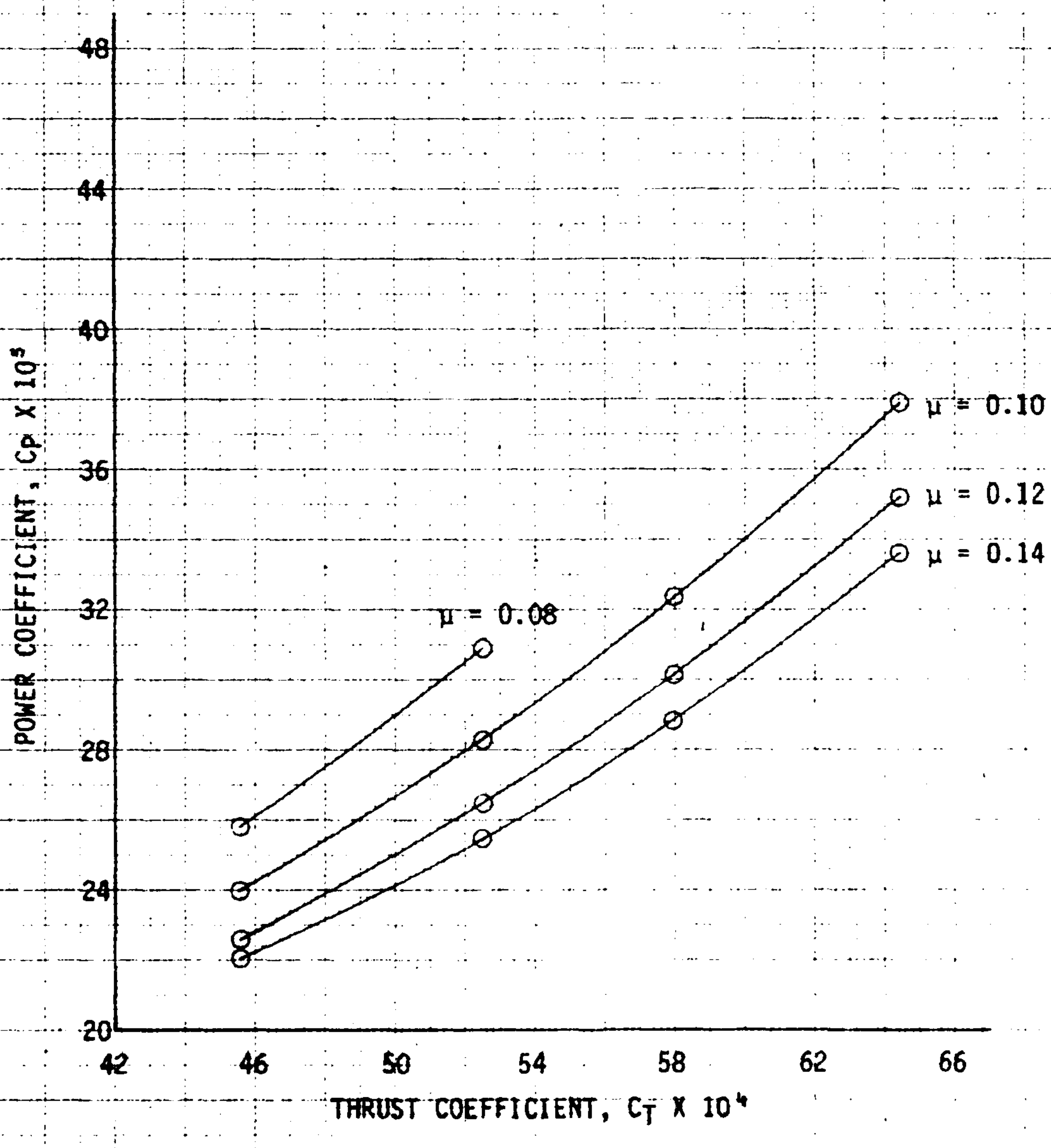
Figure 2. Vibration Rating Scale

APPENDIX E. TEST DATA

INDEX

FIGURE 1
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

NOTES: 1. CLEAN CONFIGURATION
2. ZERO SIDESLIP
3. REFERRED ROTOR SPEED = 324 RPM
4. AVG LONG. CG LOCATION FS 196.0(MID)
5. POINTS OBTAINED FROM FIGS. 3 THROUGH 6



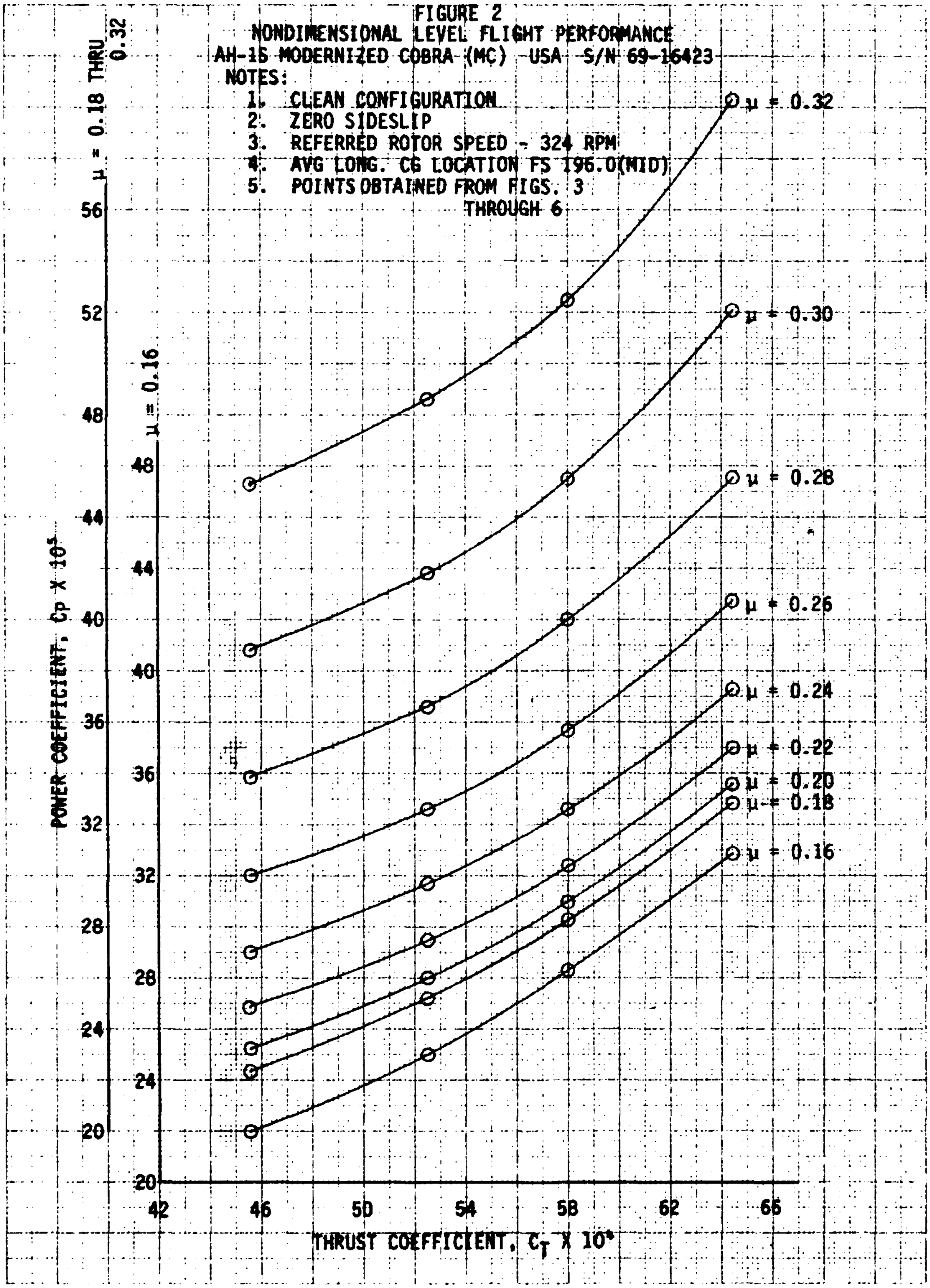
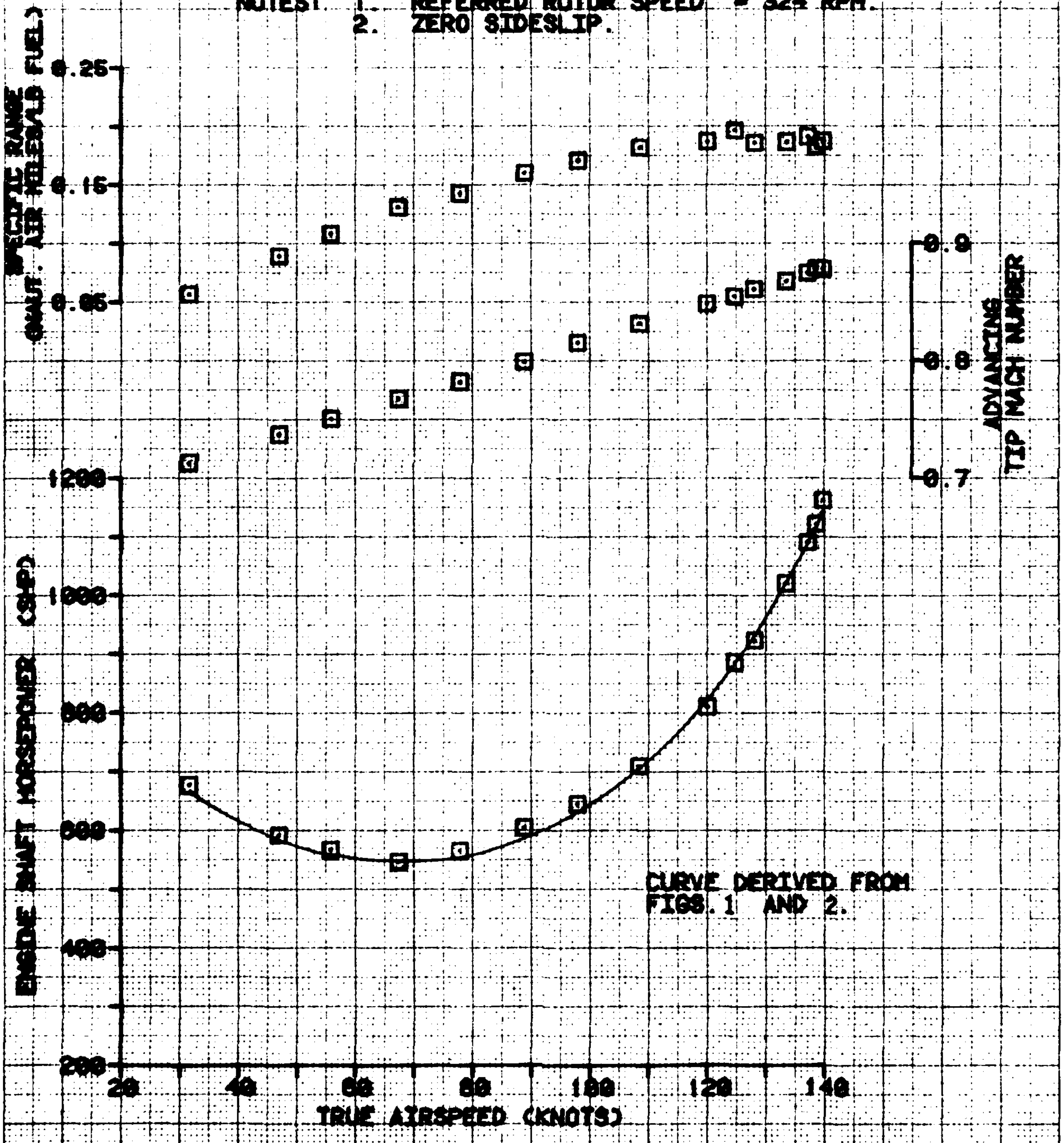


FIGURE 2
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423
NOTES:
1. CLEAN CONFIGURATION
2. ZERO SIDESLIP
3. REFERRED ROTOR SPEED - 324 RPM
4. AVG LONG. CG LOCATION FS 196.0(MID)
5. POINTS OBTAINED FROM FIGS. 3 THROUGH 6
μ = 0.18 THRU 0.32
μ = 0.16
μ = 0.32
μ = 0.30
μ = 0.28
μ = 0.26
μ = 0.24
μ = 0.22
μ = 0.20
μ = 0.18
μ = 0.16
POWER COEFFICIENT, CP X 10⁵
THRUST COEFFICIENT, CT X 10⁴
20
24
28
32
36
40
44
48
52
56
42
46
50
54
58
62
66

FIGURE 3
LEVEL FLIGHT PERFORMANCE
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONGITUDINAL CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG CT	CONFIG
8530	196.0 (MID)	1410	0.0	319	0.004555	CLEAN

NOTES: 1. REFERRED ROTOR SPEED = 324 RPM.
2. ZERO SIDESLIP.



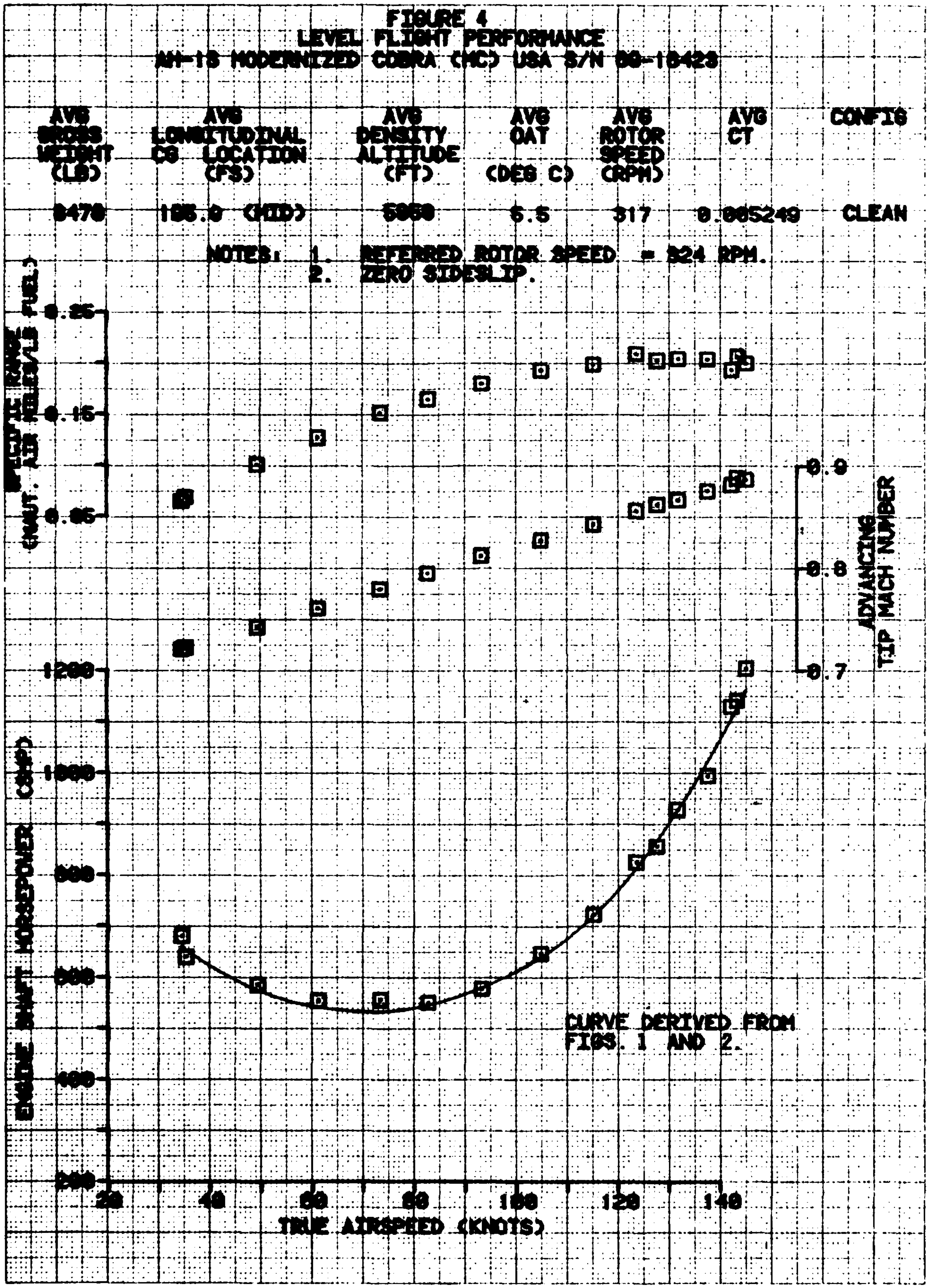


FIGURE 4
LEVEL FLIGHT PERFORMANCE
AH-1S MODERNIZED COBRA (MC) USA S/N 80-18428
AVG GROSS WEIGHT (LB)
AVG LONGITUDINAL CG LOCATION (FS)
AVG DENSITY ALTITUDE (FT)
AVG OAT (DEG C)
AVG ROTOR SPEED (RPM)
AVG CT
CONFIG
CLEAN
NOTES: 1. REFERRED ROTOR SPEED = 324 RPM.
2. ZERO SIDESLIP.
SPECIFIC RANGE (NAUT. AIR MILES/LB FUEL)
ADVANCING TIP MACH NUMBER
ENGINE SHAFT HORSEPOWER (SHP)
CURVE DERIVED FROM FIGS. 1 AND 2.
TRUE AIRSPEED (KNOTS)

FIGURE 5
LEVEL FLIGHT PERFORMANCE
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONGITUDINAL CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG CT	CONFIG
9020	196.0 (MID)	7550	5.5	319	0.005798	CLEAN

NOTES: 1. REFERRED ROTOR SPEED = 324 RPM.
2. ZERO SIDESLIP.

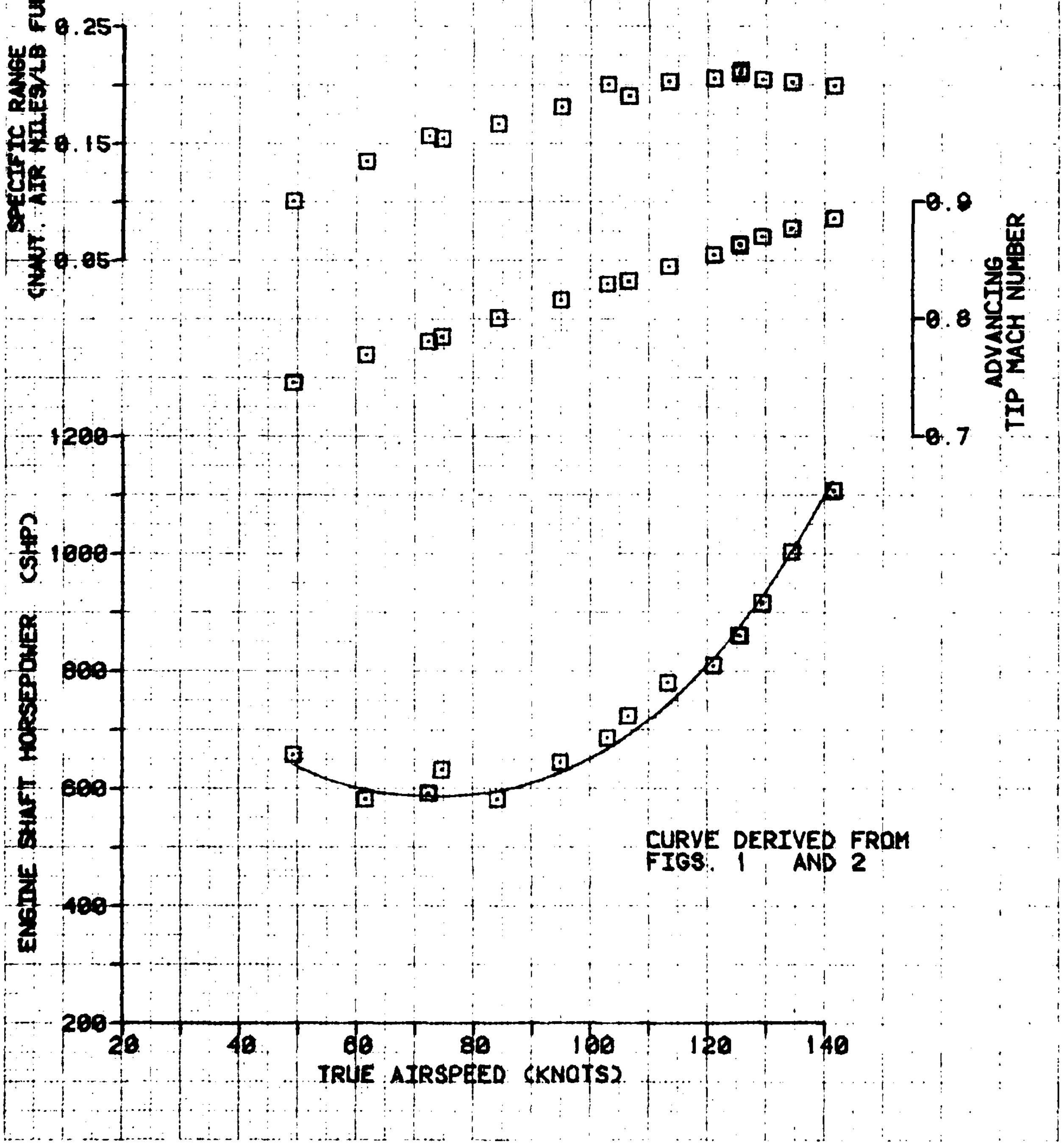
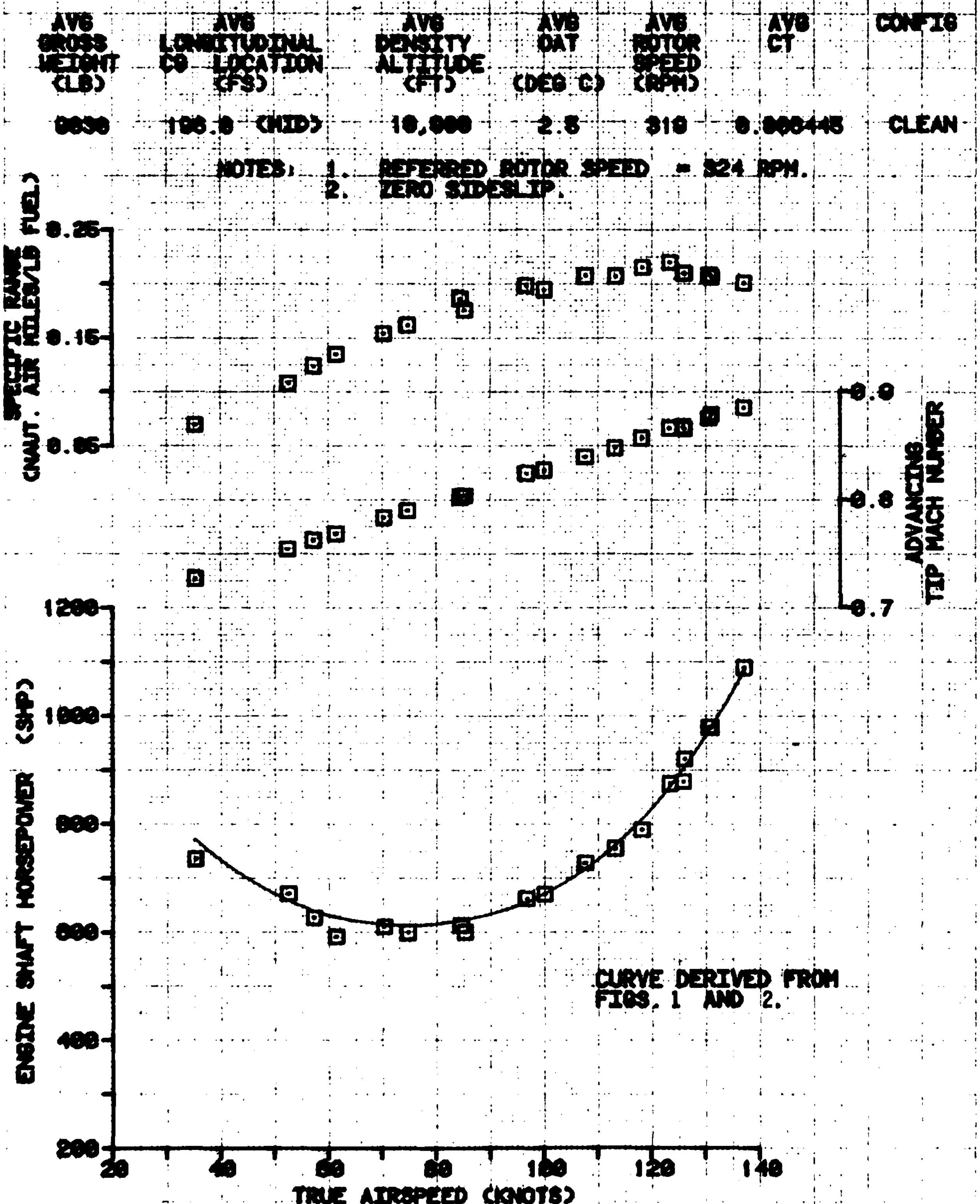


FIGURE 6
LEVEL FLIGHT PERFORMANCE
AH-1S MODERNIZED COBRA (MC) USA S/N 80-10423



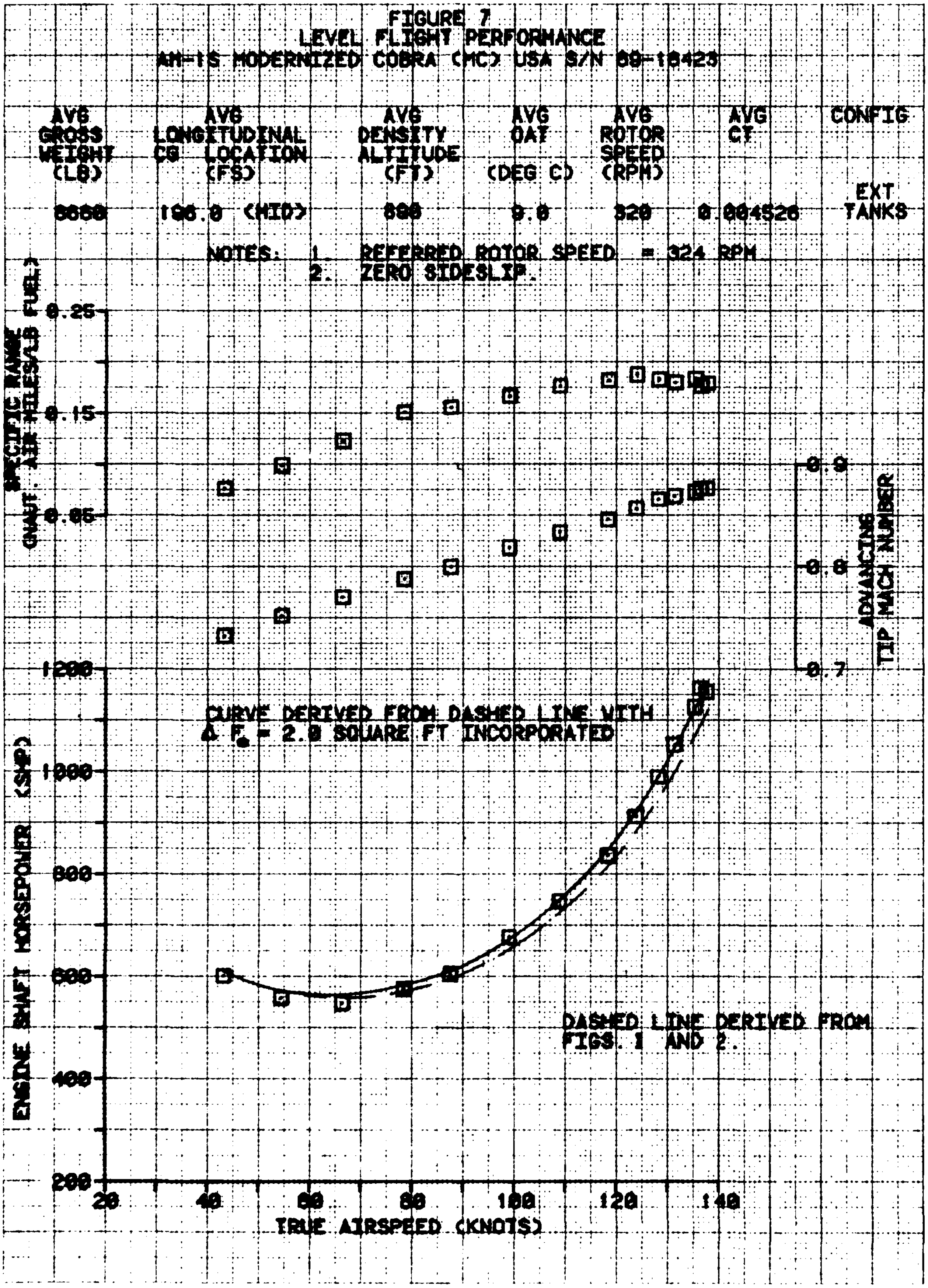


FIGURE 7
LEVEL FLIGHT PERFORMANCE
AH-1S MODERNIZED COBRA (MC) USA S/N 80-18425
AVG GROSS WEIGHT (LB) 8660
AVG LONGITUDINAL CG LOCATION (FS) 196.0 (MID)
AVG DENSITY ALTITUDE (FT) 800
AVG OAT (DEG C) 9.0
AVG ROTOR SPEED (RPM) 320
AVG CT 0.004526
CONFIG EXT TANKS
NOTES: 1. REFERRED ROTOR SPEED = 324 RPM
2. ZERO SIDESLIP.
SPECIFIC RANGE (NAUT. AIR MILES/LB FUEL)
ADVANCING TIP MACH NUMBER
CURVE DERIVED FROM DASHED LINE WITH Δ Fe = 2.0 SQUARE FT INCORPORATED
DASHED LINE DERIVED FROM FIGS. 1 AND 2.
ENGINE SHAFT HORSEPOWER (SHP)
TRUE AIRSPEED (KNOTS)

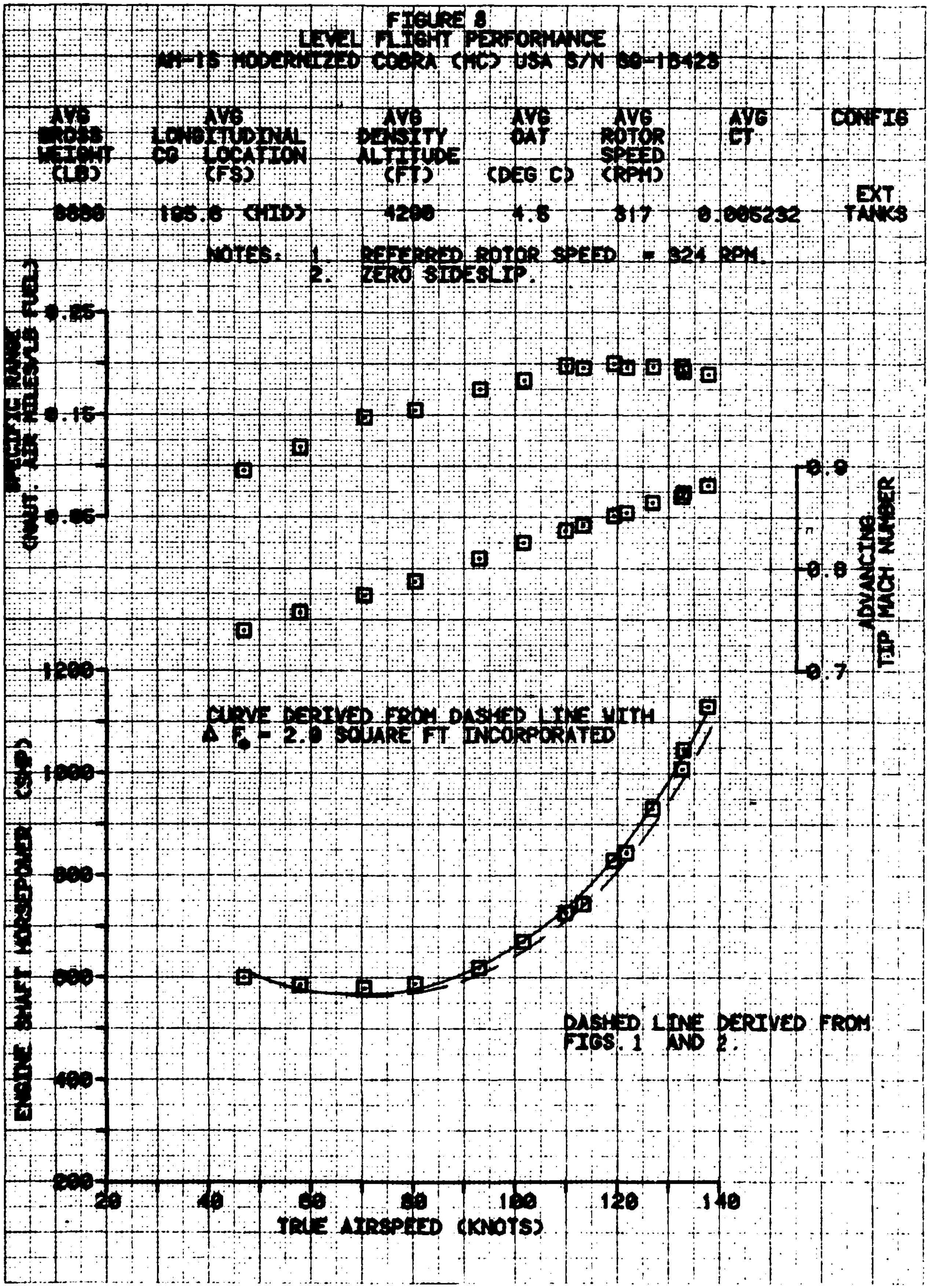


FIGURE 8
LEVEL FLIGHT PERFORMANCE
AH-1S MODERNIZED COBRA (MC)

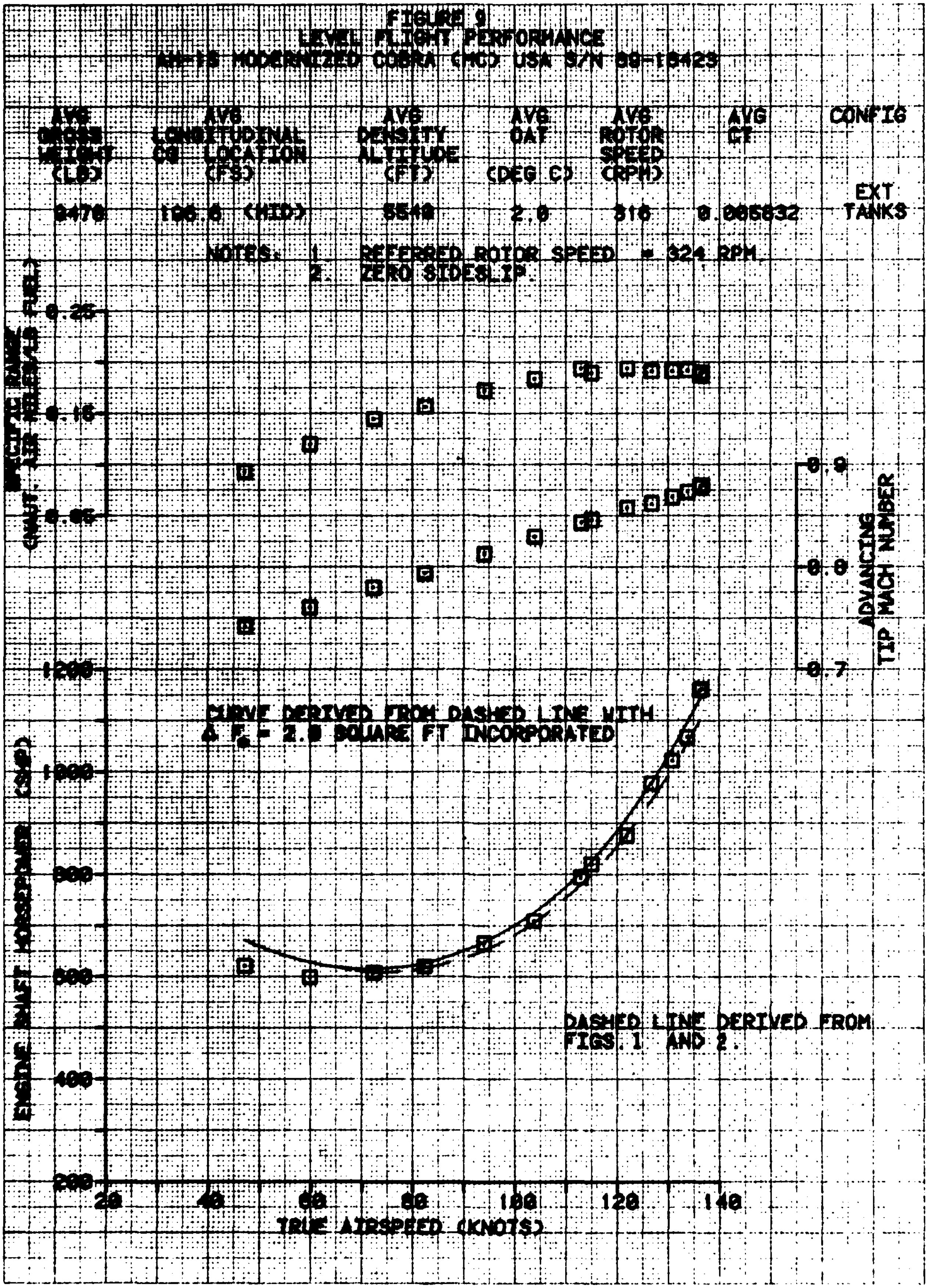


FIGURE 9
LEVEL FLIGHT PERFORMANCE
AH-1S MODERNIZED COBRA (MC) USA S/N 68-15423
AVG GROSS WEIGHT (LB)
AVG LONGITUDINAL CG LOCATION (FS)
AVG DENSITY ALTITUDE (FT)
AVG OAT (DEG C)
AVG ROTOR SPEED (RPM)
AVG CT
CONFIG
9470
196.6 (MID)
5540
2.0
316
0.005832
EXT TANKS
NOTES: 1. REFERRED ROTOR SPEED = 324 RPM
2. ZERO SIDESLIP
SPECIFIC RANGE (NAUT. AIR MILES/LB FUEL)
0.25
0.15
0.05
ADVANCING TIP MACH NUMBER
0.9
0.8
0.7
CURVE DERIVED FROM DASHED LINE WITH
Δ Fe = 2.0 SQUARE FT INCORPORATED
ENGINE SHAFT HORSEPOWER (SHP)
1200
1000
800
600
400
200
DASHED LINE DERIVED FROM
FIGS. 1 AND 2.
20
40
60
80
100
120
140
TRUE AIRSPEED (KNOTS)

FIGURE 10
LEVEL FLIGHT PERFORMANCE
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONGITUDINAL CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG CT	CONFIG
8970	196.2 (MID)	10,990	-1.0	314	0.006627	EXT TANKS

NOTES: 1. REFERRED ROTOR SPEED = 324 RPM.
2. ZERO SIDESLIP.

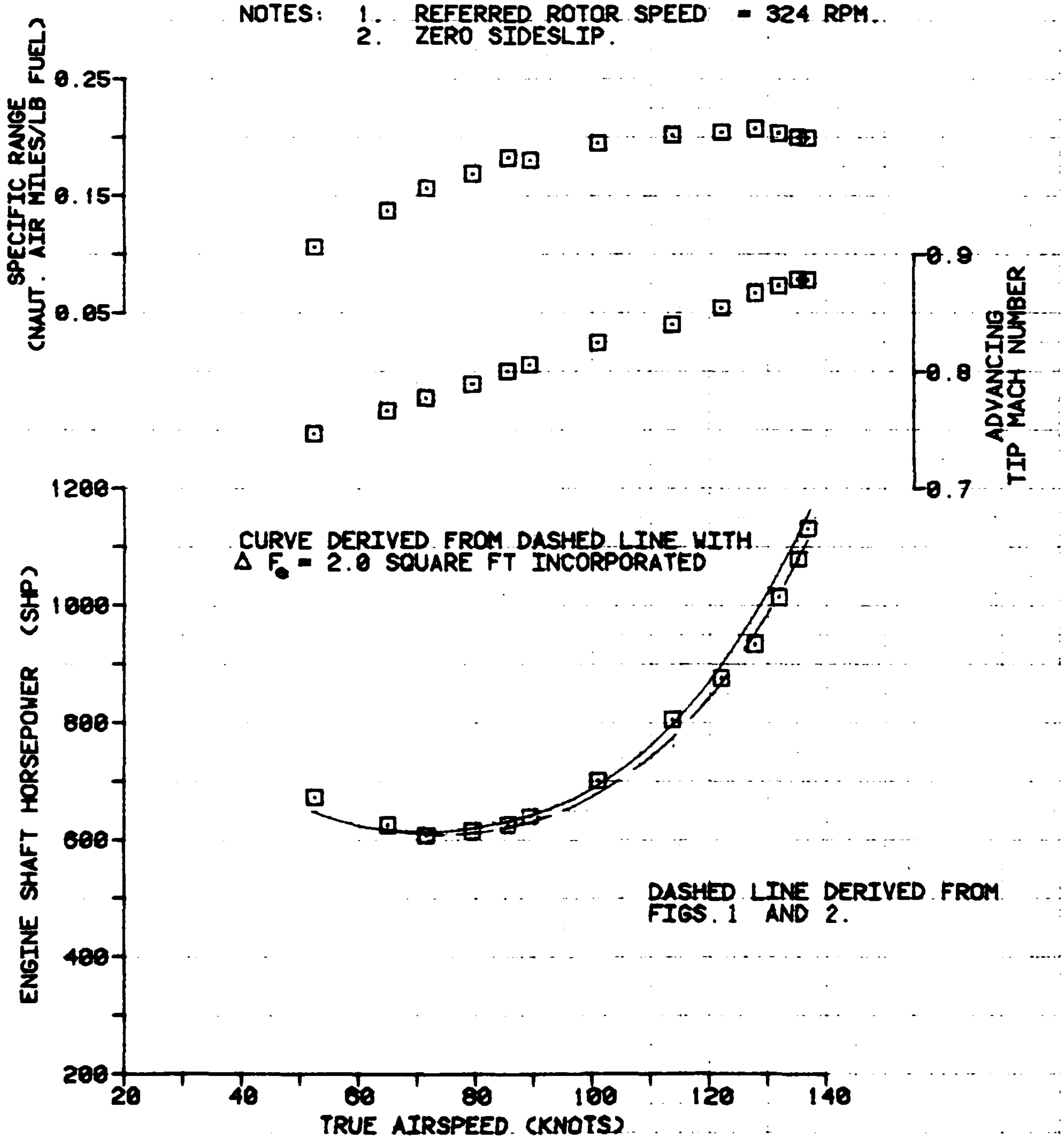


FIGURE 11
AUTOROTATIONAL DESCENT PERFORMANCE
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONGITUDINAL CG LOCATION (FS)	AVG PRESSURE ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)
8930	196.1 (MID)	5000	11.0	320

NOTES: 1. EXTERNAL FUEL TANKS FULL CONFIGURATION
2. BALL-CENTERED FLIGHT

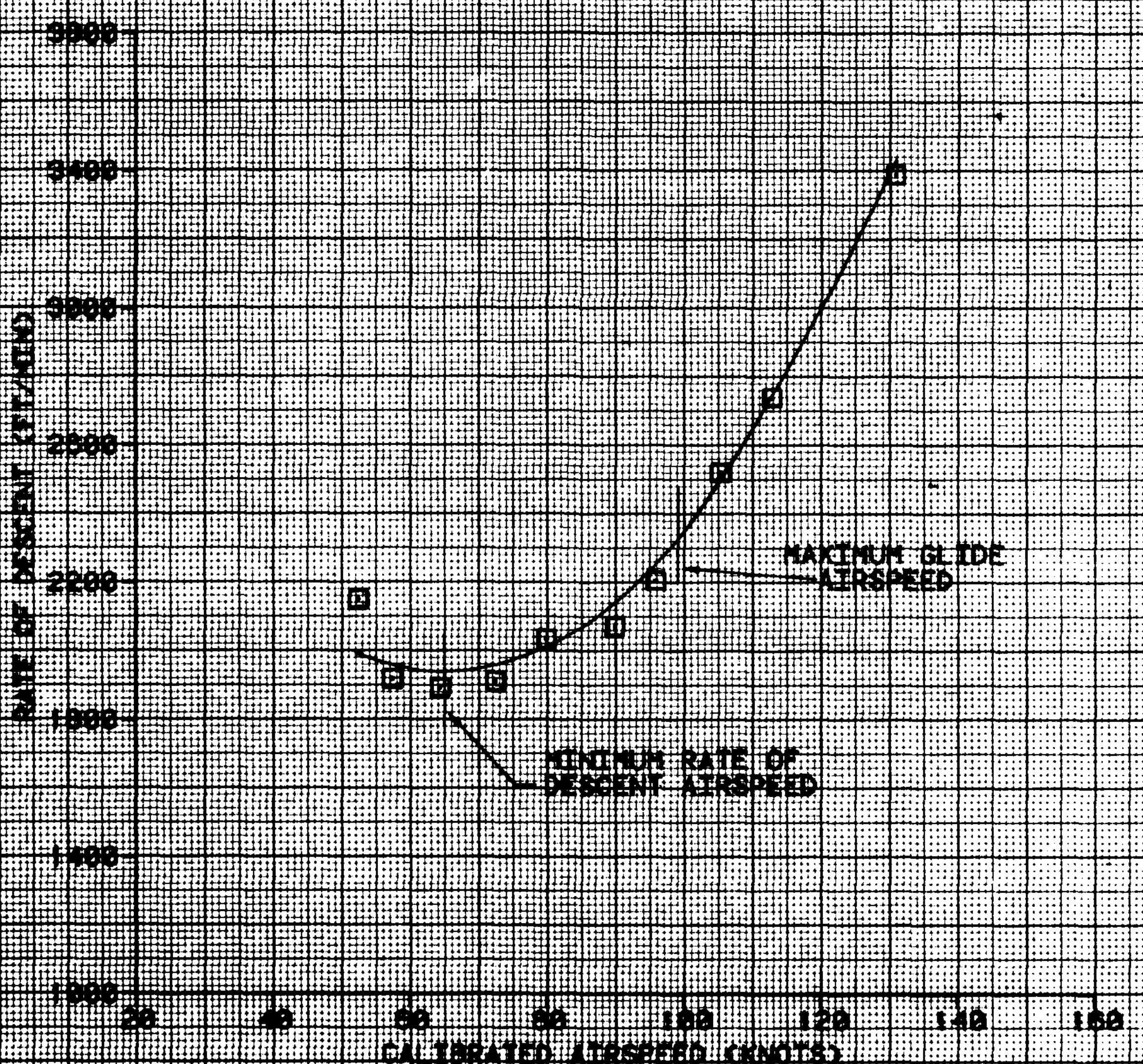
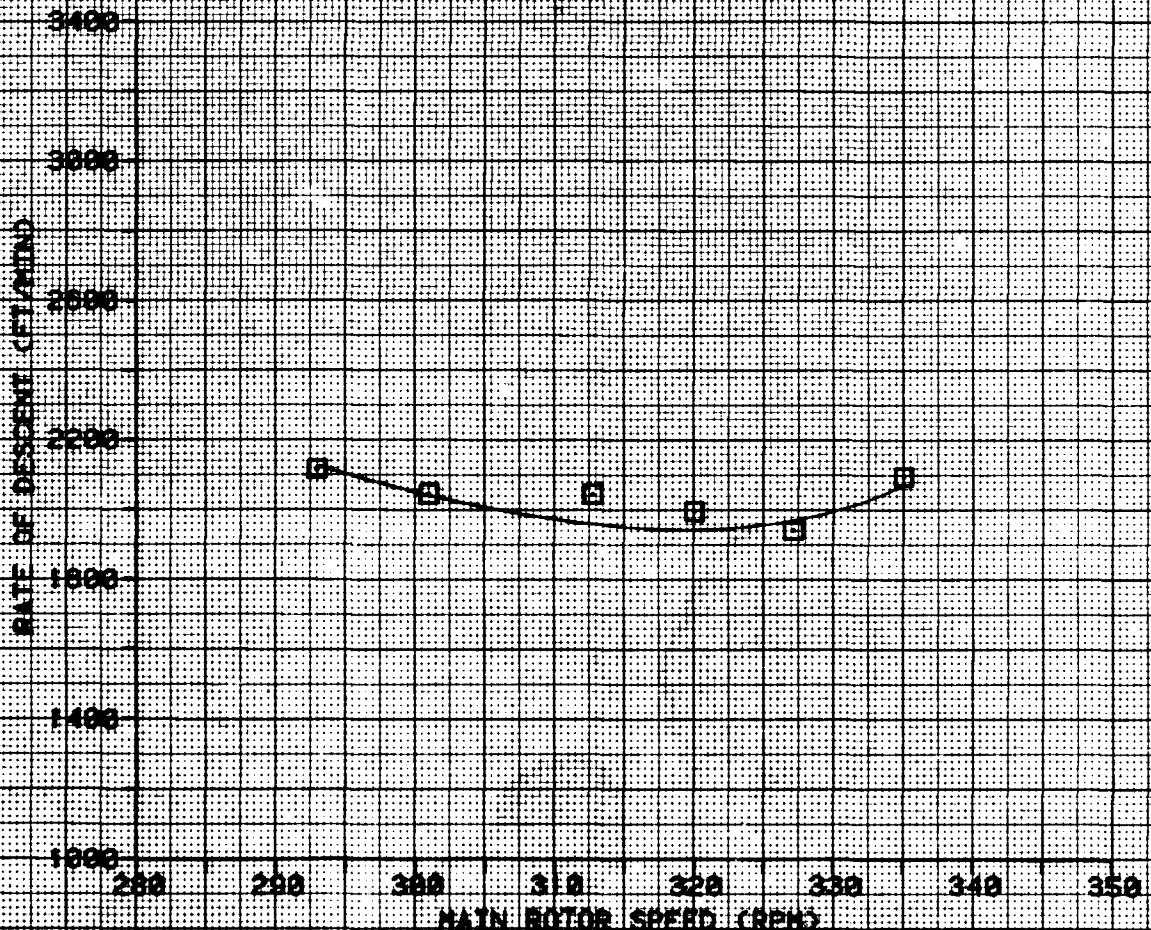


FIGURE 12
AUTOROTATIONAL DESCENT PERFORMANCE
AH-1S MODERNIZED COBRA USA S/N 69-16428

AVG GROSS WEIGHT (LB)	AVG LONGITUDINAL CG LOCATION (FS)	AVG PRESSURE ALTITUDE (FEET)	AVG OAT (DEG C)	AVG CALIBRATED AIRSPEED (KTS)
10100	196.4 (MID)	5000	14.3	85

NOTES: 1. EXTERNAL FUEL TANKS FULL CONFIGURATION
2. BALL-CENTERED FLIGHT



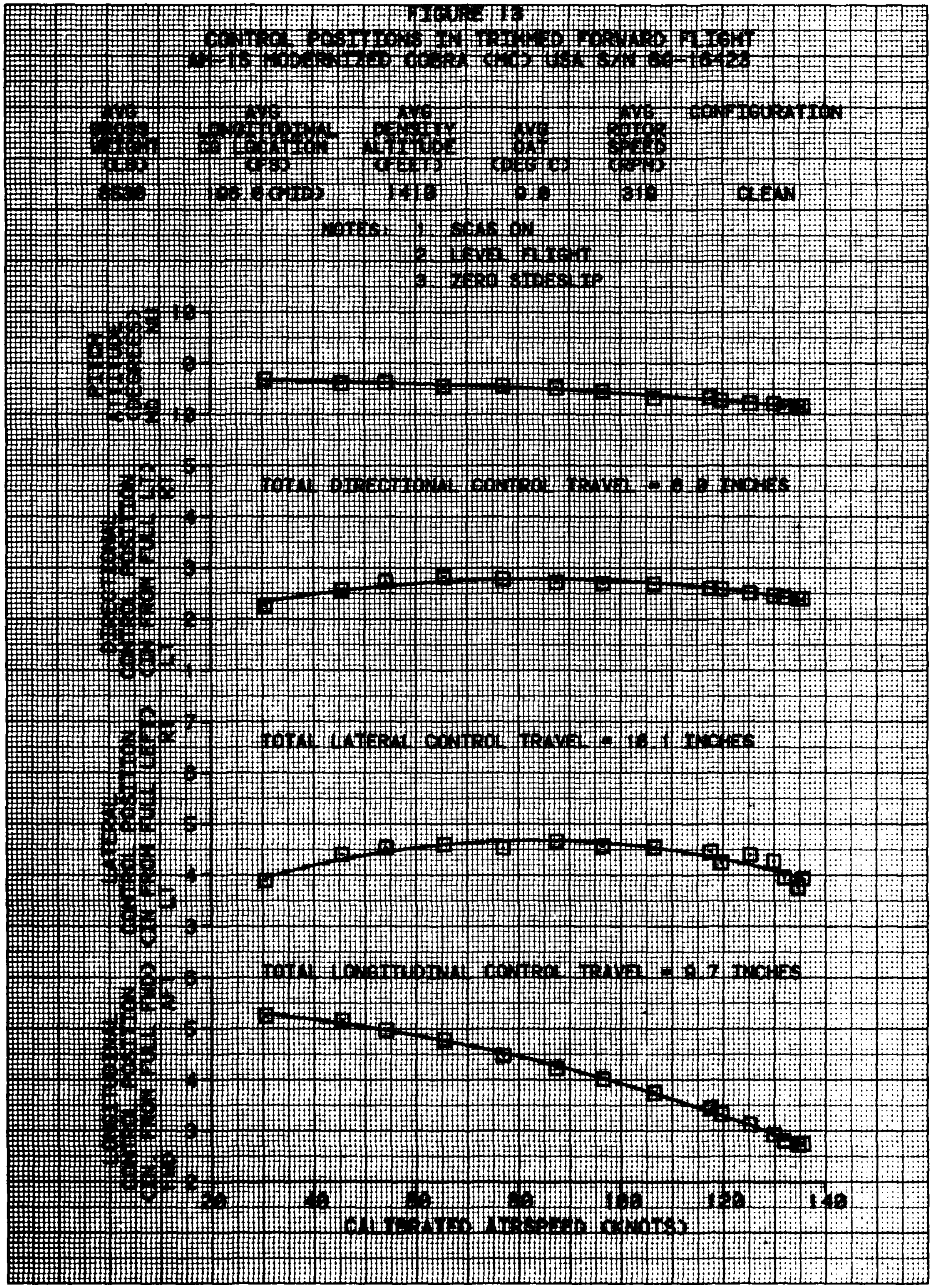


FIGURE 13
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
AH-1S MODERNIZED COBRA (MC) USA S/N

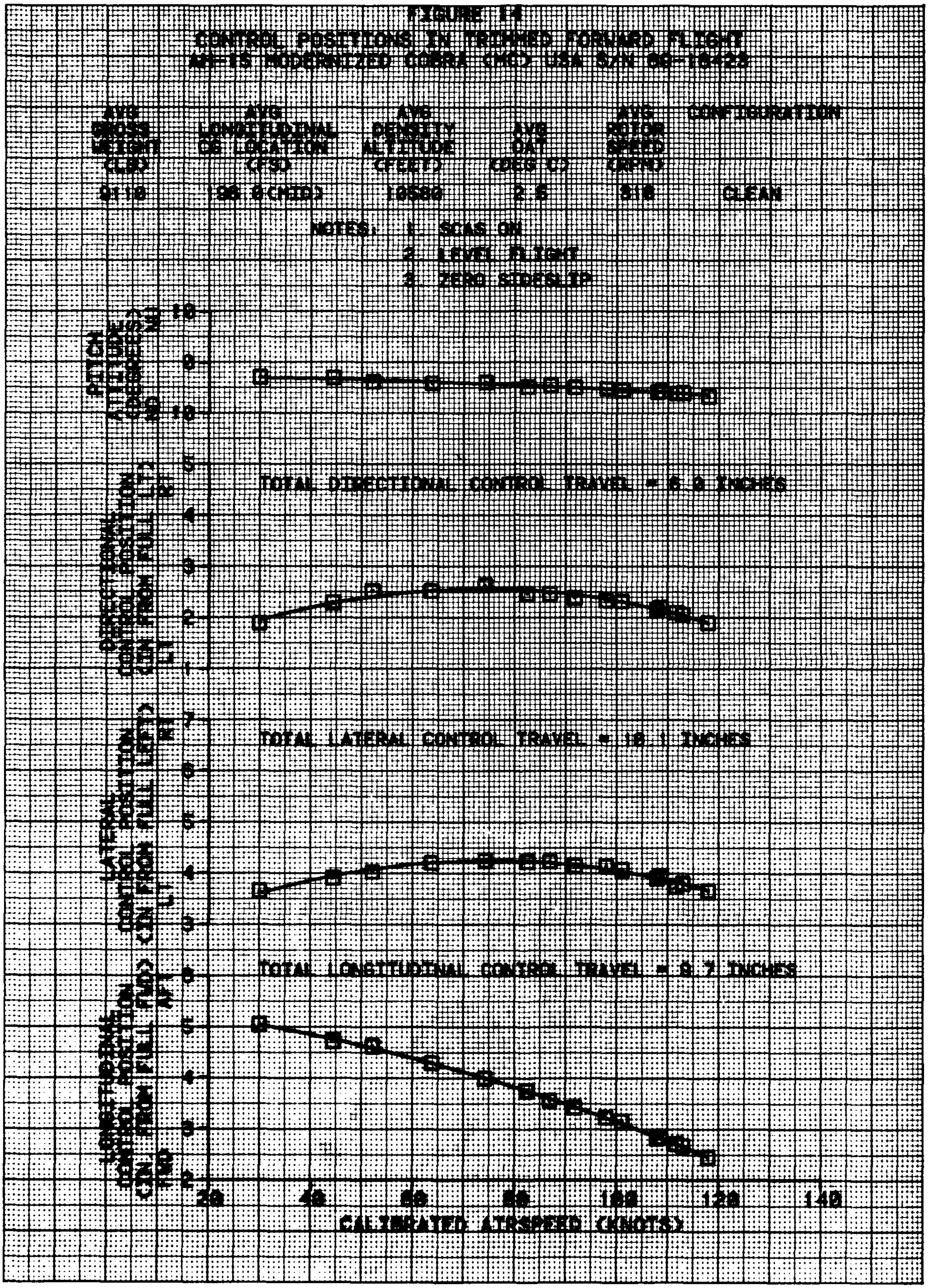
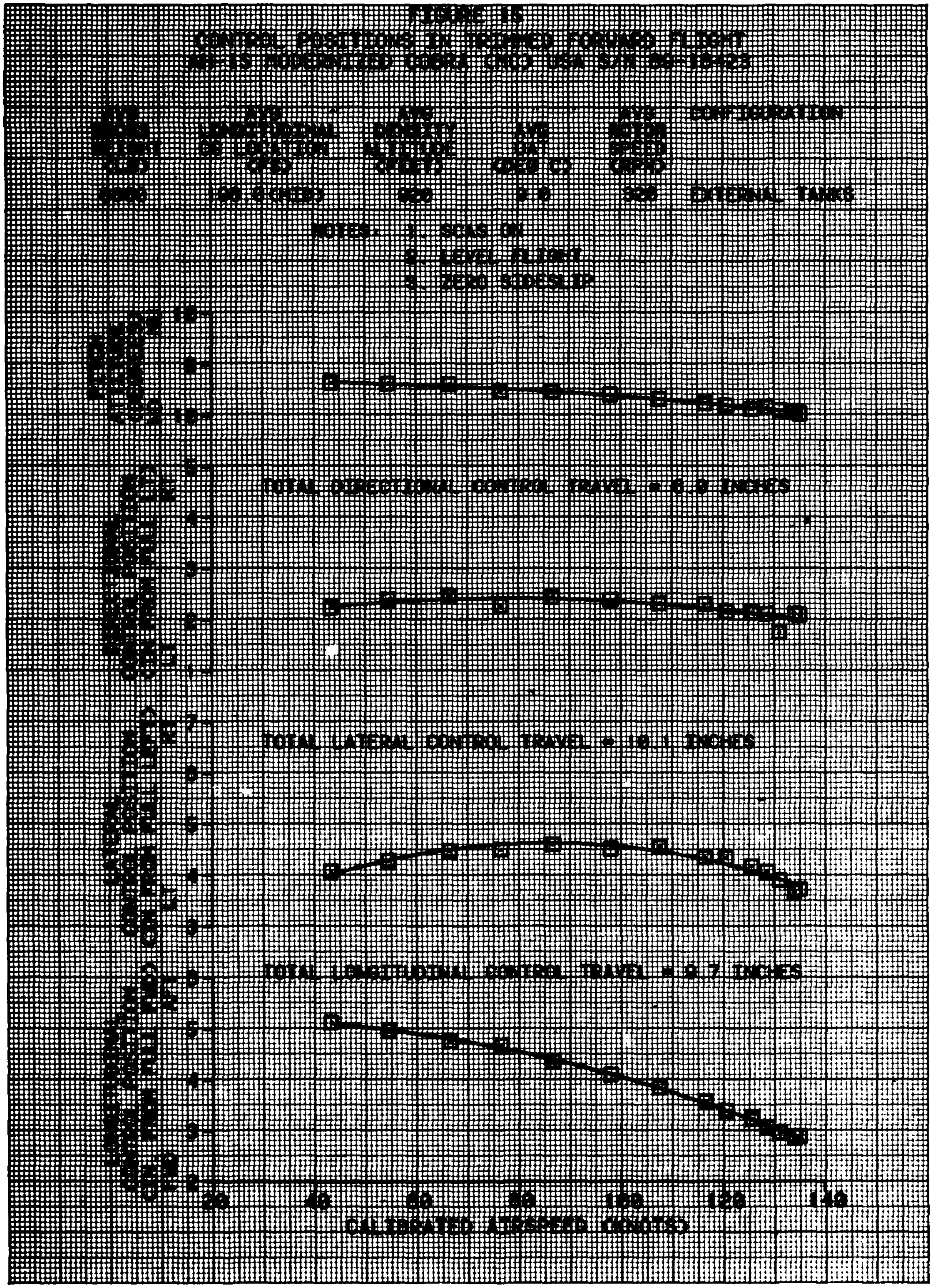
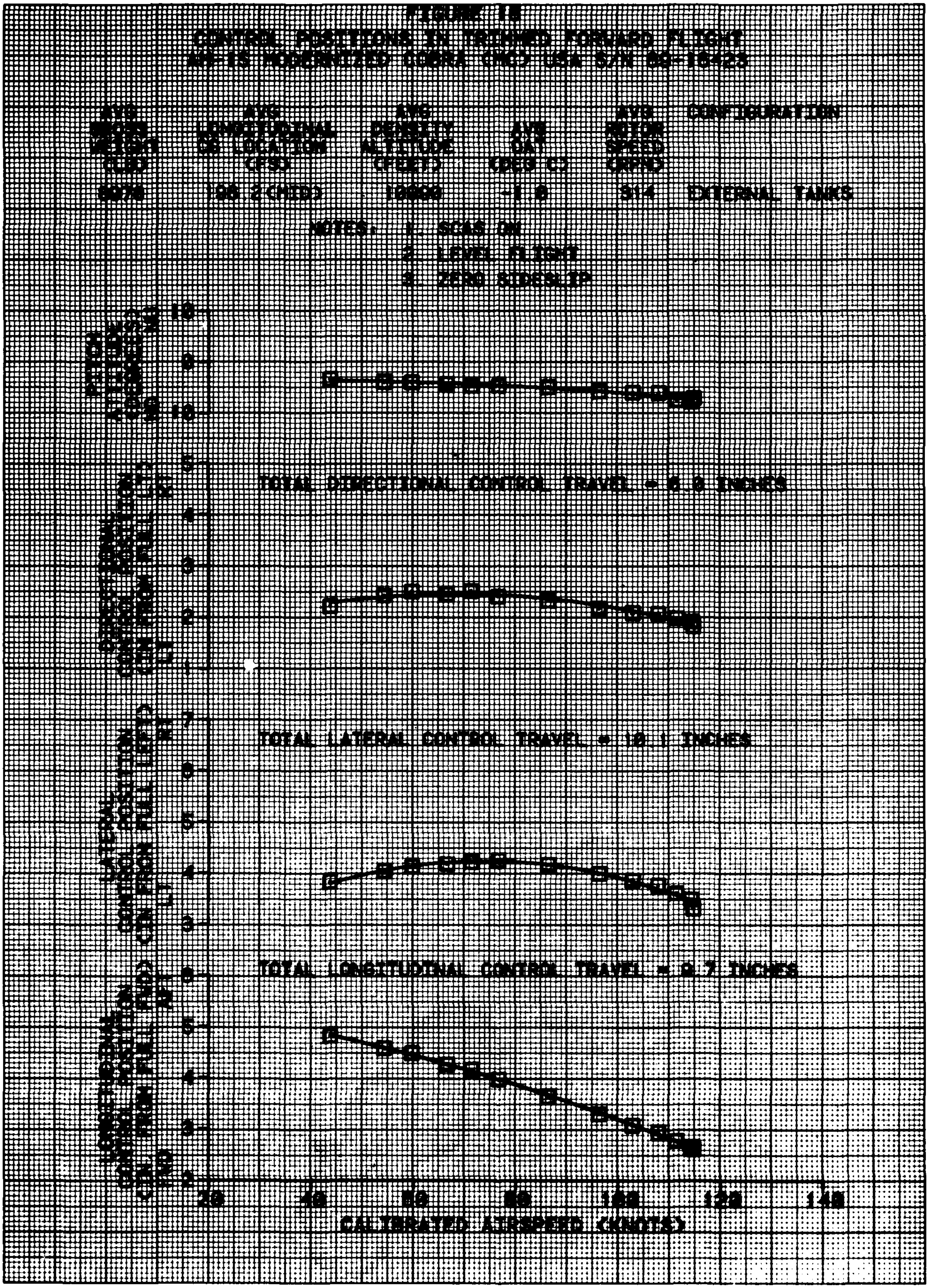


FIGURE 14
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
AH-1S MODERNIZED COBRA (MC) USA S/N 66-16423
AVG GROSS WEIGHT (LB)
AVG LONGITUDINAL CG LOCATION (FS)
AVG DENSITY ALTITUDE (FEET)
AVG OAT (DEG C)
AVG ROTOR SPEED (RPM)
CONFIGURATION
9110
196.0(MID)
10580
2.5
316
CLEAN
NOTES: 1. SCAS ON
2. LEVEL FLIGHT
3. ZERO SIDESLIP
PITCH ATTITUDE (DEGREES)
UP
DN
10
0
10
DIRECTIONAL CONTROL POSITION (IN FROM FULL LEFT)
RT
LT
TOTAL DIRECTIONAL CONTROL TRAVEL = 6.9 INCHES
5
4
3
2
1
LATERAL CONTROL POSITION (IN FROM FULL LEFT)
RT
LT
TOTAL LATERAL CONTROL TRAVEL = 10.1 INCHES
7
6
5
4
3
LONGITUDINAL CONTROL POSITION (IN FROM FULL FWD)
AFT
FWD
TOTAL LONGITUDINAL CONTROL TRAVEL = 9.7 INCHES
6
5
4
3
2
20
40
60
80
100
120
140
CALIBRATED AIRSPEED (KNOTS)


CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
NOTES: 1. SCAS ON
2. LEVEL FLIGHT
3. ZERO SIDESLIP
TOTAL LATERAL CONTROL TRAVEL
TOTAL LONGITUDINAL CONTROL TRAVEL
20
40
60
80
100
120
140
CALIBRATED AIRSPEED (KNOTS)


CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
AVG ROTOR SPEED (RPM)
AVG OAT (DEG C)
CONFIGURATION
314
EXTERNAL TANKS
NOTES: 1. SCAS ON
2. LEVEL FLIGHT
3. ZERO SIDESLIP
TOTAL DIRECTIONAL CONTROL TRAVEL
TOTAL LATERAL CONTROL TRAVEL
TOTAL LONGITUDINAL CONTROL TRAVEL
CALIBRATED AIRSPEED (KNOTS)

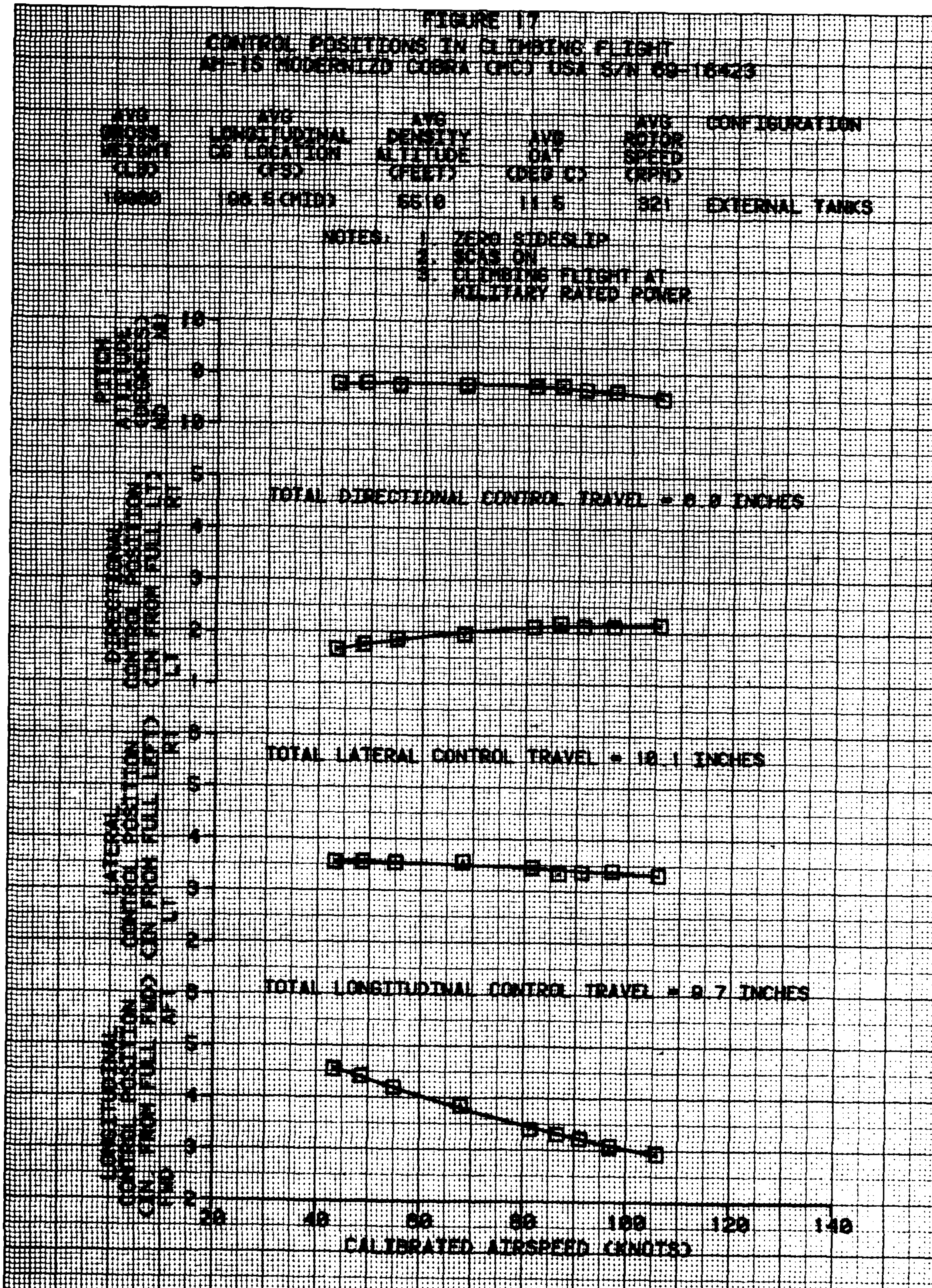


FIGURE 17
CONTROL POSITIONS IN CLIMBING FLIGHT
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423
AVG GROSS WEIGHT (LB)
AVG LONGITUDINAL CG LOCATION (FS)
AVG DENSITY ALTITUDE (FEET)
AVG OAT (DEG C)
AVG ROTOR SPEED (RPM)
CONFIGURATION
198.5(MID)
5510
11.5
321
EXTERNAL TANKS
NOTES: 1. ZERO SIDESLIP
2. SCAS ON
3. CLIMBING FLIGHT AT MILITARY RATED POWER
PITCH ATTITUDE (DEGREES)
TOTAL DIRECTIONAL CONTROL TRAVEL = 6.0 INCHES
DIRECTIONAL CONTROL POSITION (IN. FROM FULL LEFT)
TOTAL LATERAL CONTROL TRAVEL = 10.1 INCHES
LATERAL CONTROL POSITION (IN. FROM FULL LEFT)
TOTAL LONGITUDINAL CONTROL TRAVEL = 9.7 INCHES
LONGITUDINAL CONTROL POSITION (IN. FROM FULL FWD)
20
40
60
80
100
120
140
CALIBRATED AIRSPEED (KNOTS)

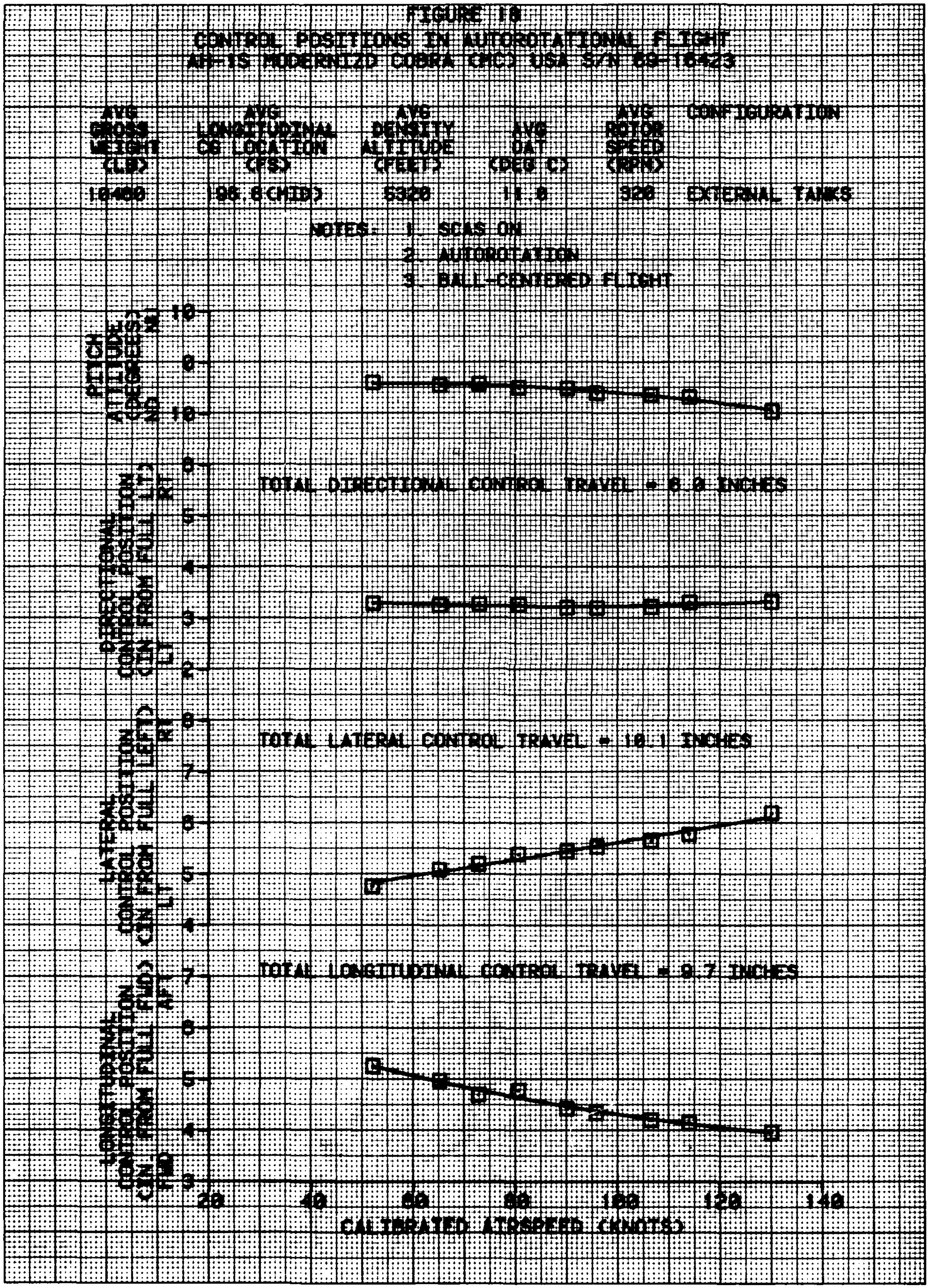
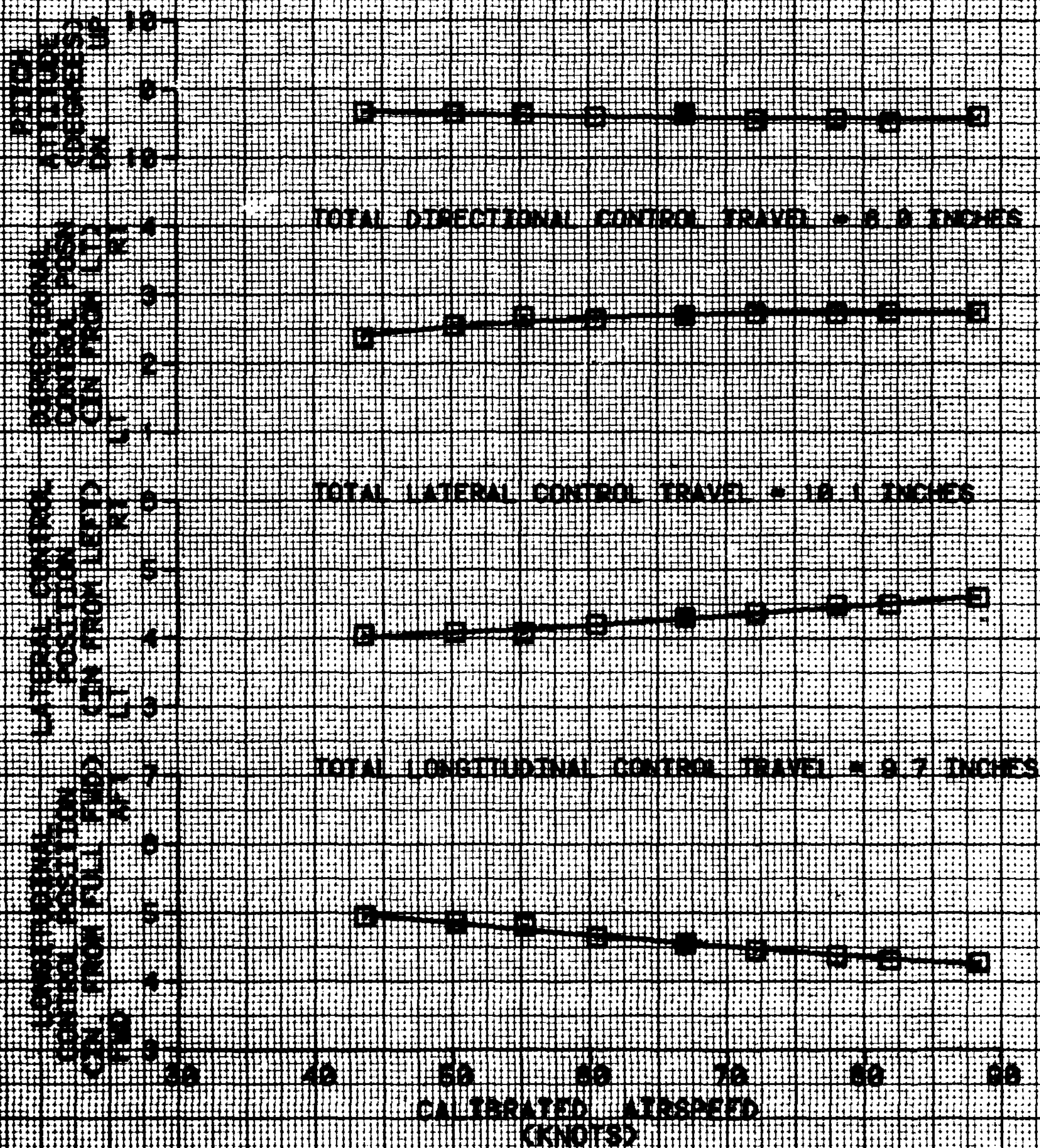


FIGURE 18
CONTROL POSITIONS IN AUTOROTATIONAL FLIGHT
AH-1S MODERNIZD COBRA (MC) USA S/N 69-16423

FIGURE 19
STATIC LONGITUDINAL STABILITY
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONGITUDINAL CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION
10070	196.4 (MID)	4400	10.0	323	LEVEL

NOTES: 1. EXTERNAL FUEL TANKS EMPTY CONFIGURATION
2. SHADED SYMBOLS DENOTE TRIM
3. SCAS ON



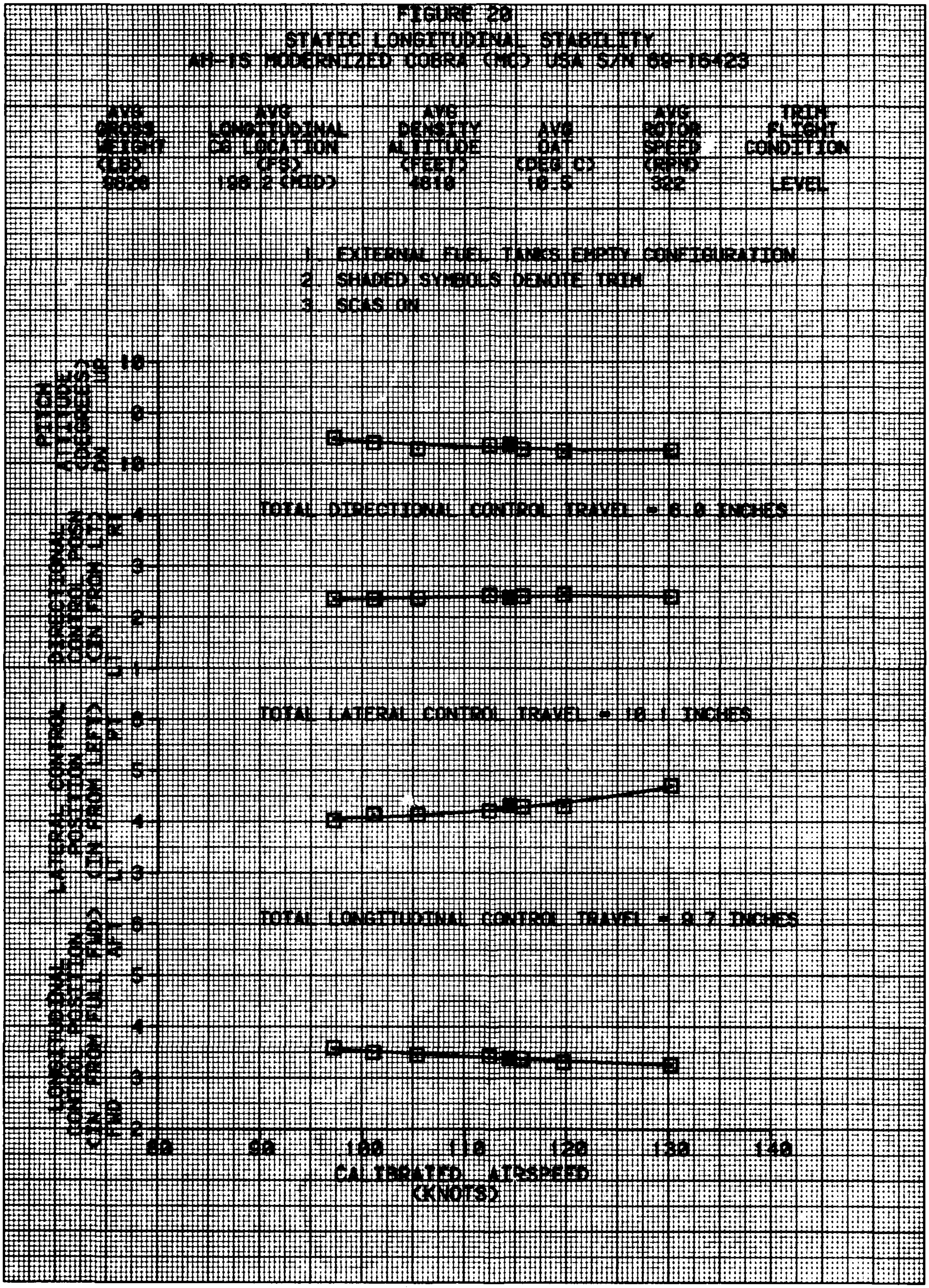


FIGURE 20
STATIC LONGITUDINAL STABILITY
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423
AVG GROSS WEIGHT (LB) 9820
AVG LONGITUDINAL CG LOCATION (FS) 190.2 (MID)
AVG DENSITY ALTITUDE (FEET) 4810
AVG OAT (DEG C) 10.5
AVG ROTOR SPEED (RPM) 322
TRIM FLIGHT CONDITION LEVEL
1. EXTERNAL FUEL TANKS EMPTY CONFIGURATION
2. SHADED SYMBOLS DENOTE TRIM
3. SCAS ON
PITCH ATTITUDE (DEGREES) UP DN
TOTAL DIRECTIONAL CONTROL TRAVEL = 6.0 INCHES
DIRECTIONAL CONTROL POSITION (IN FROM LT) RT LT
TOTAL LATERAL CONTROL TRAVEL = 10.1 INCHES
LATERAL CONTROL POSITION (IN FROM LEFT) RT LT
TOTAL LONGITUDINAL CONTROL TRAVEL = 9.7 INCHES
LONGITUDINAL CONTROL POSITION (IN FROM FULL FWD) AFT FWD
80 90 100 110 120 130 140
CALIBRATED AIRSPEED (KNOTS)

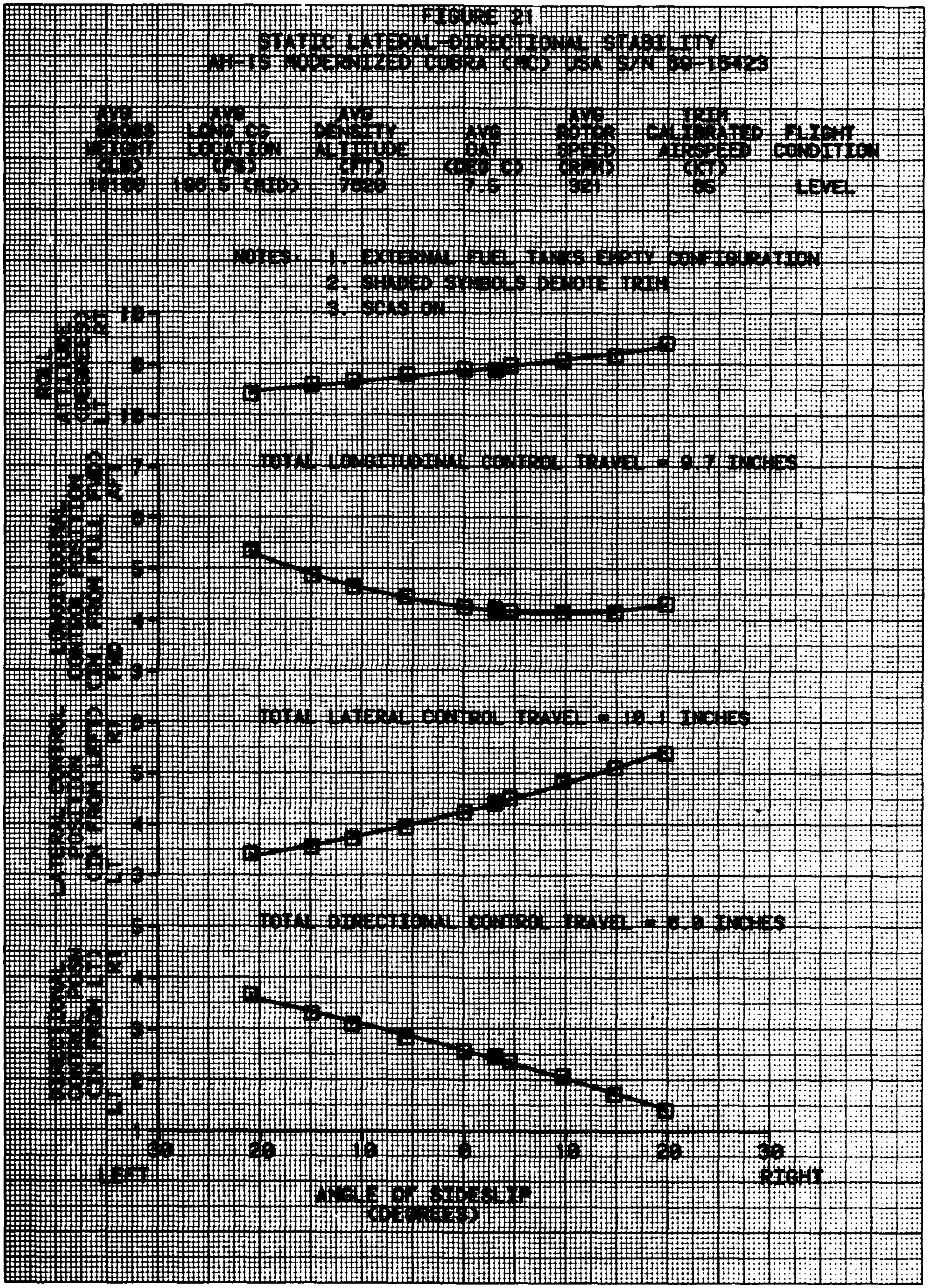


FIGURE 21
STATIC LATERAL-DIRECTIONAL STABILITY
AH-1S MODERNIZED COBRA (MC) USA S/N 80-15423
AVG GROSS WEIGHT (LB)
AVG LONG CG LOCATION (FS) 186.5 (MID)
AVG DENSITY ALTITUDE (FT) 7020
AVG OAT (DEG C) 7.5
AVG ROTOR SPEED (RPM) 321
TRIM CALIBRATED AIRSPEED (KT) 85
FLIGHT CONDITION LEVEL
NOTES: 1. EXTERNAL FUEL TANKS EMPTY CONFIGURATION
2. SHADED SYMBOLS DENOTE TRIM
3. SCAS ON
TOTAL LONGITUDINAL CONTROL TRAVEL = 9.7 INCHES
TOTAL LATERAL CONTROL TRAVEL = 10.1 INCHES
TOTAL DIRECTIONAL CONTROL TRAVEL = 6.9 INCHES
30 20 10 0 10 20 30
LEFT
RIGHT
ANGLE OF SIDESLIP (DEGREES)

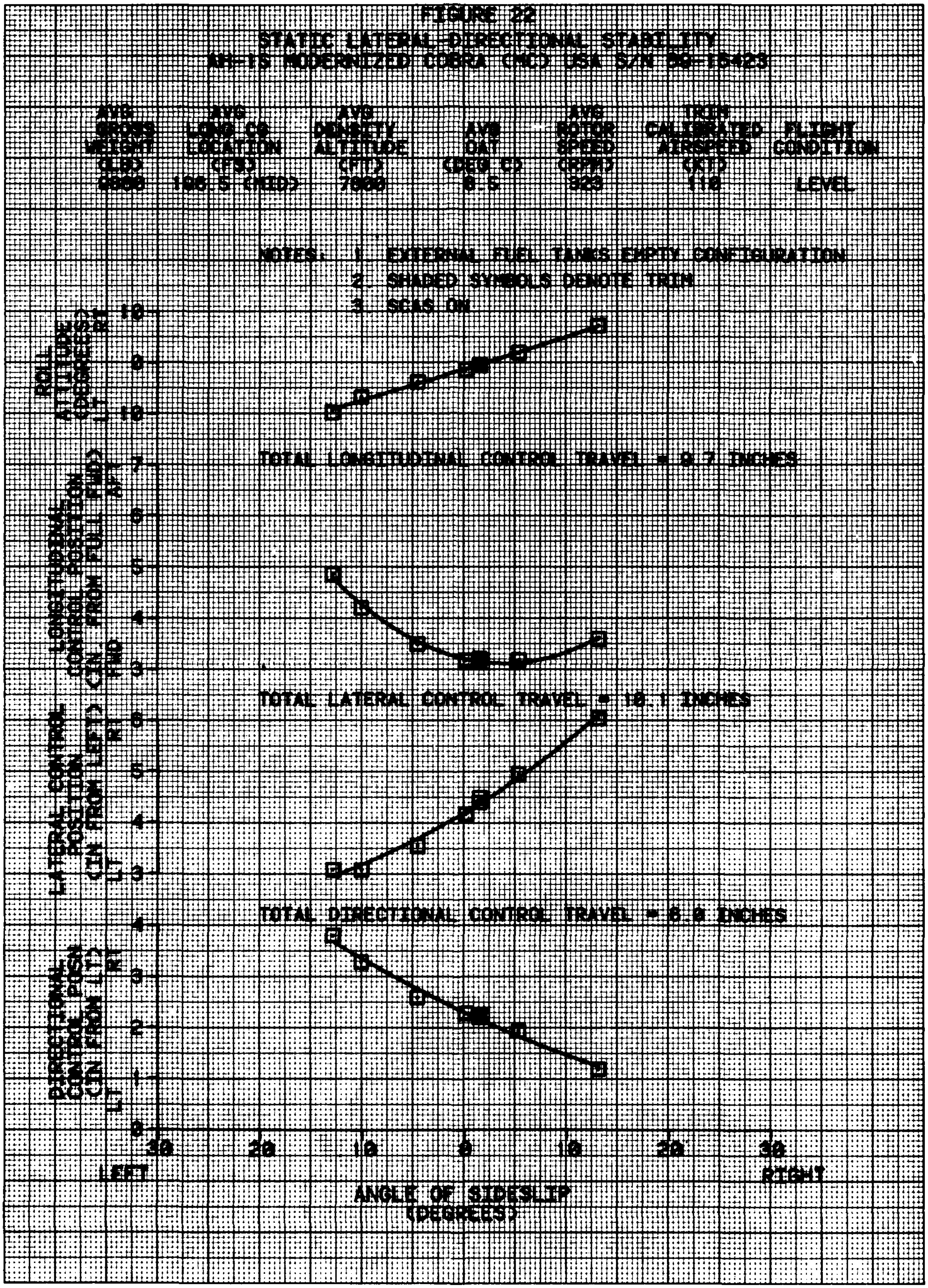


FIGURE 22
STATIC LATERAL-DIRECTIONAL STABILITY
AH-1S MODERNIZED COBRA (MC) USA S/N 80-15423
AVG GROSS WEIGHT (LB) 9000
AVG LONG CG LOCATION (FS) 196.5 (MID)
AVG DENSITY ALTITUDE (FT) 7000
AVG OAT (DEG C) 8.5
AVG ROTOR SPEED (RPM) 323
TRIM CALIBRATED AIRSPEED (KT) 110
FLIGHT CONDITION LEVEL
NOTES: 1. EXTERNAL FUEL TANKS EMPTY CONFIGURATION
2. SHADED SYMBOLS DENOTE TRIM
3. SCAS ON
ROLL ATTITUDE (DEGREES)
RT
LT
TOTAL LONGITUDINAL CONTROL TRAVEL = 9.7 INCHES
LONGITUDINAL CONTROL POSITION (IN. FROM FULL FWD)
AFT
FWD
TOTAL LATERAL CONTROL TRAVEL = 10.1 INCHES
LATERAL CONTROL POSITION (IN FROM LEFT)
RT
LT
TOTAL DIRECTIONAL CONTROL TRAVEL = 6.0 INCHES
DIRECTIONAL CONTROL PUSH POSITION (IN FROM LT)
RT
LT
LEFT
RIGHT
ANGLE OF SIDESLIP (DEGREES)

FIGURE 23
LONGITUDINAL PULSE INPUT
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
8800	196.2 (MID)	7040	13.5	319	126	LEVEL

NOTES: 1. EXTERNAL FUEL TANKS EMPTY CONFIGURATION
2. SCAS ON

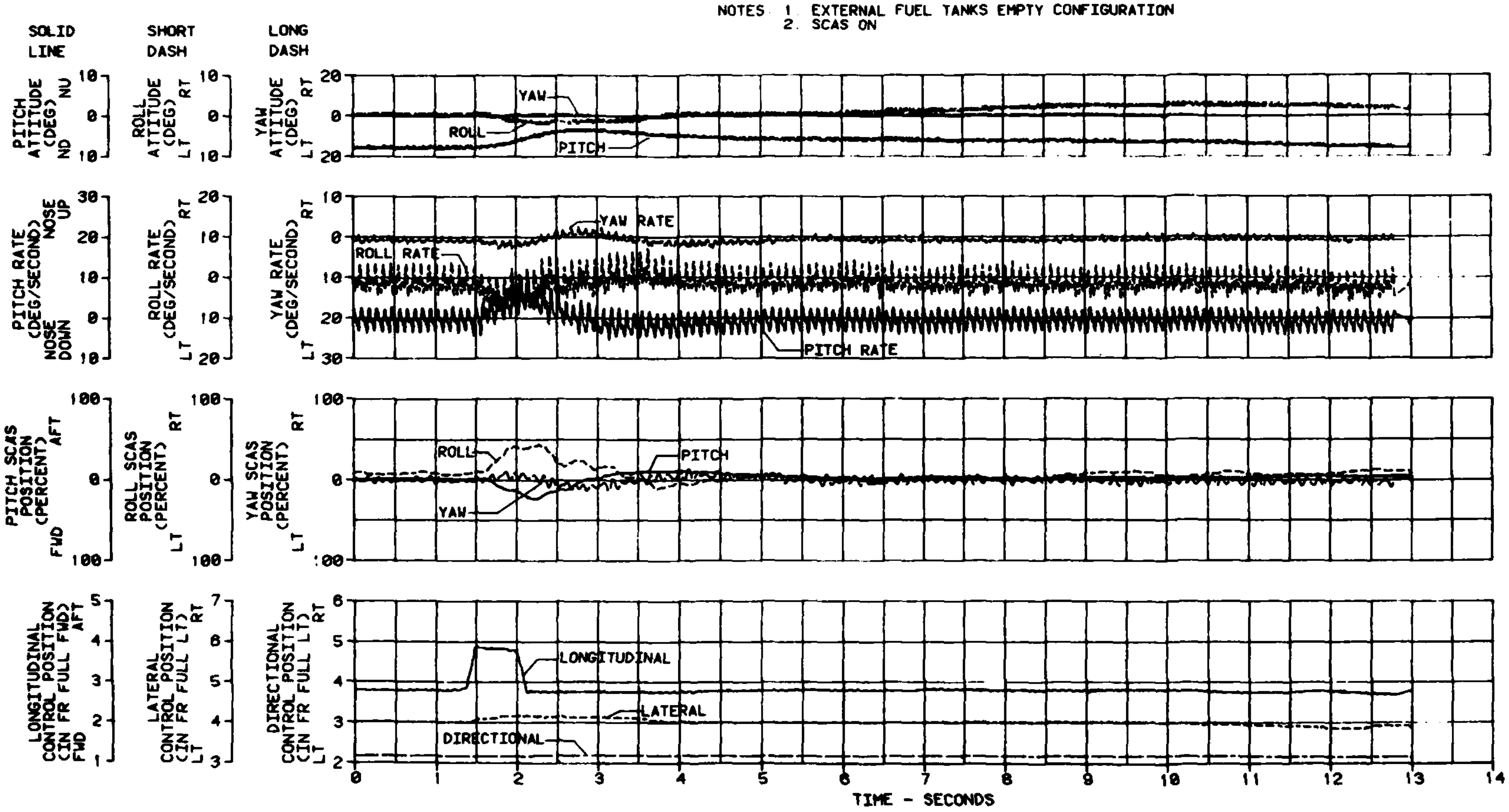


FIGURE 24

LONGITUDINAL PULSE INPUT
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9920	196.4 (MID)	7160	-2.0	322	123	LEVEL

NOTES: 1. EXTERNAL FUEL TANKS FULL CONFIGURATION
2. SCAS ON

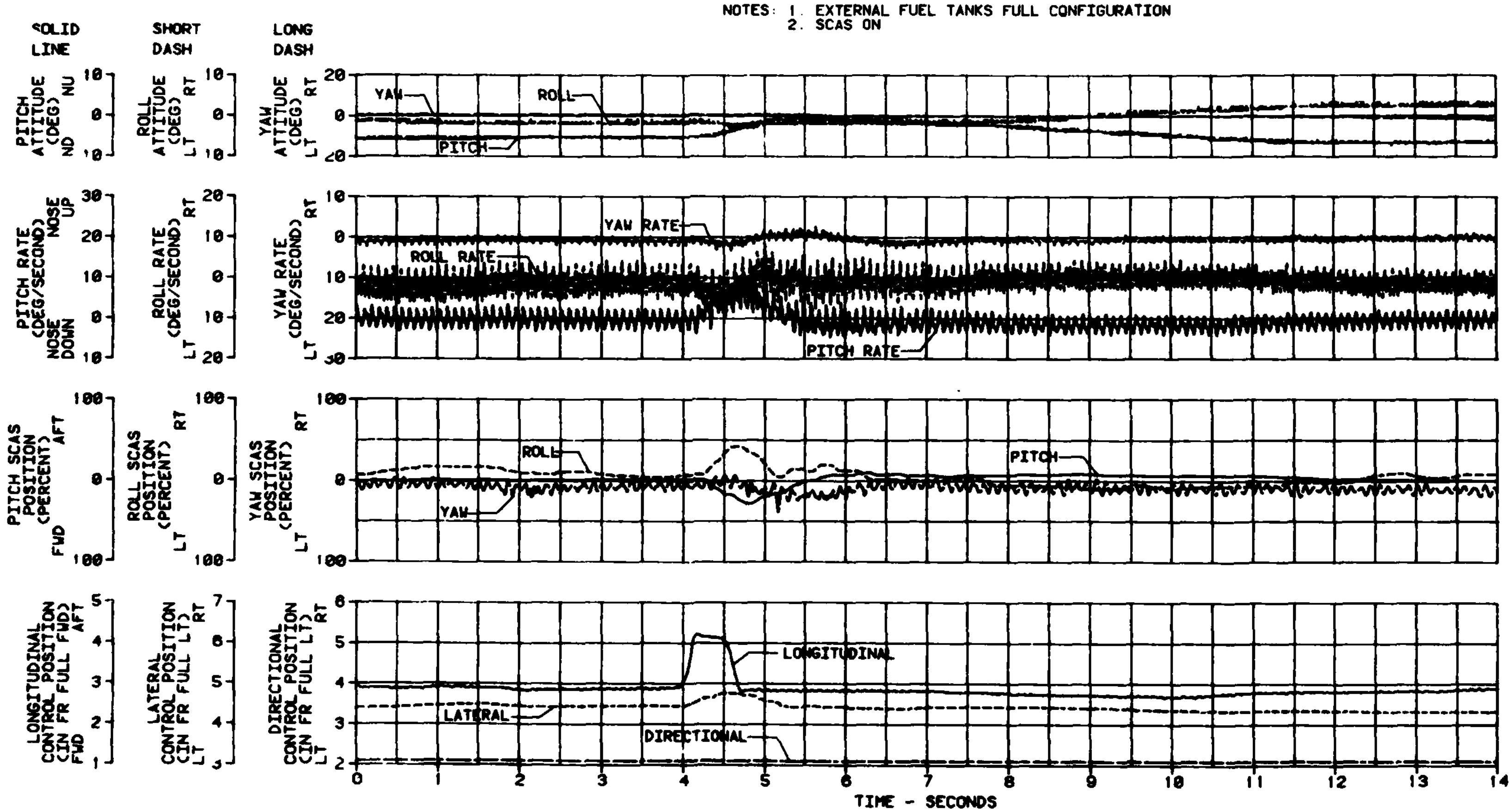


FIGURE 25

LATERAL PULSE INPUT
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
8780	196.2 (MID)	7040	13.5	319	127	LEVEL

NOTES: 1. EXTERNAL FUEL TANKS EMPTY CONFIGURATION
2. SCAS ON

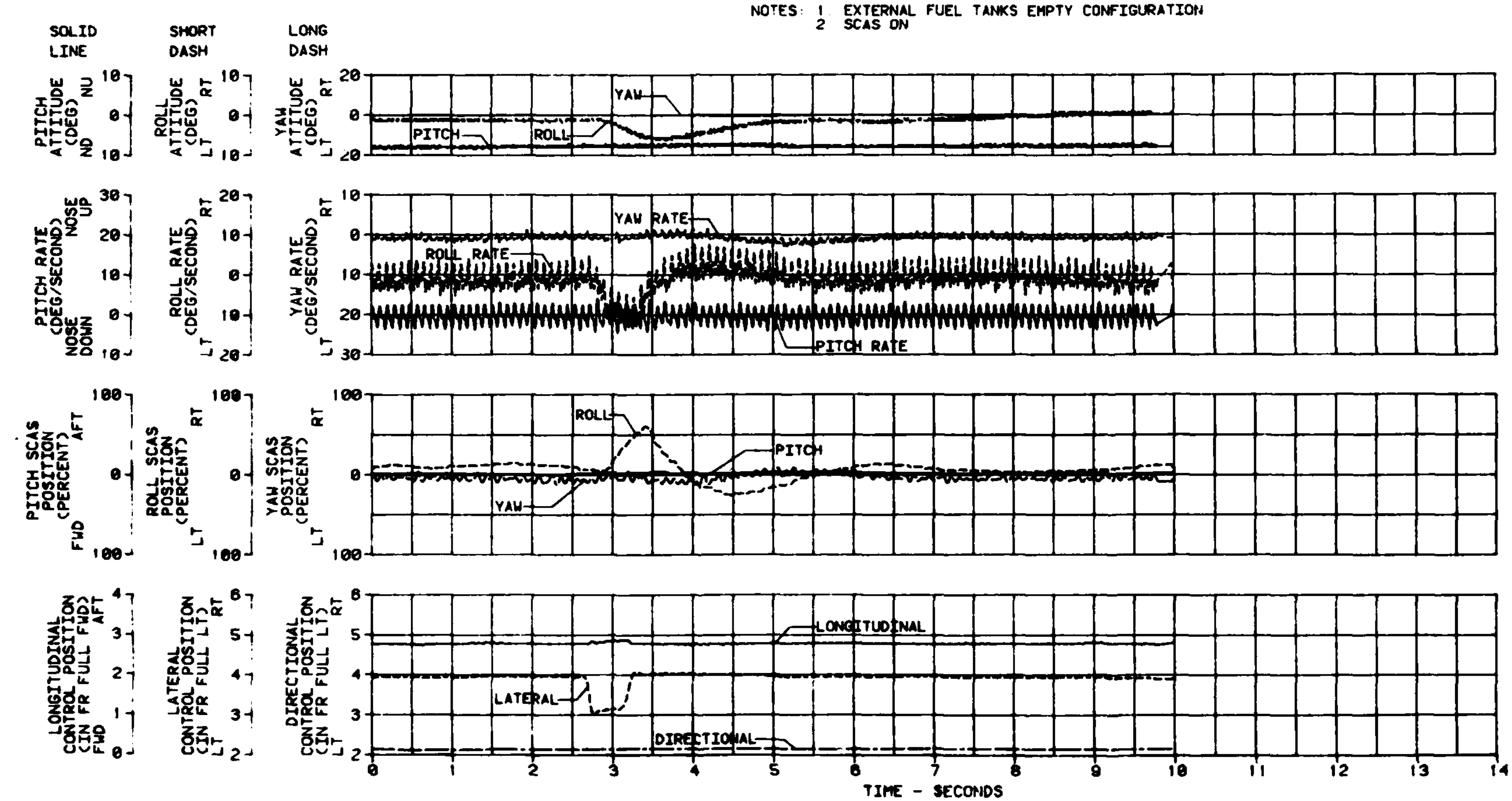


FIGURE 26
LATERAL PULSE INPUT
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
10210	196.6 (MID)	7090	13.0	322	121	LEVEL

NOTES: 1. EXTERNAL FUEL TANKS FULL CONFIGURATION
2. SCAS ON

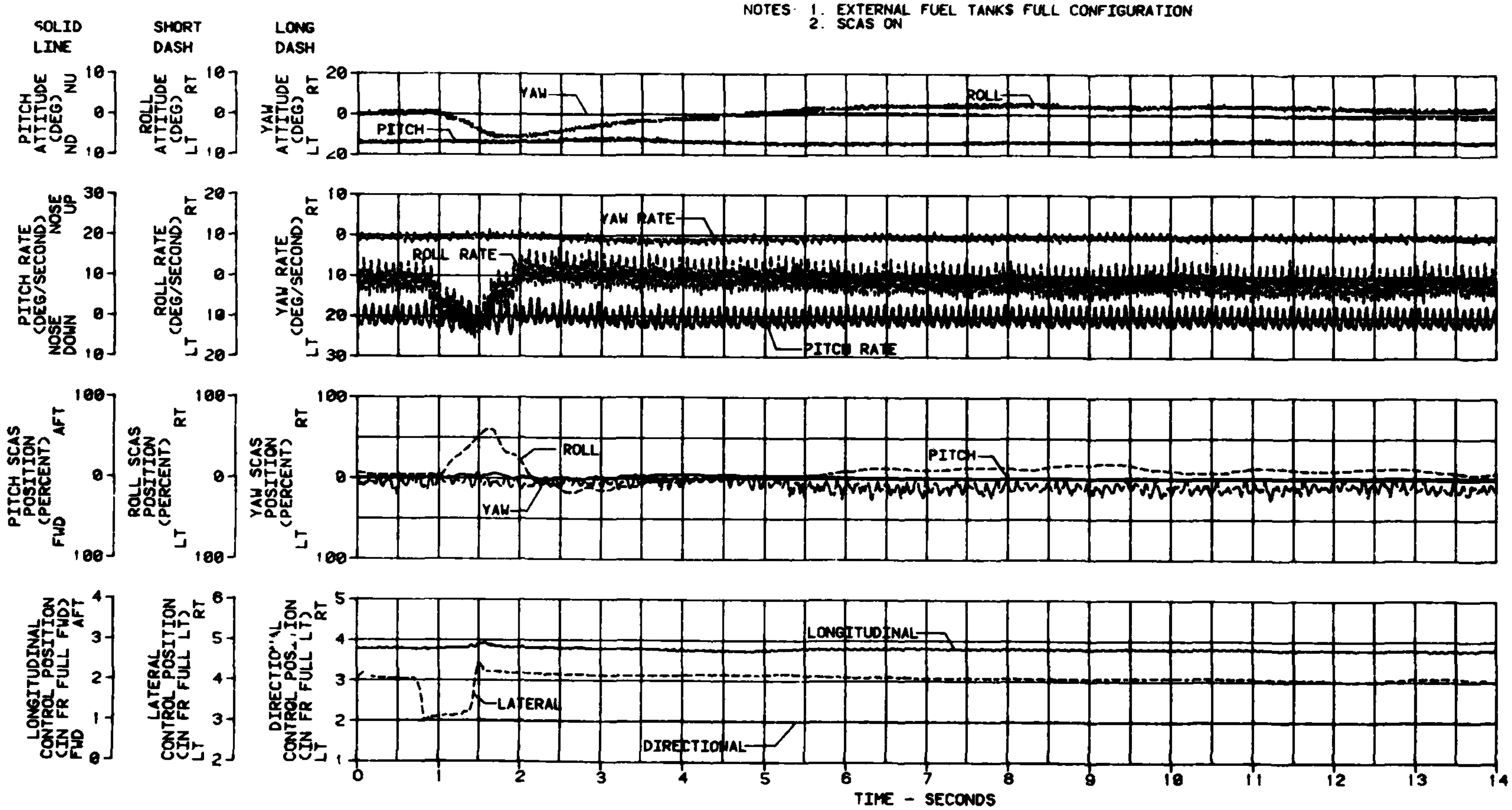


FIGURE 27
DIRECTIONAL PEDAL PULSE INPUT
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
8690	196.1 (MID)	7130	13.0	319	126	LEVEL

NOTES: 1. EXTERNAL FUEL TANKS EMPTY CONFIGURATION
2. SCAS ON

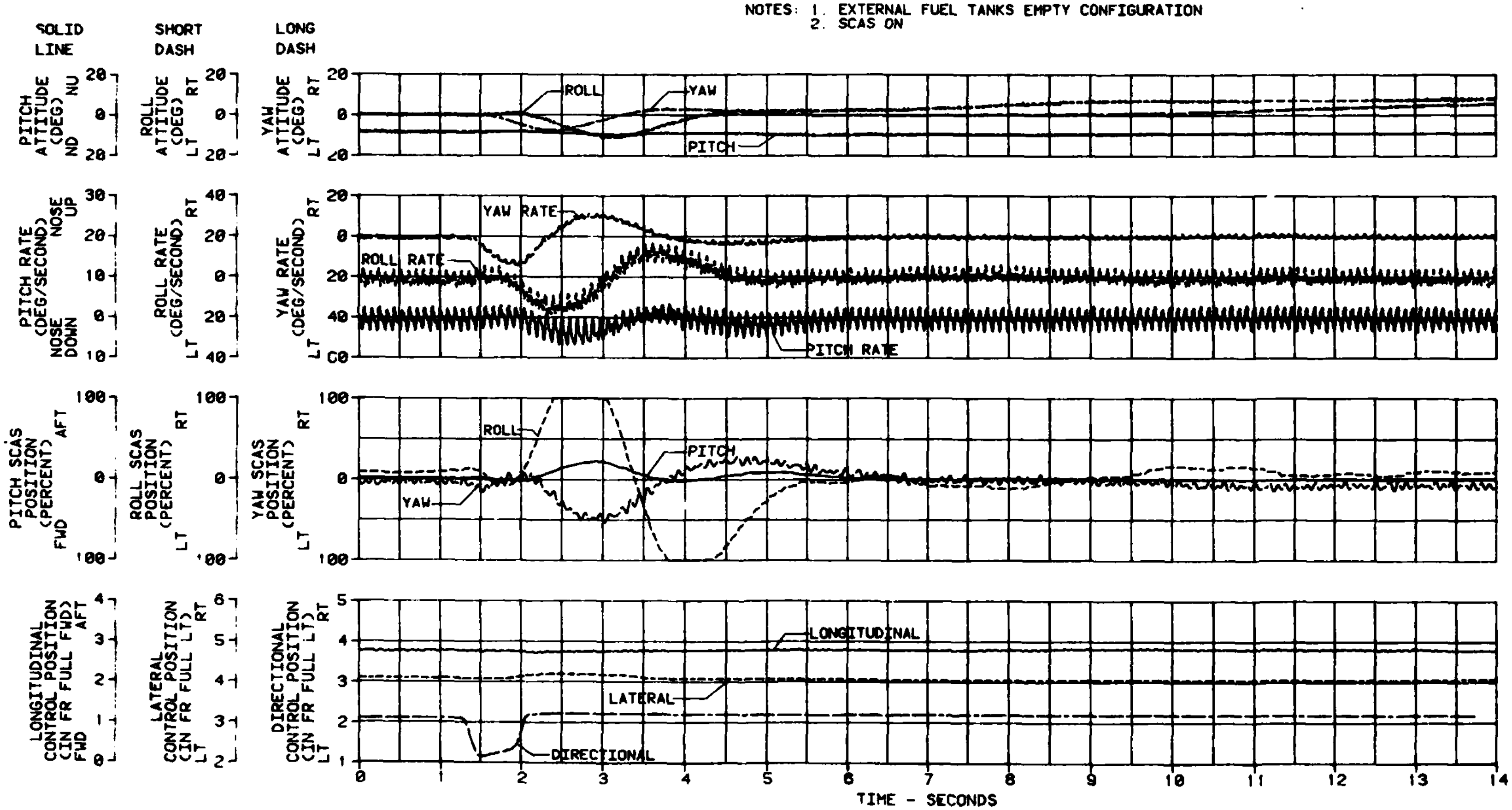


FIGURE 28
DIRECTIONAL PEDAL PULSE INPUT
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
10070	196 5 (MID)	7170	12 5	322	120	LEVEL

NOTES: 1. EXTERNAL FUEL TANKS FULL CONFIGURATION
2. SCAS ON

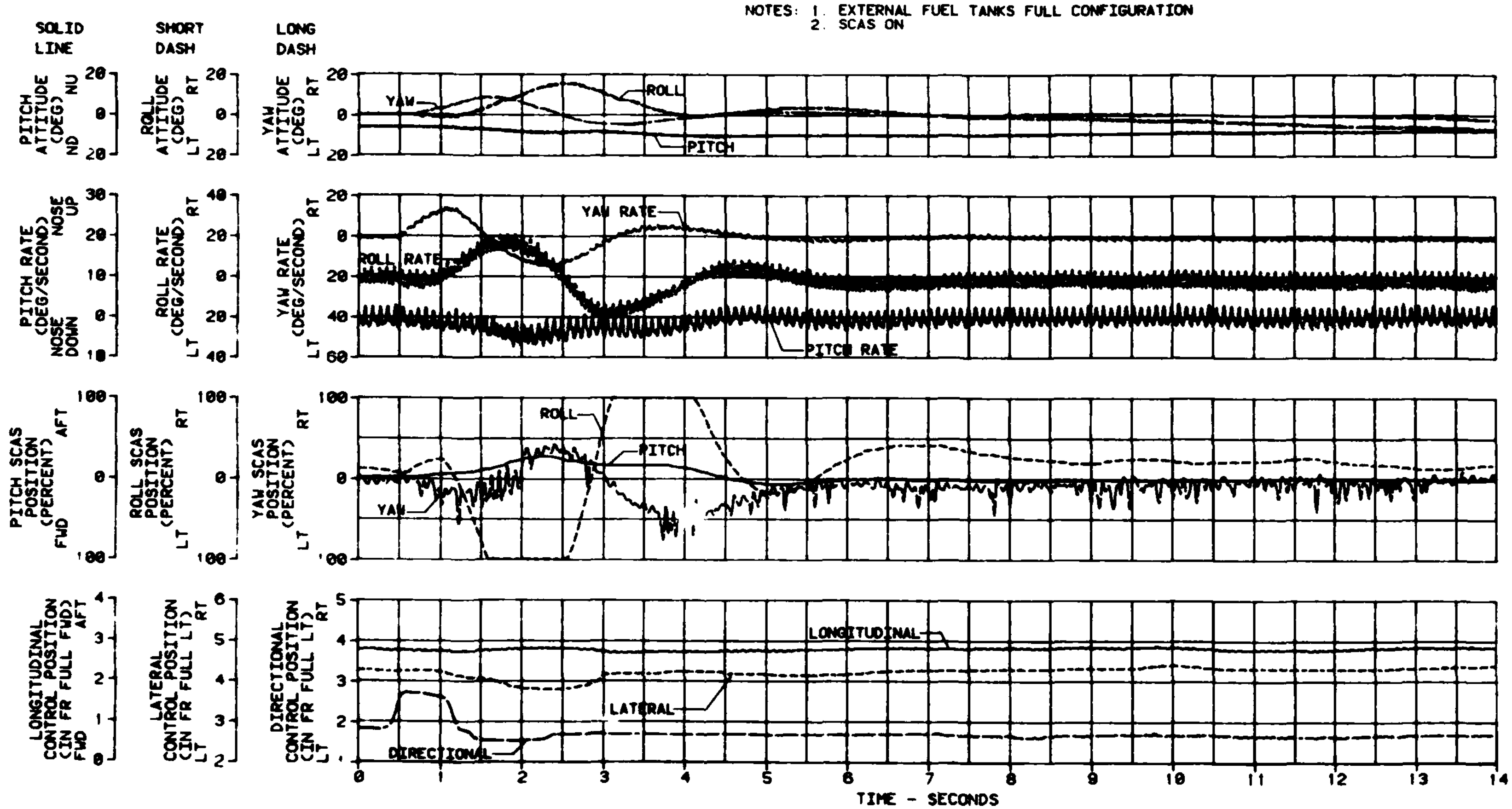


FIGURE 29
SIMULATED ENGINE FAILURE
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY CALIBRATED AIRSPEED (KT)	ENTRY ENGINE TORQUE (PERCENT)
8540	196.1 (MID)	7160	13.0	108	48

NOTES: 1. EXTERNAL FUEL TANKS EMPTY CONFIGURATION
2. ENTRY FROM BALL-CENTERED LEVEL FLIGHT
3. SCAS ON

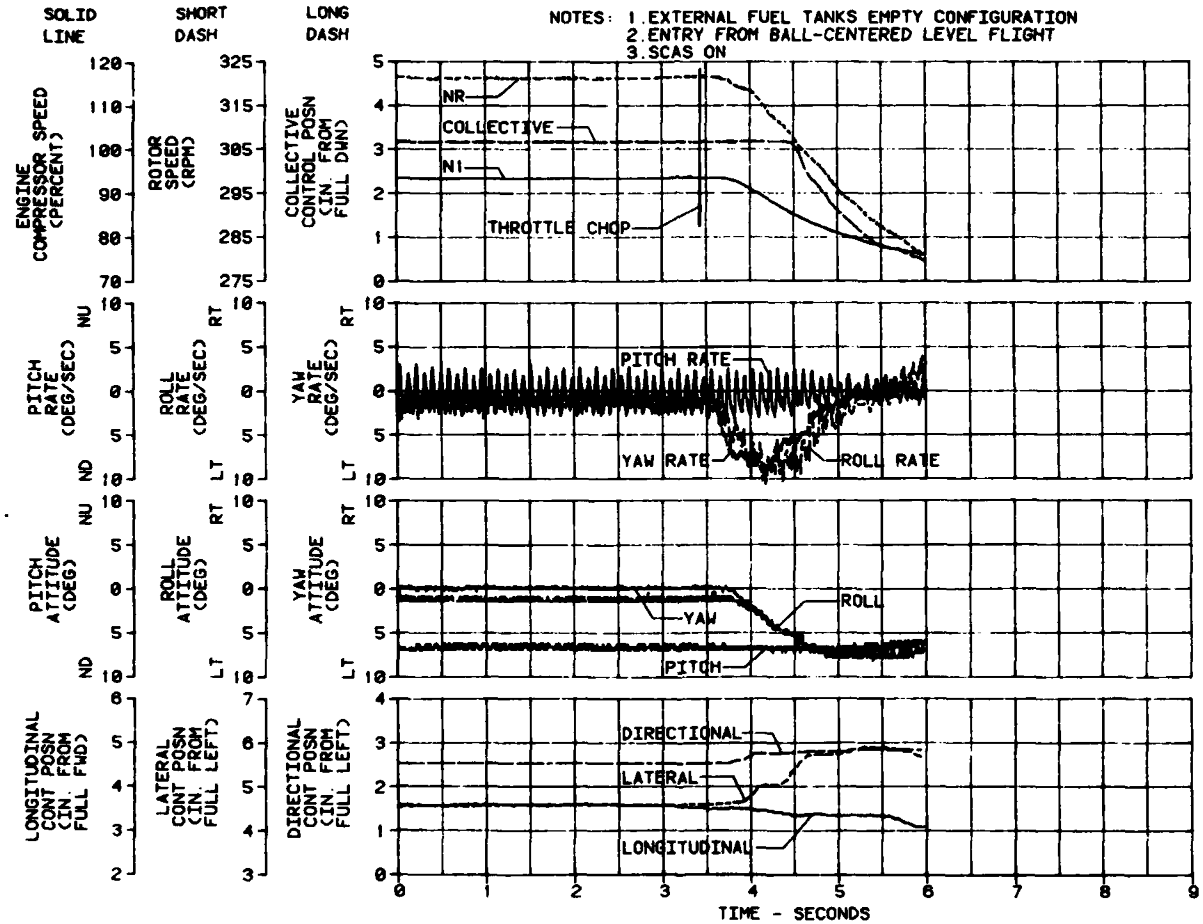


FIGURE 30

SIMULATED ENGINE FAILURE

AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY CALIBRATED AIRSPEED (KT)	ENTRY ENGINE TORQUE (PERCENT)
8480	196.0 (MID)	7320	12.5	120	62

NOTES: 1. EXTERNAL FUEL TANKS EMPTY CONFIGURATION
2. ENTRY FROM BALL-CENTERED LEVEL FLIGHT
3. SCAS ON

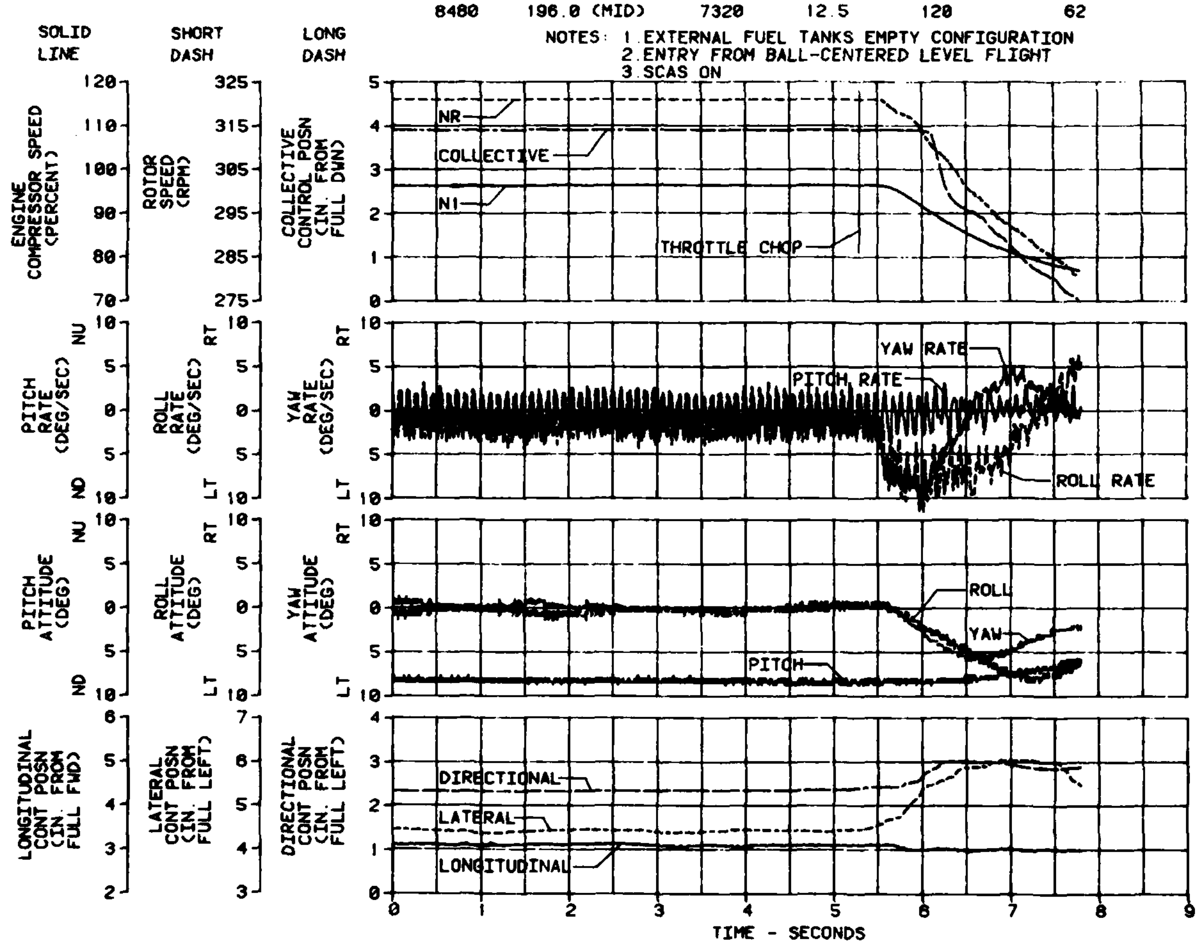


FIGURE 31
SCAS DISENGAGEMENT
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
8650	196.0 (MID)	6920	13.5	321	87	LEVEL

NOTES: 1. EXTERNAL FUEL TANKS EMPTY CONFIGURATION
2. ENTRY FROM BALL-CENTERED LEVEL FLIGHT

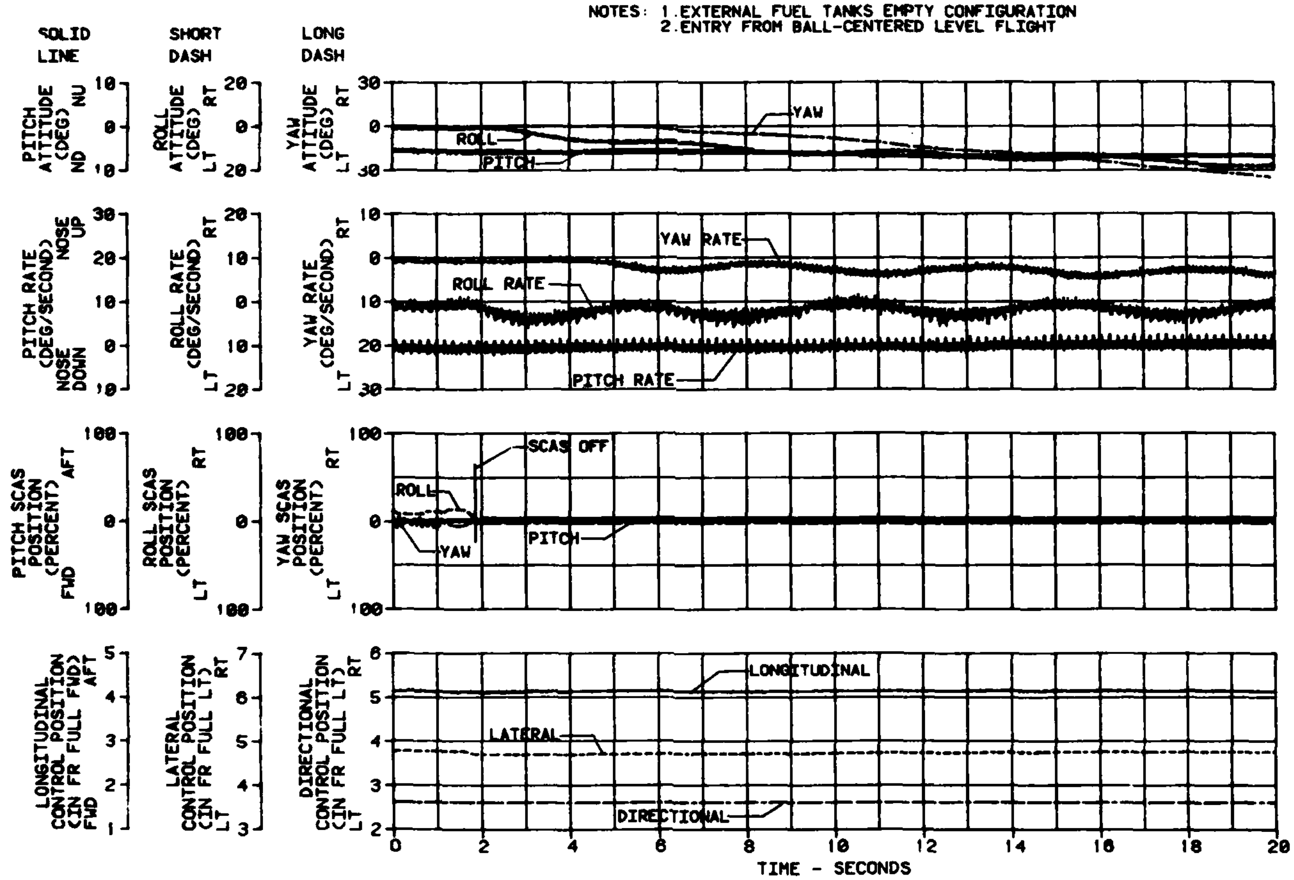


FIGURE 32
SCAS DISENGAGEMENT
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
8600	196.0 (MID)	6820	13.5	320	117	LEVEL

NOTES: 1. EXTERNAL FUEL TANKS EMPTY CONFIGURATION
2. ENTRY FROM BALL-CENTERED LEVEL FLIGHT

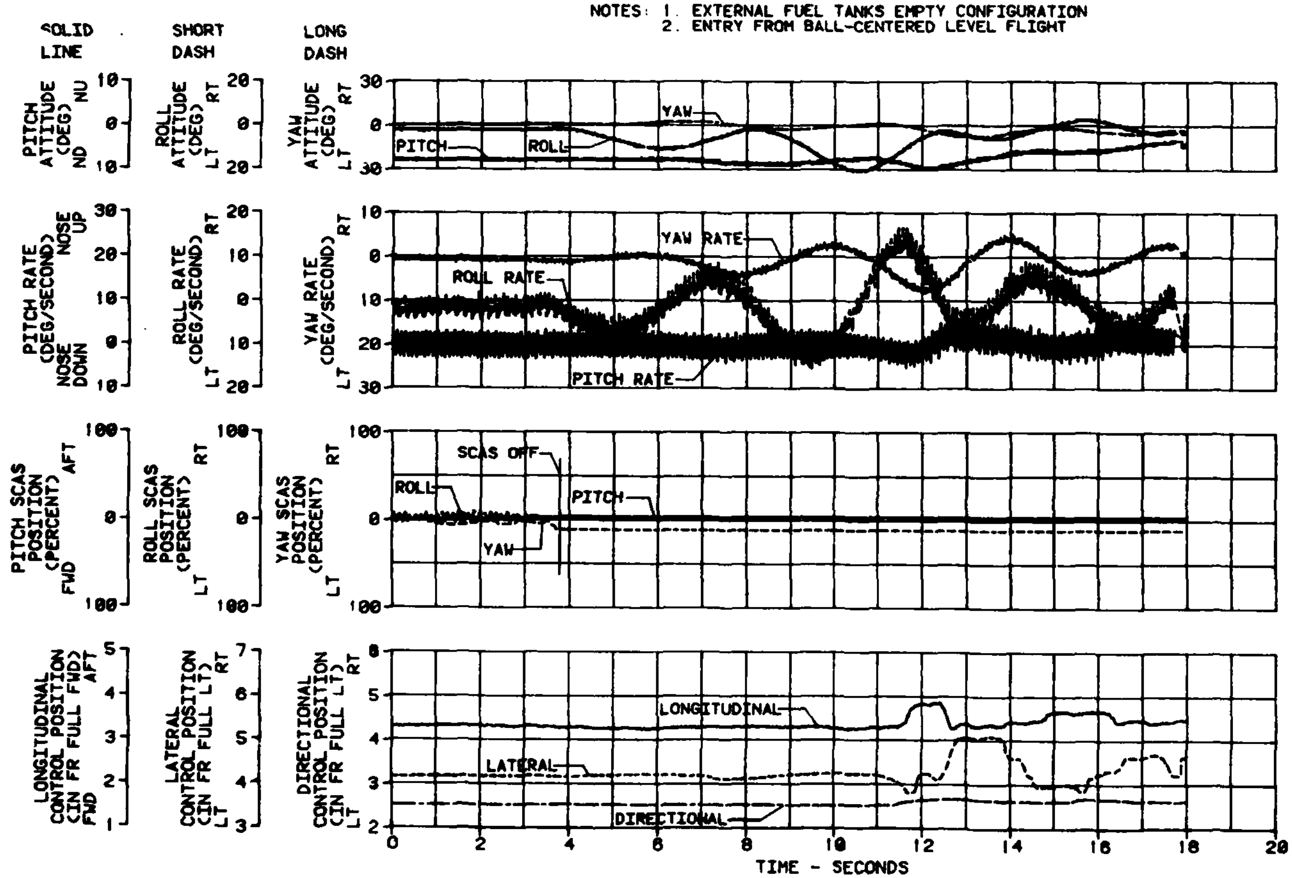


FIGURE 33
SCAS DISENGAGEMENT
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
10050	196.5 (MID)	6530	-2.0	324	65	LEVEL

NOTES: 1. EXTERNAL FUEL TANKS FULL CONFIGURATION
2. ENTRY FROM BALL-CENTERED LEVEL FLIGHT

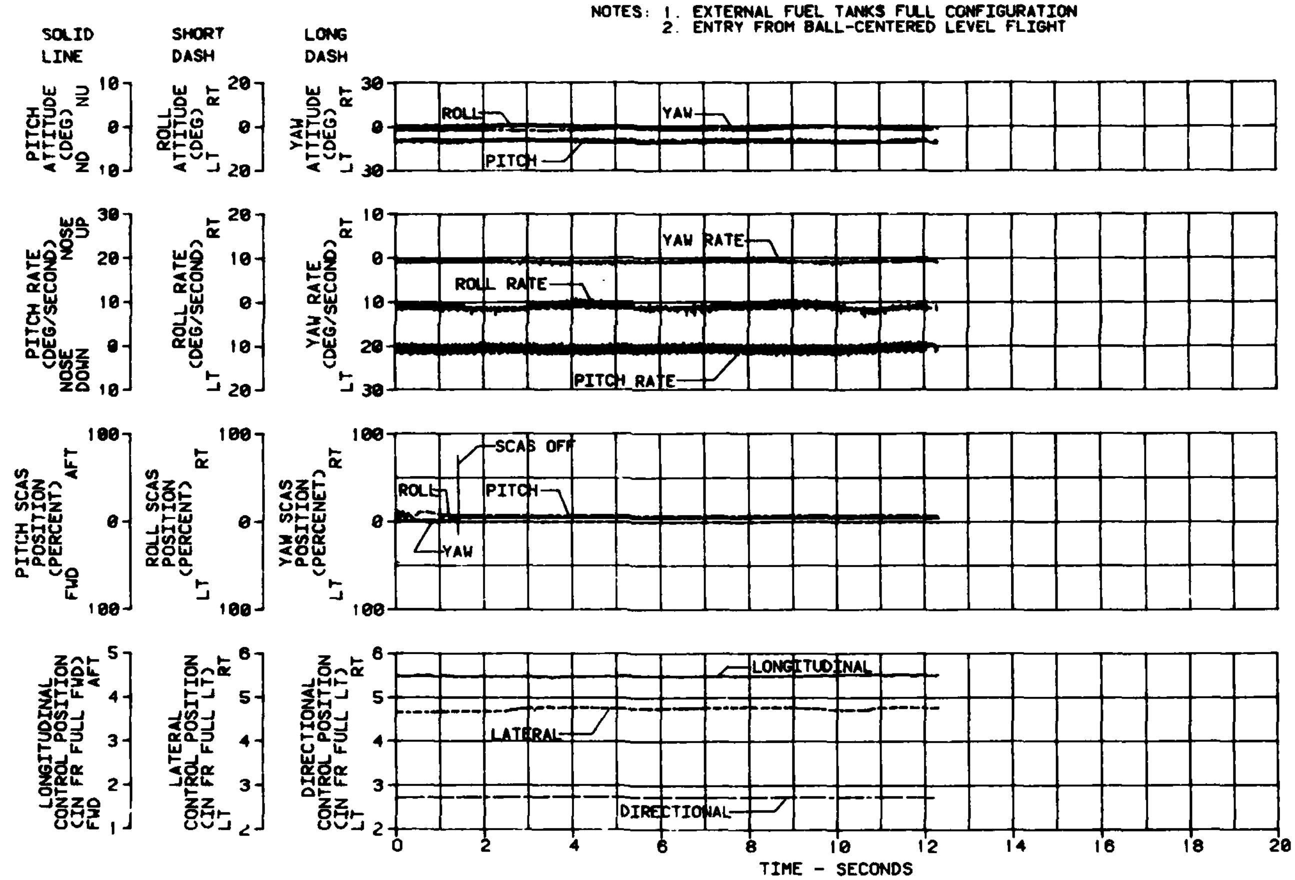


FIGURE 34
SCAS DISENGAGEMENT
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
10010	196.5 (MID)	6740	-0.5	323	111	LEVEL

NOTES: 1. EXTERNAL FUEL TANKS FULL CONFIGURATION
2. ENTRY FROM BALL-CENTERED LEVEL FLIGHT

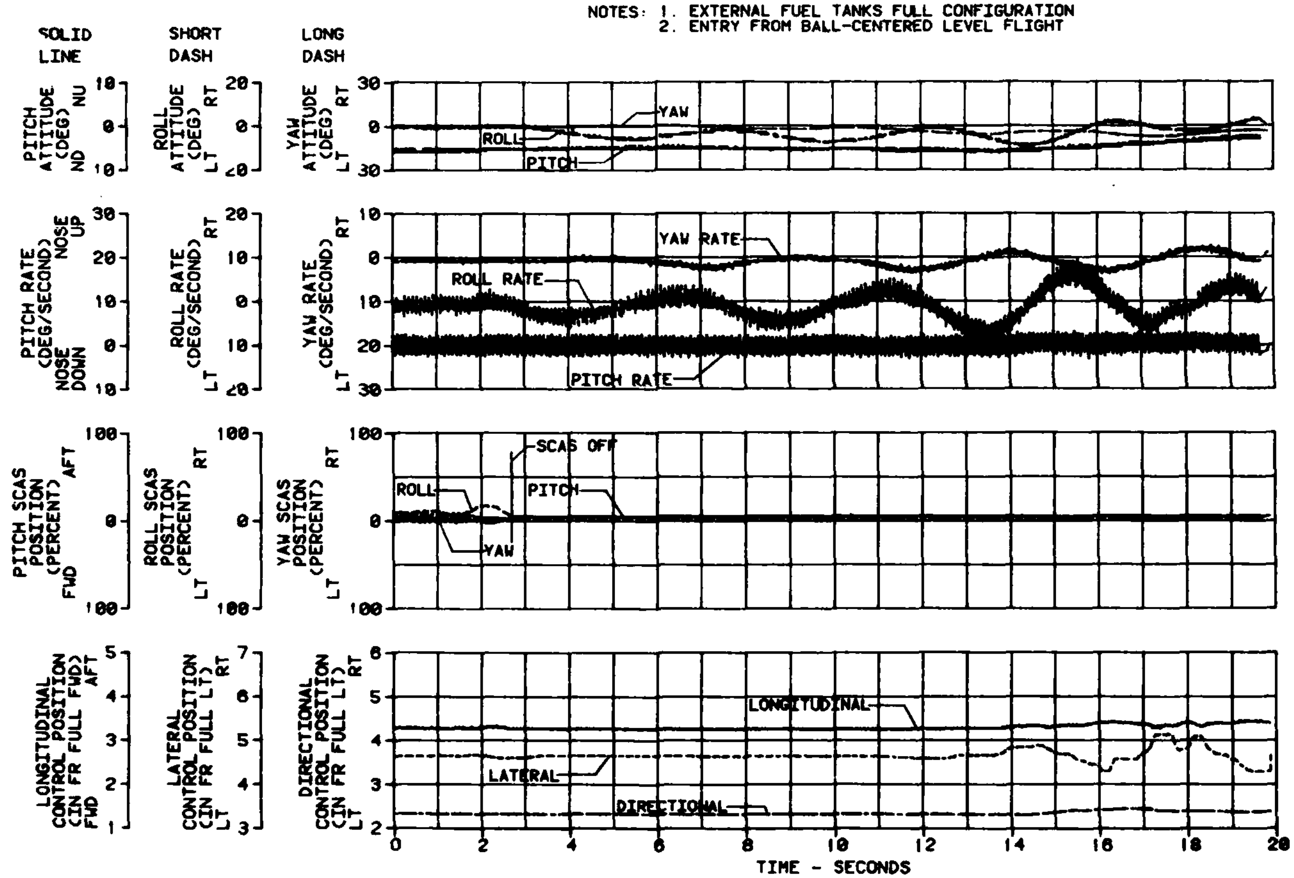


FIGURE 35
UPPER MID WING LUG OSCILLATORY LOAD
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONGITUDINAL CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)
9000	196.4 (MID)	5000	0.0	321

NOTE: EXTERNAL FUEL TANKS FULL CONFIGURATION

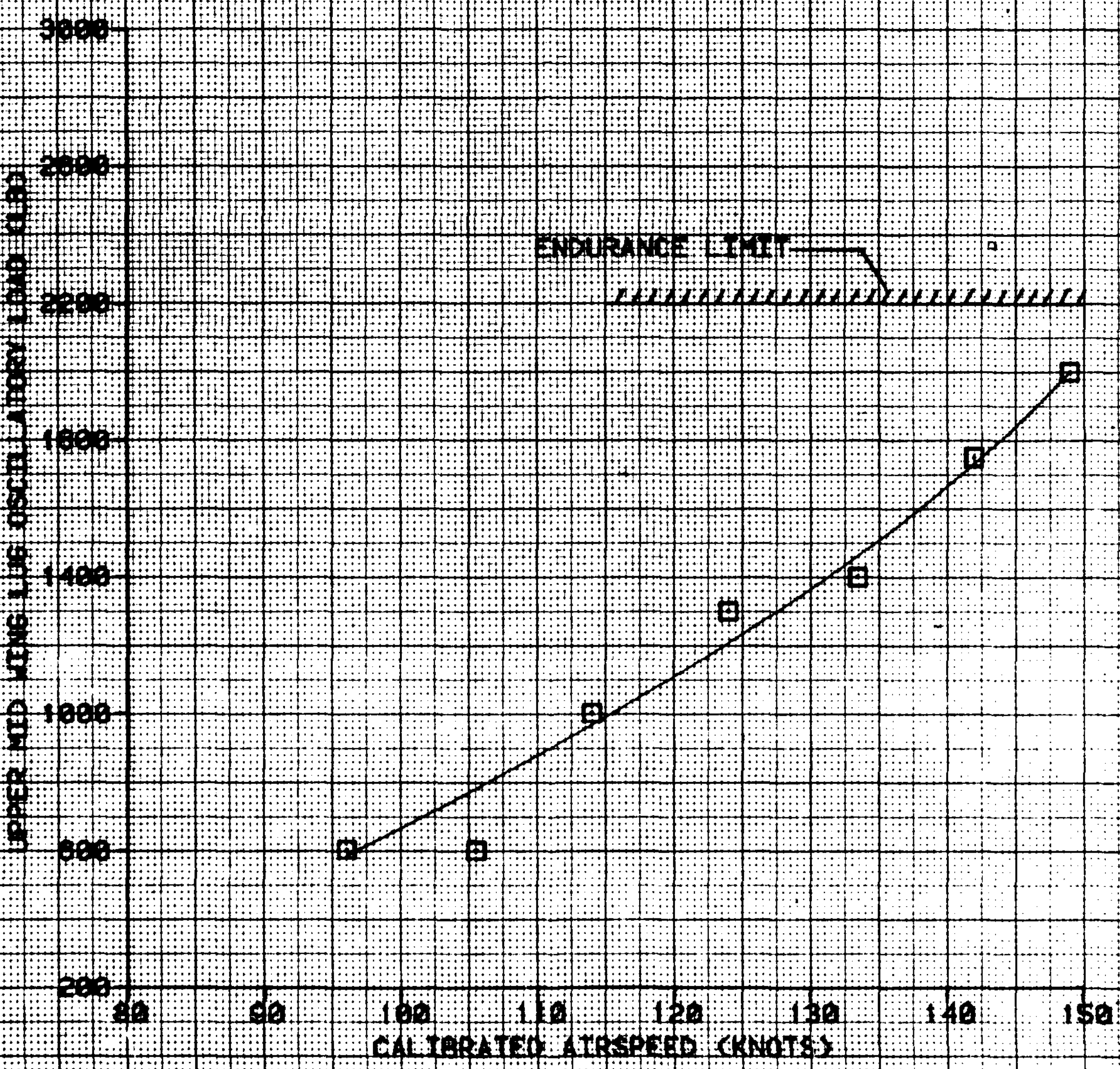
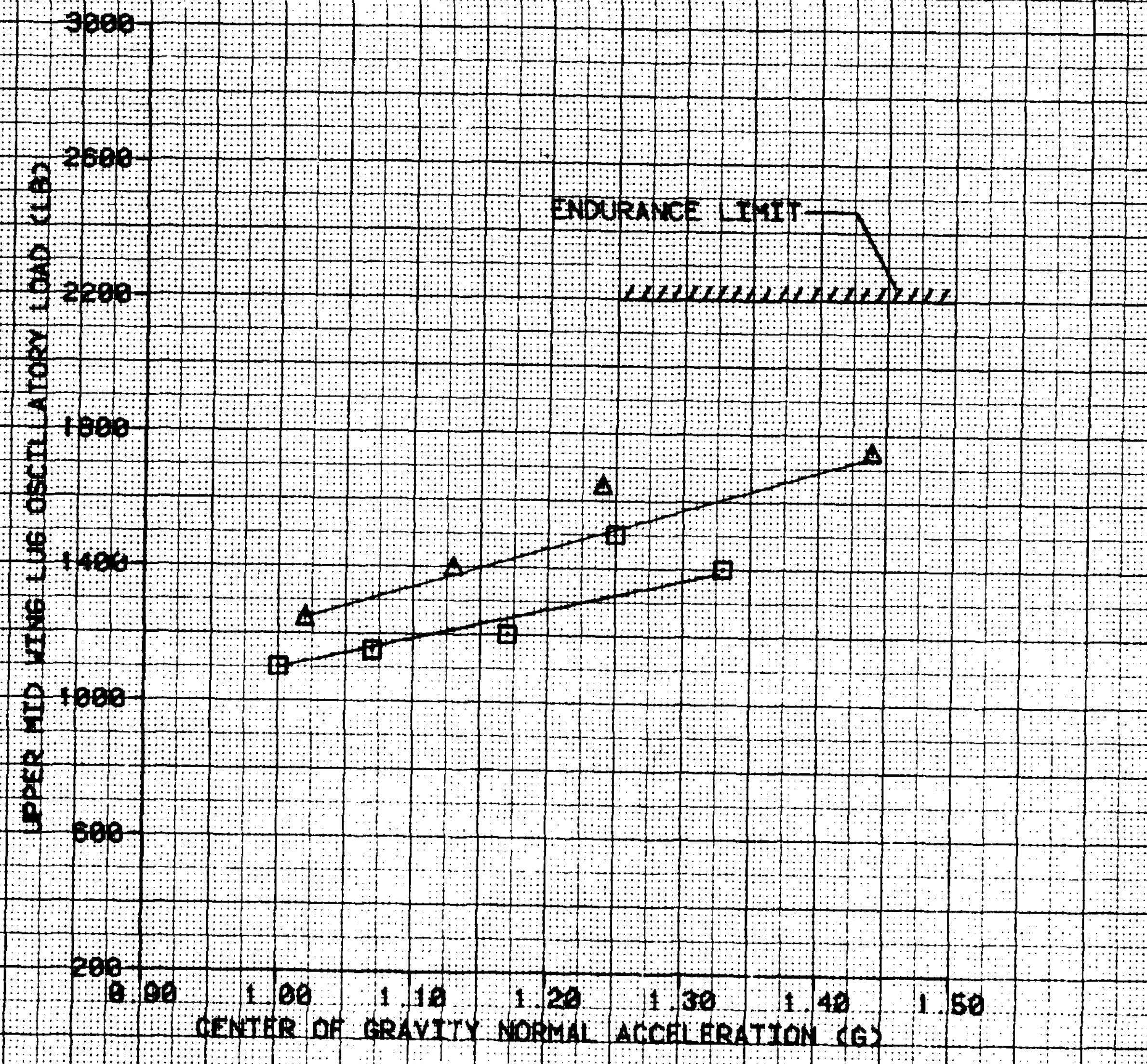


FIGURE 36
UPPER MID WING LUG OSCILLATORY LOAD
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG LONGITUDINAL CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG CALIBRATED AIRSPEED (KT)
10,140	196.5 (MID)	6270	7.5	322	125

NOTES: 1. EXTERNAL FUEL TANKS FULL CONFIGURATION
2. LEFT TURNS ⊡
RIGHT TURNS ◬



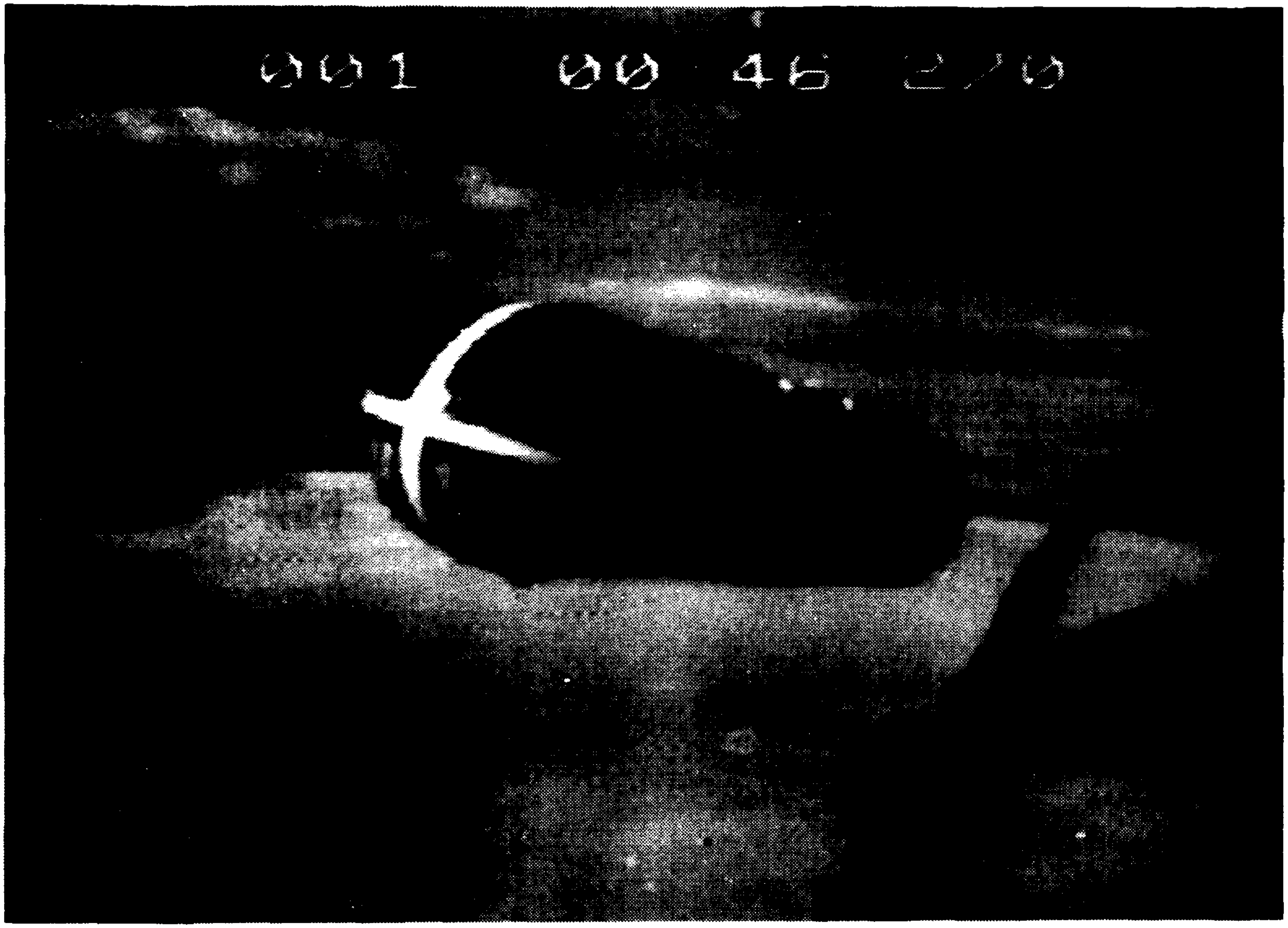


Photo 1. External Fuel Tank Jettison Sequence
106 KCAS Autorotation

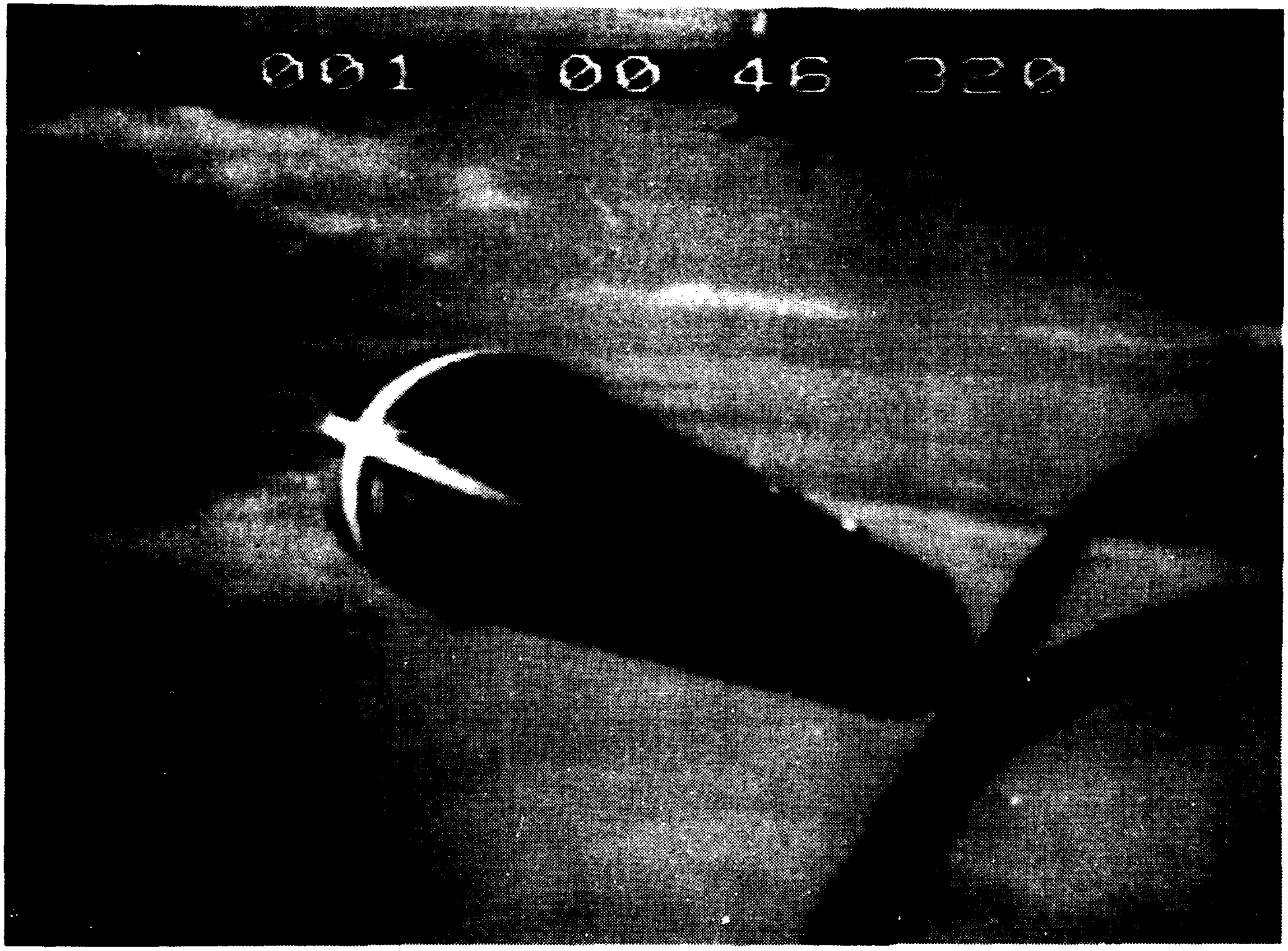


Photo 2. External Fuel Tank Jettison Sequence
106 KCAS Autorotation

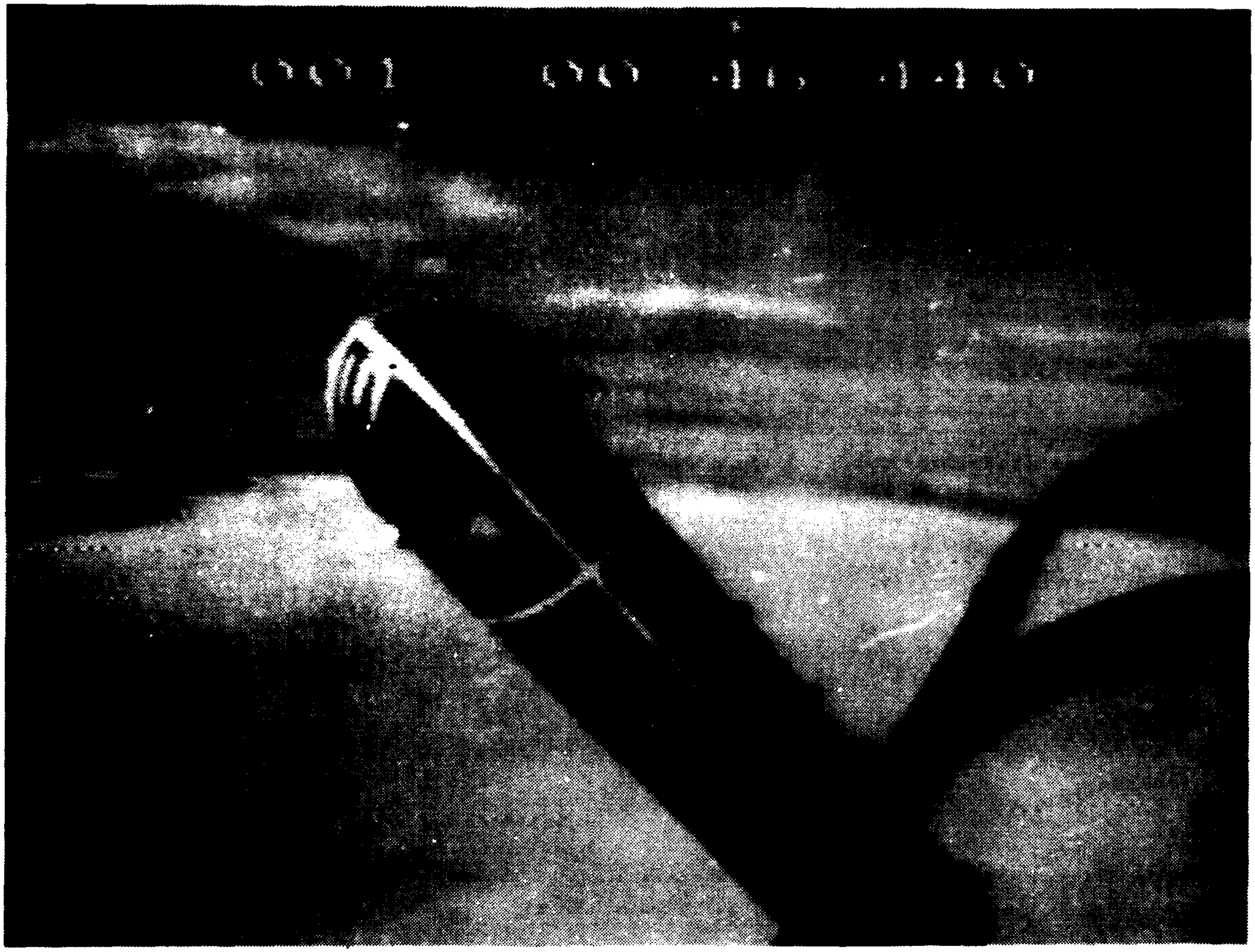


Photo 3. External Fuel Tank Jettison Sequence
106 KCAS Autorotation

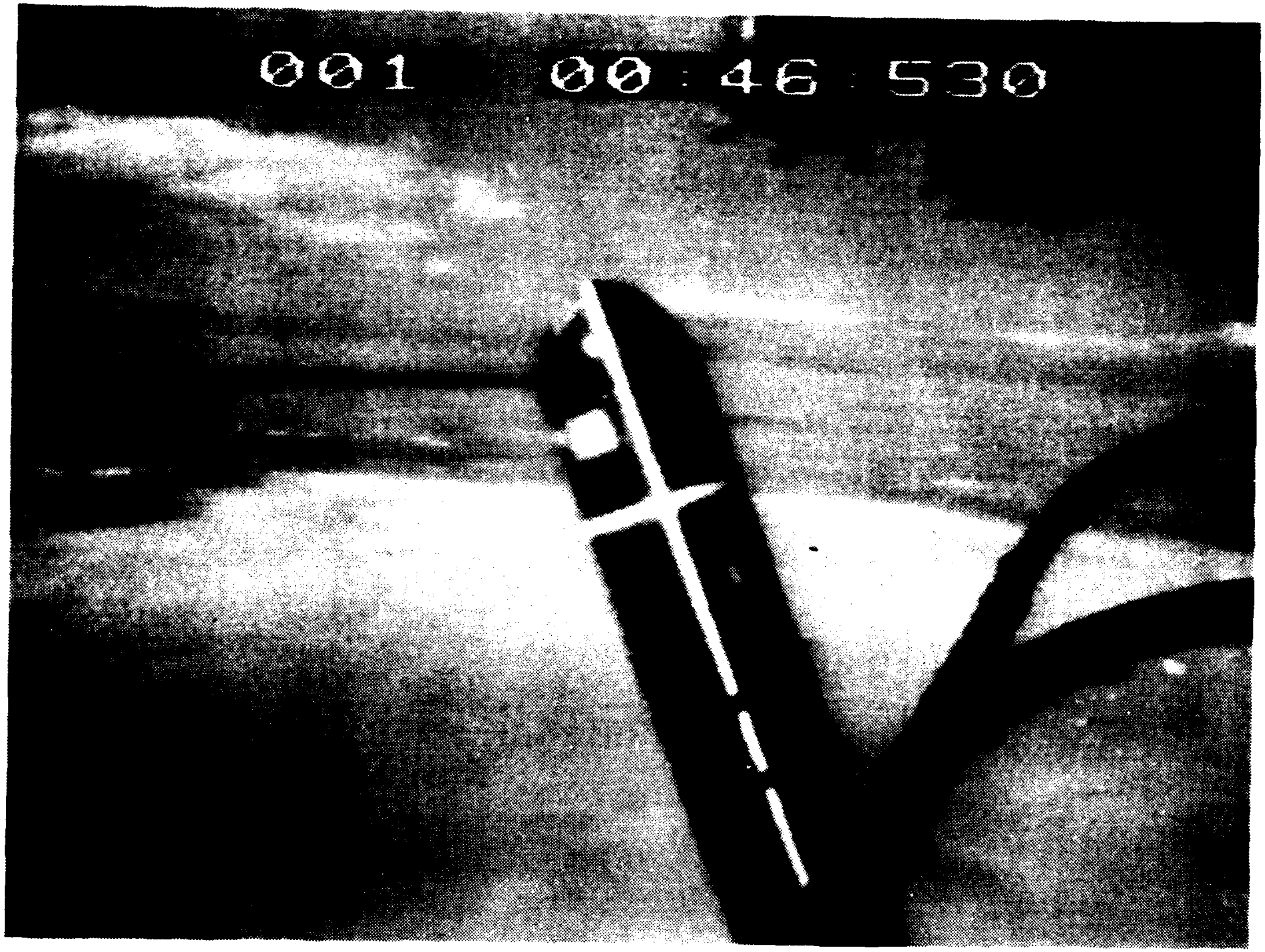


Photo 4. External Fuel Tank Jettison Sequence
106 KCAS Autorotation

Photo 5. External Fuel Tank Jettison Sequence
106 KCAS Autorotation

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