

AD-A178 764

2

USAAEFA PROJECT NO. 84-16-1

DTIC FILE COPY



US ARMY
AVIATION
SYSTEMS COMMAND

AH - 1S (MC) DEGRADED HYDRAULICS MODE EVALUATION

PATRICK J. SULLIVAN
CW4, USA
PROJECT OFFICER/PILOT

AUSTIN R. OMLIE
CPT, AV
PROJECT PILOT

RICHARD ADLER
PROJECT ENGINEER

JANUARY 1986

FINAL REPORT

USAAEFA



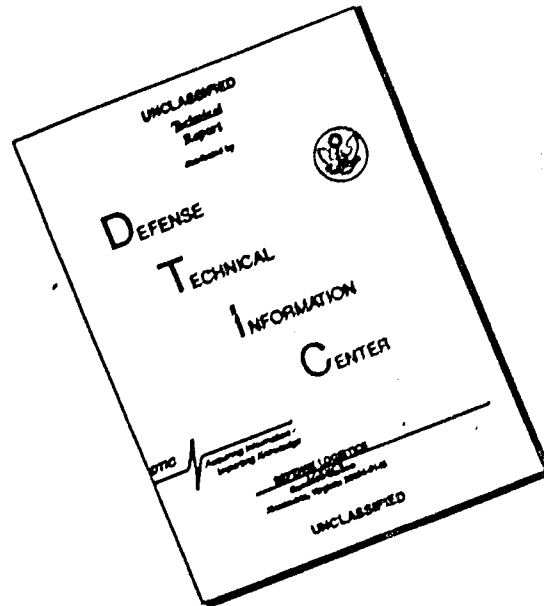
DTIC
ELECTE
APR 2 1987
S E D
E

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED.

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

87- 4 2 008

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER USAAEFA PROJECT NO. 84-16-1	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AH-1S(MC) DEGRADED HYDRAULICS MODE EVALUATION		5. TYPE OF REPORT & PERIOD COVERED FINAL 5-14 OCTOBER 1985
7. AUTHOR(s) PATRICK J. SULLIVAN, AUSTIN R. OMLIE RICHARD ADLER		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS US ARMY AVN ENGINEERING FLIGHT ACTIVITY EDWARDS AIR FORCE BASE, CA 93523-5000		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS US ARMY AVIATION SYSTEMS COMMAND 4300 GOODFELLOW BOULEVARD ST. LOUIS, MO 63120-1798		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 21-4-Z0033-01-21-EC
14. MONITORING AGENCY NAME & ADDRESS (If different from Controlling Office)		12. REPORT DATE JANUARY 1986
		13. NUMBER OF PAGES 58
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		Accession For NTIS GRA&I <input checked="" type="checkbox"/> DTIC TAB <input type="checkbox"/> Unannounced <input type="checkbox"/> Justification
18. SUPPLEMENTARY NOTES		By _____ Distribution/ Availability Codes Avail and/or Special
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) AH-1S (Modernized Cobra) Degraded Hydraulics Mode Evaluation In a		Dist A-1
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A limited evaluation to assess degraded hydraulic system collective control limiting of the AH-1S(MC) helicopter equipped with K747 main rotor blades, was conducted by the US Army Aviation Engineering Flight Activity (USAAEFA). Testing was conducted at Edwards Air Force Base, California between 5 October and 14 October 1985. Twelve flights were flown totalling 9.5 hours, of which 7.9 hours were productive. One deficiency was identified: the collective control limiting after a hydraulic system failure which if experienced in		

DTIC
COPY
INSPECTED
6

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(cont)
UNCLASSIFIED

←
→
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

an out-of-ground effect hover may result in a mishap. Collective control limiting occurred when the minimum value of the collective actuator load reached 1050 +50 pounds. The maintenance test flight (MTF) procedure which was evaluated was unsatisfactory. A recommended MTF procedure was developed during this test and is included in this report.

A

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	
Background.....	1
Test Objectives.....	1
Description.....	1
Test Scope.....	2
Test Methodology.....	2
RESULTS AND DISCUSSION	
General.....	5
Collective Control Limiting.....	5
General.....	5
Collective Control Characteristics.....	5
Collective Actuator Axial Loads.....	6
Airspeed Effects.....	6
Density Altitude Effects.....	7
Rotor Speed Effects.....	7
Gross Weight Effects.....	7
Operation on No. 1 or No. 2 Hydraulic System.....	7
Turning Flight.....	7
Operation on the Emergency Hydraulic System.....	8
Minimum Airspeed with No. 1 or No. 2 Hydraulic System.....	8
Maximum Airspeed with No. 1 or No. 2 Hydraulic System.....	9
Simulated No. 1 or No. 2 Hydraulic System Failures....	9
General.....	9
Simulated Hydraulic System Failures Hover.....	9
Simulated Hydraulic System Failures at V_H	11
Maintenance Test Flight (MTF) Procedure Evaluation....	12
General.....	12
Procedure Evaluation.....	13
CONCLUSIONS	
General.....	15
Deficiency.....	15
RECOMMENDATIONS.....	16

APPENDIXES

A. References.....	18
B. Description.....	19
C. Instrumentation.....	29
D. Test Techniques and Data Analysis Methods.....	35
E. Test Data.....	38
F. Maintenance Test Flight Procedures.....	49

DISTRIBUTION

INTRODUCTION

Reports to...

BACKGROUND

1. The US Army Aviation Systems Command has received several reports that AH-1S helicopters, when equipped with the K747 rotor blades, experienced what was described as a collective servo 'lock-up' when one hydraulic system was selected off. Concern was raised that this condition may exist on fielded aircraft, and could occur under actual emergency single hydraulic system operation. There is no procedure in the Maintenance Test Flight (MTF) Manual (app A, ref 1) to detect this condition. AVSCOM tasked the US Army Aviation Engineering Flight Activity (USAAEFA) to evaluate a maintenance procedure to detect single hydraulic system collective lock-up (ref 2). A restriction or limiting of upward collective control travel was experienced during the evaluation. AVSCOM was advised that the total travel of the collective control may be reduced during a single hydraulic system failure on some or all AH-1S helicopters equipped with K747 main rotor blades (ref 3). Consequently, AVSCOM tasked USAAEFA to further investigate this problem (ref 4).

TEST OBJECTIVES

2. The primary objective of this test was for USAAEFA to conduct an evaluation of procedures to assess single hydraulic system collective control limiting. Additional objectives were: document the variation of collective control limiting in different flight modes, validate a safe flight envelope for single hydraulic system operation, determine whether a transition to a safe flight mode can be made following a single hydraulic system failure, modify emergency procedures in the operator's manual (ref 5) for hydraulic failures and recommend changes to the MTF procedure which field units may use to assess the impact of a single hydraulic system failure.

DESCRIPTION

3. The AH-1S(MC) is a two-place, tandem seat, single-engine attack helicopter incorporating skid landing gear. It is manufactured by Bell Helicopter Textron, Inc. (BHTI) and powered by an Avco Lycoming T53-L-703 Turboshaft engine. The maximum gross weight of the helicopter is 10,000 pounds. The K747 main rotor blades, Part No. K747-003-205, are glass fiber epoxy resin bonded assemblies with a leading edge estane erosion guard. The helicopter is equipped with a three-axis, limited authority, rate stability and control augmentation system (SCAS). The dual main hydraulic system (No. 1 and No. 2 systems) pumps are driven by

the main transmission and are designed to pressurize each system to 1500 pounds per square inch (psi). The No. 1 system provides hydraulic power to the main rotor cyclic (longitudinal and lateral) actuators, main rotor collective actuator, tail rotor (directional) actuator, and yaw SCAS actuator. The No. 2 system provides hydraulic power to the main rotor cyclic actuator, main rotor collective actuator, pitch and roll SCAS actuators, and articulated wing pylons. The emergency hydraulic system utilizes an electric pump designed to provide 1100 psi at full flow rate. The emergency system provides hydraulic power for ground maintenance checks (pylon boresighting) or to the No. 2 portion of the main rotor collective servo if selected on by the flight crew when the No. 2 system is depressurized. Two non-standard hydraulic test (HYDR TEST) switches were installed in the front cockpit to allow the the No. 1 and/or the No. 2 hydraulic systems to be disabled by the copilot. A more detailed description of the helicopter is contained in the operator's manual, the maintenance manual (ref 6) and in appendix B. The test helicopter, AH-1S(MC) serial number 69-16423, is a production AH-1S(MC) helicopter.

TEST SCOPE

4. The evaluation was conducted in 12 flights totalling 9.5 hours, of which 7.9 were productive. Testing was conducted at Edwards Air Force Base, California (elevation 2302 feet) between 5 October and 14 October 1985. USAAEFA installed, calibrated, and maintained the test instrumentation. Data reduction and analysis, aircraft maintenance, and logistical support were provided by USAAEFA. The tests were conducted in accordance with the test plan (ref 7) and within the flight restrictions contained in the operator's manual and the airworthiness release (ref 8).

5. The production hydraulic test switch in the aft cockpit was used to evaluate procedures for inclusion in the MTF. The two non-standard hydraulic test switches installed in the front cockpit were used for the remaining tests. Testing was conducted at two target gross weights (8500 and 10,000 pounds) and two main rotor speeds (314 and 324 rpm).

TEST METHODOLOGY

6. Test techniques are briefly described in the applicable sections of this report and in appendix D. A Handling Qualities Rating Scale (HORS) contained in appendix D was used to augment pilot comments relative to handling qualities.

7. Data were recorded by hand, on magnetic tape onboard the aircraft, and via telemetry to the Real Time Data Acquisition and Processing System (RDAPS). A detailed listing of parameters is contained in appendix C.

Table 1. Test Conditions¹

Test	Weight (lb)	Altitude (ft)	Airspeed (knots)	Propeller RPM	Remarks
Level Flight Power Sweep	7880-9990	4630-11,680	38-114	309-325	Trim at PLF ³ -10% torque. Increase in 10% increments until max allowable or achievable is reached. Configurations were as stated in note 2, additionally, No. 1 and emergency systems "ON", No. 2 OFF.
	8120	6000-10,500	70	323	Emergency system "ON"/ No. 1 and No. 2 "OFF"
Hover Power Sweep	10,100	2480	0	324	Flat pitch to OGE ⁴ hover in 10% torque increments
Accelerated Flight Power Sweep	8330-8715	4950-8470	73-91	319-324	Trim for level flight. Enter 30° & 45° left and right constant altitude turn. Increase torque in 10% increments
Level Flight Acceleration and Deceleration	8240-10,130	6050-10,550	0-118	308-325	Slow acceleration from trim. Slow deceleration from trim.
Simulated Hydraulic System Failures	7880-10,050	1560-6660	0-117	320-325	Begin at 70 KIAS level flight. Decrease trim pt. in 10 kt increments. Recover back to 70 KIAS
					Begin at 70 KIAS level flight. Increase trim pt. in 10 kt increments. Recover back to 70 KIAS
Maintenance Test Flight Procedure	8080-9880	2630-4020	0	308-320	Ref 2, app A

NOTES:

¹8500 lb gross weight tests were conducted without stores with a longitudinal center of gravity at FS 199.3. 10,000 lb tests were conducted at a longitudinal cg of FS 197.3 with XM159C rocket pods inboard and M65 TOW racks outboard.

²Test configurations were No. 1 "ON"/No. 2 and emergency "OFF" and No. 2 "ON"/No. 1 and emergency "OFF" except as noted.

³Power for level flight.

⁴Out-of-ground effect.

RESULTS AND DISCUSSION

GENERAL

8. A limited evaluation was conducted to assess degraded hydraulic system collective control limiting of the AH-1S(MC) helicopter at the conditions presented in table 1. Collective control limiting is a limit of upward collective travel as a result of rotor system loads exceeding the capability of the collective actuator. Below the limit position collective control travel is unrestricted. No downward collective control creep was noted after a hydraulic system failure while operating above the single hydraulics collective limiting position. One aircraft deficiency was noted: the collective control limiting after failure of the No. 1 or No. 2 hydraulic system. The maintenance test flight procedure was determined to be inadequate. A modified procedure is presented in appendix F.

COLLECTIVE CONTROL LIMITING

General

9. Collective control limiting was evaluated to determine the capability of continued safe flight with one or both primary hydraulic systems depressurized. The No. 1 and/or No. 2 hydraulic system(s) were selected ON or OFF by use of the non-standard HYDR TEST switches in the front cockpit. To determine collective control limit position the test helicopter was stabilized at the desired trim condition and the appropriate hydraulic system(s) were depressurized. The collective control was then raised incrementally by the pilot. The limit position was reached when an abrupt increase in the upward force applied by the pilot resulted in no apparent upward collective control movement. Points at which collective control limiting occurred were noted and related to collective actuator axial loads, airspeed, altitude, gross weight, rotor speed, normal load factor, engine torque, engine shaft horsepower, and collective control position. Qualitative evaluations were conducted to determine the effect of collective control force and control input rate on collective control limiting.

Collective Control Characteristics

10. Collective control characteristics were qualitatively evaluated concurrently with all tests. Control forces and rates of application were assessed for effect on collective control limiting. The forces required for collective control movement when either or both hydraulic systems were depressurized and the collective control was below the control limit position were

perceived to be the same as when all hydraulic systems were operating normally. The pilot perceived the collective control mechanical characteristics at this point to be similar to reaching the full up collective control travel stop. Continued upward control force with considerable pilot effort normally resulted in a slight increase of upward control travel, corresponding to 2-3 percent increase in indicated torque, beyond the initial limit position. The rate of control position change was varied with essentially no change in the limit position. A collective control limit was not reached with the No. 1 and emergency systems pressurized, No. 2 system depressurized.

Collective Actuator Axial Loads

11. Collective actuator axial loads were quantitatively evaluated throughout the test. Data are presented in figures 1 through 5, appendix E. These loads were the sum of a mean load and an oscillatory load at a frequency of 10.8 Hz (2/rev) at a main rotor speed of 324 rpm. The test aircraft encountered single hydraulic system (No. 1 or No. 2) collective control limiting of upward travel whenever collective actuator axial load was greater than or equal to the maximum collective actuator output capacity (1050 +50 pounds). When the minimum oscillatory collective actuator load (sum of this mean and oscillatory component) decreased below the maximum actuator output capacity it was possible for the actuator to overcome the rotor system loads and allow upward collective travel, although the mean actuator loads were greater than the maximum actuator capacity. The irreversible valve prevented downward collective creep when the rotor system loads exceeded the capacity of the collective actuator. The maximum collective actuator output capacity and corresponding axial loads could vary among fielded aircraft as a result of individual main rotor blade, collective actuator, and hydraulic system characteristics.

Airspeed Effects

12. The effects of airspeed on collective control limiting were evaluated. Test data are presented in figure 1. The collective control position where limiting was encountered was 3.4 +0.1 inches from full down while hovering in-ground effect (IGE). At 103 knots calibrated airspeed (KCAS) the control limit position increased to approximately 4.2 +0.2 inches from full down. The engine torque at the control limit was 83 +2 percent at an IGE hover and 86 +7 percent at 103 KCAS. The mean oscillatory collective actuator axial load increased with increasing airspeed, however, the minimum oscillatory load at which limiting occurred remained essentially unchanged.

Density Altitude Effects

13. Density altitude effects on collective control limiting were evaluated. Test data are presented in figure 1. The mean engine torque at the control limit decreased approximately 5% in forward flight as density altitude increased from 6000 feet to 12,000 feet. Variation of density altitude resulted in insignificant effects on collective control position at the collective control limit.

Rotor Speed Effects

14. Rotor speed effects on collective control limiting were evaluated. Test data are presented in figure 2. Decreasing rotor speed from 324 to 314 rpm at 75 KCAS resulted in an increase in the collective control limit position of 0.4 inches and a corresponding increase in engine torque of 5 percent. Engine shaft horsepower at the collective control limit position was essentially unchanged with variation of rotor speed.

Gross Weight Effects

15. Gross weight effects on collective control limiting were evaluated. Test data are presented in figure 3. The collective control limit position was essentially unchanged with variation in gross weight.

Operation on No. 1 or No. 2 Hydraulic System

16. Operation on either the No. 1 or No. 2 hydraulic system was evaluated to determine the effect on collective control limiting. Test data are presented in figure 4. The handling qualities of the aircraft were degraded in either pitch and roll, or yaw, depending on which hydraulic system was disabled, as described in the operator's manual. There were no significant differences in the collective actuator loads or collective control limits between the No. 1 and No. 2 hydraulic systems either at a hover or in forward flight.

Turning Flight

17. Accelerated flight while operating on the No. 1 hydraulic system (No. 2 and emergency hydraulic systems depressurized) was evaluated. Test data are presented in figure 5. The collective control limiting position was essentially unchanged with increasing load factor.

Operation on the Emergency Hydraulic System

18. Operation on the Emergency Hydraulic System was evaluated for effect on collective control limiting. The test was initiated at 70 KCAS and at an indicated torque ten percent less than that required for level flight. The No. 2 hydraulic system was depressurized, then the emergency hydraulic pump was selected ON. The No. 1 hydraulic system was then depressurized which resulted in the emergency hydraulic pump providing pressure through the No. 2 system to the collective actuator. Test data are presented in figure 6. All SCAS channels disengaged with the failure of the No. 1 and No. 2 hydraulic systems. The cyclic and tail rotor controls were unboosted and required higher forces for movement. Aircraft attitude oscillations were controllable. The collective control was raised in increments corresponding to approximately 10 percent indicated torque. No unusual control force was required to move the collective control. At each increasing collective control position, a 0.3 Hz roll oscillation became more pronounced. The amplitude increased as collective position and torque were increased. Lateral cyclic control force required to dampen the oscillation increased correspondingly. The lateral cyclic force exerted was estimated to vary from zero to 60 pounds to the right, 180 degrees out of phase to the roll rate. In a climb with less than 60 percent torque and the No. 1 and No. 2 hydraulic systems inoperative, the roll attitude was maintained +10 deg with extreme difficulty and required asymmetrical lateral cyclic inputs of approximately 0.7 inches left to 0.2 inches right every 4-5 seconds (HQRS 9). Exceeding 62 percent torque resulted in an uncontrollable, divergent, roll oscillation which required the pilot to reduce power and restore pressure to the No. 2 hydraulic system in order to maintain control of the aircraft (HQRS 10). It is recommended that paragraph 9-66 of the operator's manual, Hydraulic System No. 1 and No. 2 Failure, should include a discussion regarding the divergent, uncontrollable roll characteristics encountered in high power climbs after dual hydraulic system failure and probable corrective actions (reduction of power).

Minimum Airspeed with No. 1 or No. 2 Hydraulic System

19. Minimum airspeed attainable while operating on a single (No. 1 or No. 2) hydraulic system was determined. At a trim airspeed of 70 KCAS the designated hydraulic system was selected (the alternate and emergency hydraulic systems were depressurized). The appropriate SCAS channel(s) disengaged. The aircraft was decelerated until the collective control limit or other aircraft limit was reached. At an average gross weight of 8500 pounds with either the No. 1 or No. 2 hydraulic system selected, the

minimum airspeed was out-of-ground effect (OGE) hover. No collective control limit was reached and the collective actuator loads were considerably below that for collective limiting. At an average gross weight of 9700 pounds with either hydraulic system the minimum airspeed was just above effective translational lift (ETL). At higher density altitude (6000 ft and above) the minimum airspeed was limited by the engine torque limit, zero left pedal margin, or collective limiting. All limiting conditions were encountered at approximately the same time. At lower density altitudes, minimum airspeed was determined by collective limiting.

Maximum Airspeed with No. 1 or No. 2 Hydraulic System

20. Maximum airspeed attainable while operating on a single (No. 1 or No. 2) hydraulic system was determined. The procedure described in paragraph 18 was followed with the exception that the aircraft was accelerated to the maximum airspeed until the collective control limit or other aircraft limit was reached. The aircraft was flown to the operator's manual airspeed limit prescribed for SCAS off flight (100 KIAS) without encountering collective limiting.

SIMULATED NO. 1 OR NO. 2 HYDRAULIC SYSTEM FAILURES

General

21. The objective of these tests was to determine if transition to a safe flight mode could be made after a simulated single (No. 1 or No. 2) hydraulic system failure in an out-of-ground effect (OGE) hover or in level forward flight at the maximum airspeed at maximum continuous power. The failures were evaluated at the conditions listed in table 1. The non-standard HYDR TEST switches in the front cockpit were used to simulate the failures. The major difference between these and the previous tests was that the hydraulic system was disabled with the collective control above the position at which control limiting occurs. After each simulated failure, the aircraft was flown to a 70 KIAS level flight condition.

Simulated Hydraulic System Failures at a Hover

22. Each hydraulic system (No. 1 or No. 2) was failed at an OGE hover. Winds were less than four knots, hover power was 95 to 98 percent indicated torque, rotor speed was 324 rotor RPM (100%), and hover height was 45 feet above ground level as indicated by the production radar altimeter. Approximate gross weight was 10,000 pounds and density altitude 1300 feet. Immediately prior

to the simulated single hydraulic system failures, collective control limiting was determined by incrementally raising the collective control from full down. Collective control limiting was experienced at the collective position corresponding to 83 percent torque on either No. 1 or No. 2 system.

23. The No. 1 hydraulic system failure was simulated at a hover. A time history is presented in figure 7. The emergency hydraulic pump was not energized after failure of the No. 1 system because the No. 2 system was pressurized. Failure of the No. 1 system caused the yaw SCAS to disengage, the tail rotor servo to depressurize, and the MASTER CAUTION and #1 HYDR PRESS lights to illuminate. These cues were adequate for identification of the failure. Aircraft handling qualities were degraded due to the high directional pedal forces. Cyclic control mechanical characteristics were unchanged. The collective control could not be raised after the simulated failure. No uncommanded downward collective control movement (creep) was noted. The aircraft was then flown to a 70 KIAS level flight condition. No altitude was lost during the transition. The collective control was intentionally lowered during the acceleration. Once lowered, the collective control could not be raised above the limit position. If a No. 1 hydraulic system failure is experienced while masking at a hover (vertical descent), a mishap could result because the power required to arrest the descent would not be available due to collective limiting. The collective control limiting after a single hydraulic system failure is a deficiency. Paragraph 9-64 of the operator's manual, Hydraulic System No. 1 Failure, should be changed as follows:

- a. The following WARNING should be added:

WARNING

Do not lower the collective control until air-speed is above effective translational lift. A run on landing should be accomplished.

- b. The first step of the emergency procedure should be: Wing stores - Jettison if sufficient altitude cannot be maintained due to collective control limiting.

The following description of single hydraulic system collective control limiting should be added to chapter 8, section IV of the operator's manual: "Test results show that collective control forces are essentially unchanged below a limit position. When the collective control is raised and the limit position reached, the control movement is stopped abruptly. At the limit position,

the pilot perceives the collective control characteristics to be similar to reaching a control travel stop. If the pilot exerts considerable upward collective control force, the collective control may raise slightly. If a hydraulic system fails and the collective control is above the limit position, the collective control cannot be raised. If the collective control is lowered, it cannot be raised above the limit position. Downward collective creep should not be encountered after a single hydraulic system failure."

24. Failure of the No. 2 system caused the pitch and roll SCAS to disengage, and the MASTER CAUTION and #2 HYDR PRESS lights to illuminate. These cues were adequate for identification of the failure. A time history is presented in figure 8. The cyclic and directional control mechanical characteristics were unchanged following the failure. Handling qualities were degraded due to the pitch and roll SCAS disengagement. The collective control characteristics were similar to those experienced during the failure of the No. 1 hydraulic system. The collective control could not be raised after the simulated failure. No uncommanded downward collective control movement (creep) was noted. No altitude was lost during the transition to 70 KIAS. Energizing the emergency hydraulic pump may eliminate the collective control limiting after failure of the No. 2 hydraulic system, depending on the component that failed (para 10). Paragraph 9-65 of the operator's manual, Hydraulic System No. 2 Failure, should be changed as follows:

- a. The following warning should be added:

WARNING

Do not lower the collective control until air-speed is above effective translational lift. A run-on landing should be accomplished.

- b. The first step of the emergency procedure should be: EMER HYDR PUMP switch - EMER HYDR PUMP position if sufficient altitude cannot be maintained due to collective control limiting.

- c. The second step of the emergency procedure should be: Wing stores Jettison if sufficient altitude cannot be maintained.

Simulated Hydraulic System Failures at V_H

25. Single hydraulic system failures were simulated at V_H . Time histories are presented in figures 9 and 10. Cues of either

system failure at V_H were the same as those at a hover (as described in the preceding paragraphs). Additionally, aircraft roll or yaw attitude oscillations of ± 2 degrees were encountered. The aircraft oscillations were easily controlled by decelerating the aircraft to the maximum SCAS off speed (100 KIAS) or below. Collective control limiting was not encountered because the deceleration required that the collective control be lowered. No uncommanded downward collective control movement (creep) was noted. The high speed single hydraulic system failure characteristics are satisfactory. The following note should be added to paragraph 9-63 of the operator's manual, Hydraulic System Failure:

NOTE

Decelerate to SCAS off maximum airspeed (100 KIAS) or less after a hydraulic system failure.

MAINTENANCE TEST FLIGHT (MTF) PROCEDURE EVALUATION

General

26. The MTF procedure in reference 2 was evaluated at the conditions presented in table 1. The objective of this test was to determine if the procedure was complete, safe, and adequate. The procedure evaluated was essentially as follows:

a. Conduct the test in an area that permits a run-on landing at 50 KIAS. The test requires two rated pilots. The copilot (front cockpit) should be a thoroughly trained maintenance test pilot or instructor pilot. The copilot operates the collective control. The pilot operates the cyclic and pedal controls, and the HYDR TEST and SCAS switches.

b. From a condition of 100 percent rotor speed, and flat pitch (collective control full down), the HYDR TEST switch is moved to the SYS 1 position. Note illumination of the MASTER CAUTION and #2 HYDR PRESS lights. The PITCH and ROLL SCAS switches should disengage.

c. The copilot slowly and smoothly raises the collective control to bring the aircraft to a three foot hover. The copilot continues to raise the collective control until indicated torque is five per cent greater than the torque required at the three foot hover, or until an aircraft limit is reached. The aircraft is then landed.

d. The copilot lowers the collective control to the full down position. The pilot places the HYDR TEST switch to the center (both) position and re-engages the PITCH SCAS and ROLL SCAS switches.

e. The pilot places the HYDR TEST switch to the SYS 2 position. The MASTER CAUTION and #1 HYDR PRESS lights should illuminate, and the YAW SCAS switch should disengage. The pilot checks that the cyclic moves freely and the pedals are stiff but movable. Step c is repeated.

f. If a collective lock-up or jam occurs, note indicated torque, return the HYDR TEST switch to the center (both) position, and land the aircraft. If the collective controls become abnormally stiff or jam, do not continue before correcting the cause of the jam.

Procedure Evaluation

27. The MTF procedure has no absolute criteria to evaluate the aircraft serviceability. Engine torque at operating rotor speed is the best parameter available to correlate with collective control limiting. A minimum calibrated torque of 85 percent would permit continued flight after a single system hydraulic failure at an OGE hover. This torque value would provide sufficient power for the helicopter to unmask (vertical climb) and transition to forward flight after a single hydraulic system failure (wing stores jettison may be required). The lack of minimum criteria in the MTF procedure is unsatisfactory. Minimum criterion for No. 1 or No. 2 hydraulic system collective control limiting should be established. The recommended minimum criterion is 85 percent engine torque at 100 percent rotor speed.

28. The MTF procedure requires that the operation of the flight controls be divided between the crewmembers. This requirement increases coordination and workload because each crewmember must keep the other crewmember informed of the flight control inputs that will be made. The most difficult and critical portions of the MTF procedure are the lift-off and touchdown. Alternate procedures were evaluated that included initiating and terminating the dual-pilot operation at an IGE hover. The pilot operated all flight controls during lift-off and touchdown. The MTF objectives were accomplished and workload was reduced. If the collective control is above the limit position when the single hydraulic system is selected, the pilot should select both hydraulic systems and land. A run on landing should be made if hydraulic pressure is not restored to both systems. The division of crew duties during takeoff and landing from a hover as required

by the MTF procedure resulted in high workload and is unsatisfactory. An alternate procedure is presented in appendix F and should be incorporated in the MTF manual.

CONCLUSIONS

GENERAL

29. One deficiency was identified.

30. The current MTF procedure is unsatisfactory (para 28).

31. The test aircraft encountered single hydraulic system (No. 1 or No. 2) collective limiting of upward travel whenever collective actuator axial load was greater than or equal to the maximum collective actuator output capacity (1050 +50 pounds) (para 11).

32. The helicopter was uncontrollable in a climb with indicated torque greater than 62 percent and No. 1 and No. 2 hydraulic systems depressurized, and the emergency system pressurized (para 17).

DEFICIENCY

33. The collective control limiting after a single hydraulic system failure (para. 23).

RECOMMENDATIONS

34. The deficiency listed in paragraph 33 should be corrected as soon as possible.

35. A minimum criterion for No. 1 or No. 2 hydraulic system collective control limiting should be established. The recommended minimum criterion is 85 percent engine torque at 100 percent rotor speed (para 27).

36. The alternate procedure presented in appendix F should be incorporated in the maintenance test flight manual (para 28).

37. Paragraph 9-64 of the operator's manual, Hydraulic System No. 1 Failure, should be changed as follows:

- a. The following WARNING should be added:

WARNING

Do not lower the collective control until air-speed is above effective translational lift.
A run-on landing should be accomplished.

- b. The first step of the emergency procedure should be: Wing stores - Jettison if sufficient altitude cannot be maintained due to collective control limiting (para 23).

38. The following description of single hydraulic system collective control limiting should be added to chapter 8, section IV of the operator's manual: "Test results show that collective control forces are essentially unchanged below a limit position. When the collective control is raised and the limit position reached, the control movement is stopped abruptly. At the limit position, the pilot perceives the collective control characteristics to be similar to reaching a control travel stop. If the pilot exerts considerable upward collective control force, the collective control may raise slightly. If a hydraulic system fails and the collective control is above the limit position, the collective control cannot be raised. If the collective control is lowered, it cannot be raised above the limit position. Downward collective creep should not be encountered after a single hydraulic system failure" (para 23).

39. Paragraph 9-65 of the operator's manual, Hydraulic System No. 2 Failure, should be changed as follows:

- a. The following WARNING should be added:

WARNING

Do not lower the collective control until air-speed is above effective translational lift. A run-on landing should be accomplished.

b. The first step of the emergency procedure should be: EMER HYDR PUMP switch - EMER HYDR PUMP position if sufficient altitude cannot be maintained due to collective control limiting.

c. The second step of the emergency procedure should be: Wing stores - Jettison if sufficient altitude cannot be maintained (para 24).

40. Paragraph 9-66 of the operator's manual, Hydraulic System No. 1 and No. 2 Failure, should include a discussion regarding the divergent, uncontrollable roll characteristics encountered in high power climbs after dual hydraulic system failure and probable corrective actions (reduction of power) (para 17).

41. The following note should be added to paragraph 9-63 of the operator's manual, Hydraulic System Failure:

NOTE

Decelerate to SCAS off maximum airspeed (100 KIAS) or less after a hydraulic system failure (para 25).

APPENDIX A. REFERENCES

1. Technical Manual, TM 55-1520-236-MTF, *Maintenance Test Flight Manual, Army Model AH-1S Helicopter*, 7 November 1980, with change 3.
2. Letter, AMSAV-ED, HQ AVSCOM, 9 September 1985, subject: AH-1S(MC) Instrument Meteorological Conditions (IMC) Flight Evaluation, USAAEFA Project No. 84-16.
3. Letter, SAVTE-TI, USAAEFA, 13 September 1985, subject: AH-1S(MC) Collective Control Travel Restriction.
4. Letter, AMSAV-S, HQ AVSCOM, 11 October 1985, subject: AH-1S(MC) Degraded Hydraulic Mode Evaluation.
5. Technical Manual, TM 55-1520-236-10, *Operator's Manual, Army Model AH-1S(PROD), AH-1S(ECAS), AH-1S(Modernized Cobra) Helicopters*, 11 January 1980, with change 10.
6. Technical Manual, TM 55-1520-236-23-2, *Aviation Unit and Intermediate Maintenance Manual, Army Model AH-1S(PROD), AH-1S(ECAS), AH-1S(Modernized Cobra) Helicopters*, 8 May 1980, with change 7.
7. Test Plan, USAAEFA Project No. 84-16-1, *AH-1S(MC) Degraded Hydraulics Mode Evaluation*, October 1985.
8. Letter, HQ AVSCOM, AMSAV-E, 2 May 1985, with Revision 2, dated 3 October 1985, subject: Airworthiness Release for Instrument Meteorological Conditions (IMC) Flight Test of the JAH-1S(MC) Helicopter with Flight Control System and Airframe Modifications.

APPENDIX B. AIRCRAFT DESCRIPTION

GENERAL

1. The AH-1S Modernized Cobra (MC) helicopter (photo 1) 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 boxbeam 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 stabilized 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 is 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 529 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 at a sea level standard day condition. When installed in the AH-1S aircraft the engine is transmission limited to 1294 shp for 30 minutes.

COLLECTIVE CONTROL SYSTEM

3. The collective control system (fig. 1) includes the pilot and gunner collective stick assemblies, tube assemblies, bellcranks, and a dual hydraulic servo cylinder. The hydraulic servo cylinder



Photo 1. AH-1S(MC) Helicopter, USA S/N 69-16423

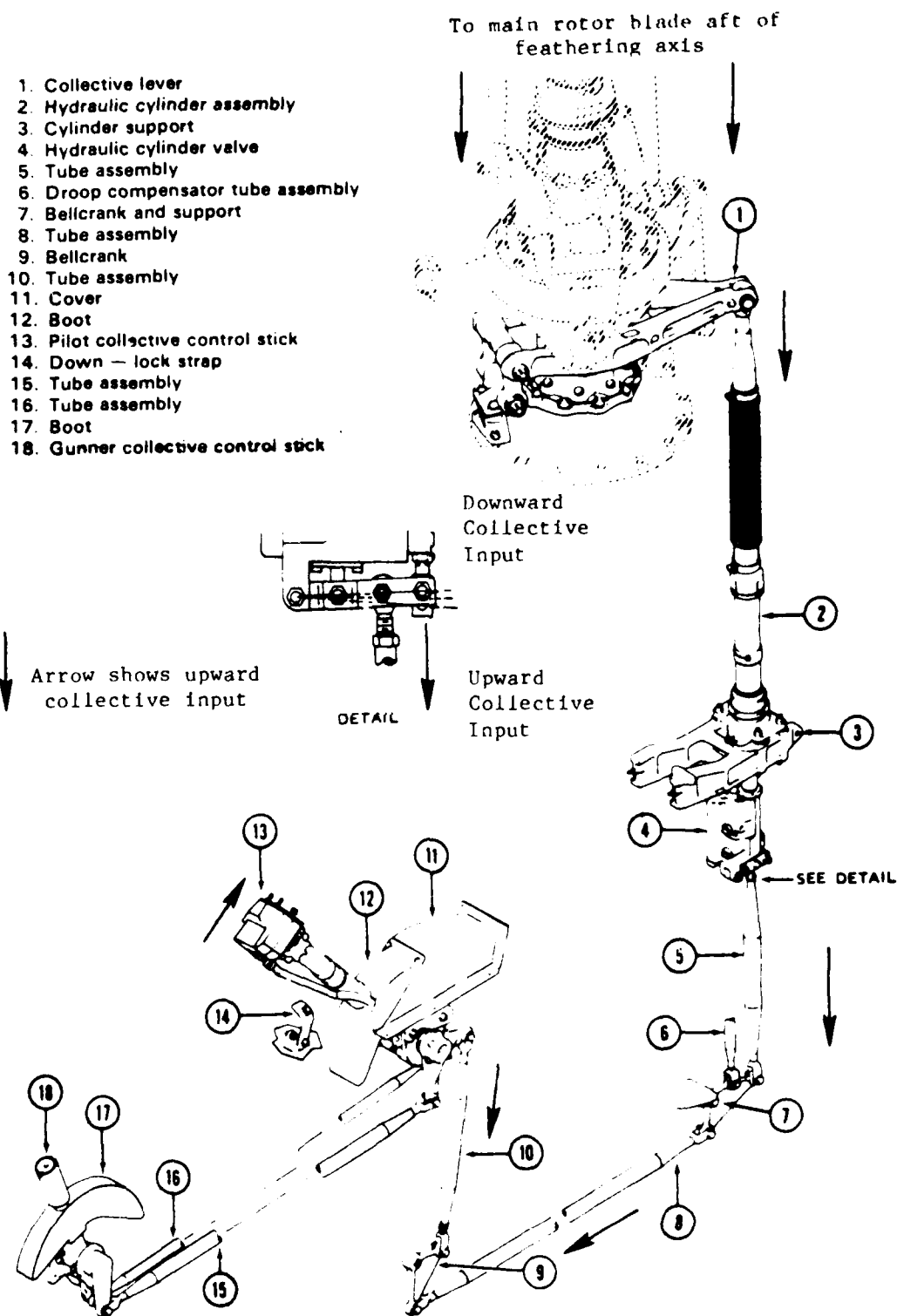


Figure 1. Collective Controls
21

is connected to the collective lever which actuates the mast-mounted scissors and sleeve assembly to control pitch of the main rotor blades. The pilot collective control stick is on the left side console. A support assembly at the base of the collective stick houses the collective friction shoes, a collective lever, and a throttle lever. Located between the base of the stick and the top is a throttle friction nut, throttle grip, collective friction nut, and a boot and support assembly. The pilot collective stick has a mechanical advantage of 1.1 to 1 ratio over the gunner collective stick because of the difference in length. The gunner collective stick is mounted on the gunner left side and has only the essential functions of collective pitch and throttle control.

HYDRAULIC SYSTEM

4. The AH-1S(MC) has three hydraulic systems identified as the No. 1 system, the No. 2 system, and the emergency system (fig 2). The No. 1 and No. 2 systems have similar reservoirs, transmission driven pumps, and module assemblies which contain system filters, solenoid valves, relief valves, and pressure switches for the caution lights. The emergency system has a reservoir, 28 VDC electric motor driven pump, solenoid valves, filter, check valves, and pressure switch for the advisory light.

5. Although the No. 1 and No. 2 systems operate the three main rotor dual servo hydraulic cylinders (actuators), there is no interconnection between systems. Each system has separate passages and piston chambers inside each actuator. In addition to the main rotor actuator, the No. 1 system provides hydraulic power for the single tail rotor actuator and the yaw SCAS actuator. The No. 2 system provides hydraulic power for the pitch and roll SCAS actuators and the pylons for M65 TOW missile launchers articulation. The emergency system can be used to provide hydraulic power to the No. 2 system side of the collective actuator when the No. 2 system is depressurized. The emergency hydraulic system can also be used to articulate the TOW missile launchers during ground maintenance checks and boresighting of the TOW missile launchers.

6. During normal operation, hydraulic fluid is supplied from the No. 1 and No. 2 system nonpressurized reservoirs by gravity feed and suction to the transmission driven pumps. The pumps are variable displacement type to provide 1475 to 1525 pounds per square inch (psi) output pressure and can provide up to 6.5 gallons per minute flow rate at 97% rotor RPM according to system demand. Fluid passes from the hydraulic pumps through the respec-

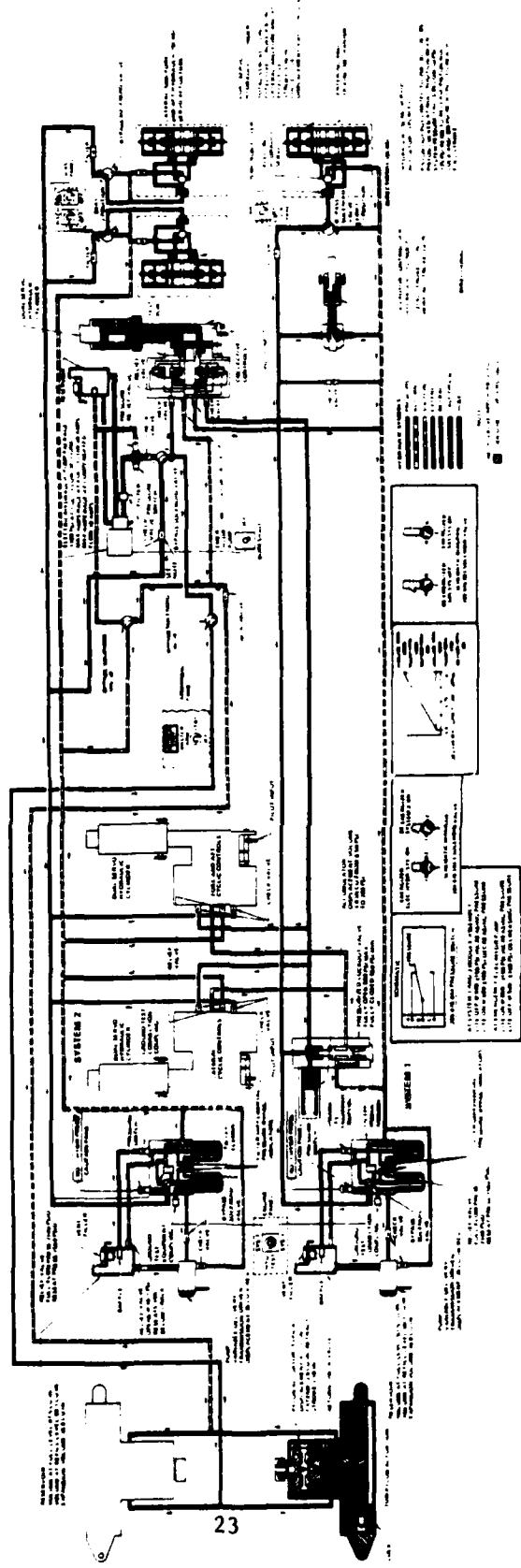


Figure 2. AH-1S(MC) Hydraulic System

tive module assembly pressure filter. The module assembly solenoid bypass valve can also be used to divert system fluid back to the reservoir if the pilot places the HYD TEST switch to the opposite system. The HYD TEST switch which is located on the pilot engine control panel is used to test the No. 1 and No. 2 systems. Holding the switch in either the SYS 1 or SYS 2 position will cause that system to be the only system supplying hydraulic power. A pressure switch is also located on the output side of the No. 1 and No. 2 modules. Each switch turns off the appropriate hydraulic system caution light at 700 to 900 psi when pressure is increasing and turn the lights back on at 500 to 700 psi when the pressure is decreasing. Hydraulic fluid is delivered from the module assemblies to the three main rotor actuator other system actuators as previously stated. Hydraulic fluid is returned from the servo cylinders and actuators through the respective module assembly return filter to the reservoirs. The No. 1 system contains a 1.0 cubic inch accumulator in the pressure fluid line between the module assembly and the main rotor servo cylinders and a lockout valve in the return line from the main rotor servo cylinders to the module assembly. The purpose of the accumulator and lockout valve in the No. 1 system is to maintain hydraulic fluid at approximately 650 psi trapped in the No. 1 system side of the main rotor servo cylinders to ensure that the irreversible valves remain full of fluid and free of air.

7. In the event of a loss of pressure in both No. 1 and No. 2 systems, the pilot can move the cyclic dual servo cylinders by engaging the mechanical stops on the servo actuators and moving the cylinders through direct mechanical coupling and internal irreversible valves. Below 40 KIAS cyclic feedback forces become uncontrollable with the Kaman K-747 rotor blades installed (20 KIAS with the B-540 rotor blades installed). The pilot will not be able to move the collective dual servo cylinder with a total loss of hydraulic power. The EMER HYDR PUMP switch activates the emergency hydraulic pump which provides 1100 psi output pressure at the maximum flow rate of 1.0 gpm. The EMER HYDR PUMP switches are located on the pilot miscellaneous control panel and on the gunner wing store jettison panel. The emergency system will only provide hydraulic power to the No. 2 system side of the collective servo. With only the emergency system providing hydraulic power, the rate of collective movement may be slower than normal and there may be less than total travel available. With a loss of No. 1 system, the pilot can move the tail rotor servo cylinder through direct mechanical coupling.

MAIN ROTOR BLADES

8. The test aircraft is equipped with Kaman K747 main rotor blades (MRB), Part No. K747-003-205. For reference purposes, a comparison will be made between the K747 and B540 MRB. Collective control limiting has not been reported on helicopters equipped with the B540 MRB. The B540 MRB utilizes a symmetrical, constant chord airfoil section with a 2024 T4 aluminum spar and nomex honeycomb core. The K747 MRB has a multicell filament wound fiberglass spar, a nomex core afterbody and a Kevlar trailing edge spline, all enclosed by fiberglass skin. At the inboard end, cheekplates carry blade loads to an aluminum adapter which attaches the blade to the AH-1 rotor hub using the standard hub pin. The K747 MRB has the same radius and essentially an equivalent solidity as the standard B540 MRB (0.0625 as compared with 0.0651 for the B540) although the blade planform is changed. The blade linear twist is increased from -10 degrees to -12 degrees and a nonsymmetrical airfoil shape is employed. The blade weight and stiffness distribution for the K747 were designed to match the dynamic characteristics of the B540.

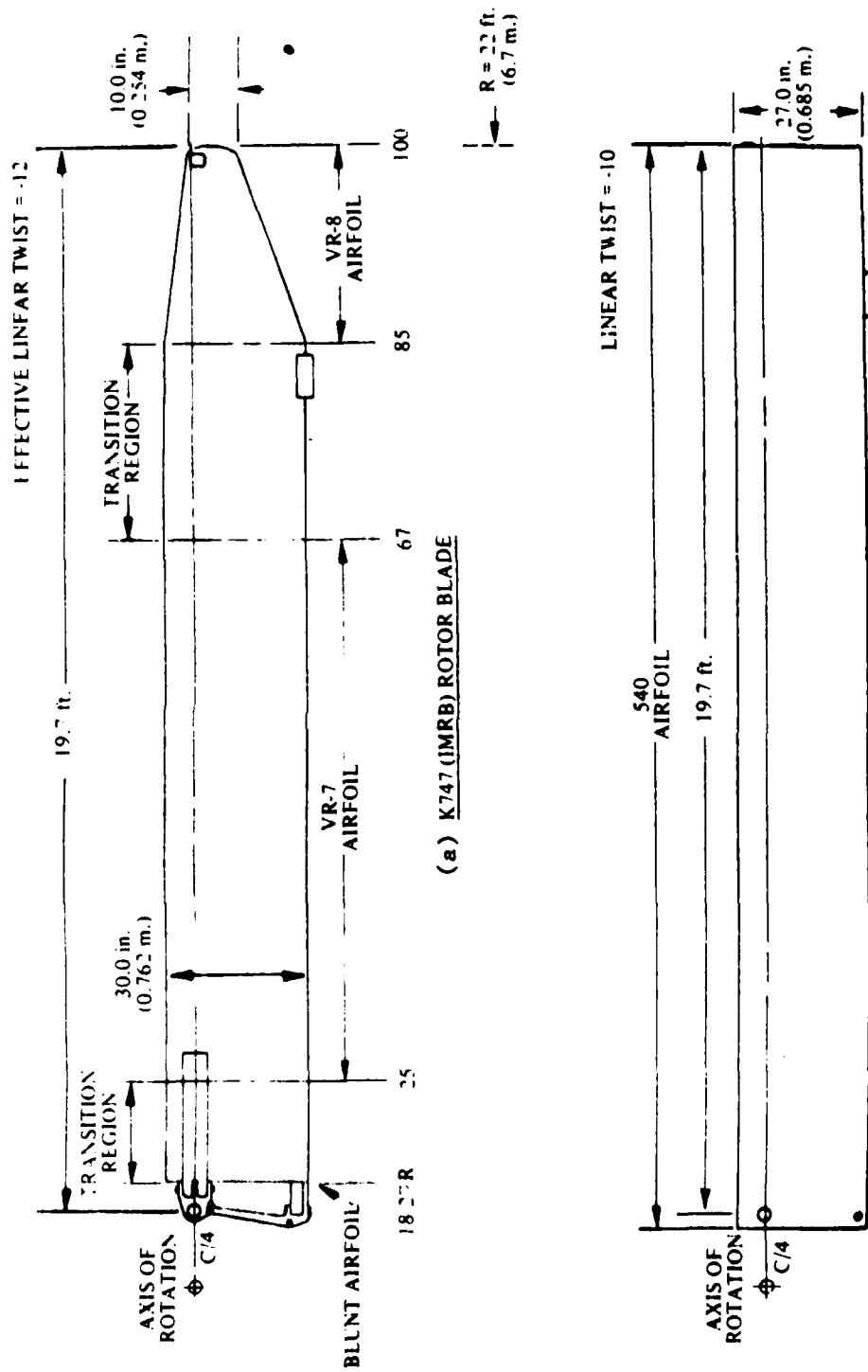
9. The K747 MRB airfoil shape is based on a family of airfoils developed by the Boeing Vertol Company. Planform dimensions are shown in figure 3. The outer 15 percent of the K747 MRB is tapered in thickness and planform with a tip chord of 0.83 foot. The airfoil design varies from blade tip to blade root as follows:

<u>r/R (Blade Radius Station)</u>	<u>Airfoil Design</u>
From Tip to 0.85	8% thick Boeing Vertol VR-8
From 0.85 to 0.67	Linear Transition to 12% thick VR-7
From 0.67 to 0.25	12% thick Boeing Vertol VR-7
From 0.25 to 0.18	Gradual buildup to 25% by cheekplates

The AH-1S hub with hub pin is located at $r/R = 0.15$. There is an attachment adapter fitting and drag brace between the pin and the end of the blade.

PRINCIPAL DIMENSIONS

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



(a) K747 (IMRB) ROTOR BLADE

(b) 540 ROTOR BLADE

Figure 3. Comparison of K747 (a) and B540 (b) Planforms

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 MRB)

Diameter	44 ft
Disc Area	1520.53 ft ²
Solidity	0.0625
No. of blades	2
Planform	Trapezoidal chord 30.0" tapering to 10.0" at tip
Blade twist	-0.556 deg/ft
Normal main rotor speed	324 RPM (100%)

Tail Rotor

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 combered section at 8.27 percent of the tip
---------	--

Tail rotor speed	1655.1 RPM (100%)
------------------	-------------------

Fuselage

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

APPENDIX C. INSTRUMENTATION

1. In addition to, or instead of, standard aircraft instruments, required test instrumentation was calibrated, installed, and maintained by the US Army Aviation Engineering Flight Activity. An airborne data acquisition system utilizing pulse code modulation (PCM) encoding was employed during these tests. Magnetic tape was used to record the PCM data aboard the aircraft. Telemetry transmission of PCM data from the test aircraft to the real time data acquisition and processing system van was utilized.
2. A boom extending forward from the nose of the aircraft incorporated an angle-of-attack sensor, an angle-of-sideslip sensor, and a swiveling pitot-static tube.
3. Two non-standard hydraulic test (HYDR TEST) switches were installed in the front cockpit to allow the No. 1 and/or the No. 2 hydraulic systems to be disabled by the copilot (fig. 1 and photo 1).
4. The collective boost tube axial load instrumentation installation is shown in figure 2 and photo 2.
5. The sensitive instrumentation and related special equipment installed included the following:

Pilot Station and Instrument Panel

Angle of sideslip
Airspeed (boom)
Altitude (boom)
Lateral acceleration

Copilot Station and Instrument Panel

Instrumentation controls and displays including an event switch and time code generator

Recorded Data (PCM)

Collective boost tube axial load
Time
Event copilot
Record number
Main rotor speed
Engine torque pressure
Engine power turbine speed
Gas generator speed

Airspeed (ship)
Altitude (ship)
Airspeed (boom)
Altitude (boom)
Outside air temperature
Fuel flow
Fuel used
Angle of attack
Angle of sideslip
Pitch attitude
Roll attitude
Yaw attitude
Pitch rate
Roll rate
Yaw rate
Longitudinal control position
Lateral control position
Directional control position
Collective control position
Longitudinal SCAS actuator position
Lateral SCAS actuator position
Directional SCAS actuator position
Center of gravity accelerations
 Longitudinal
 Lateral
 Vertical
Main rotor flapping angle

Copilot Instrumentation Panel

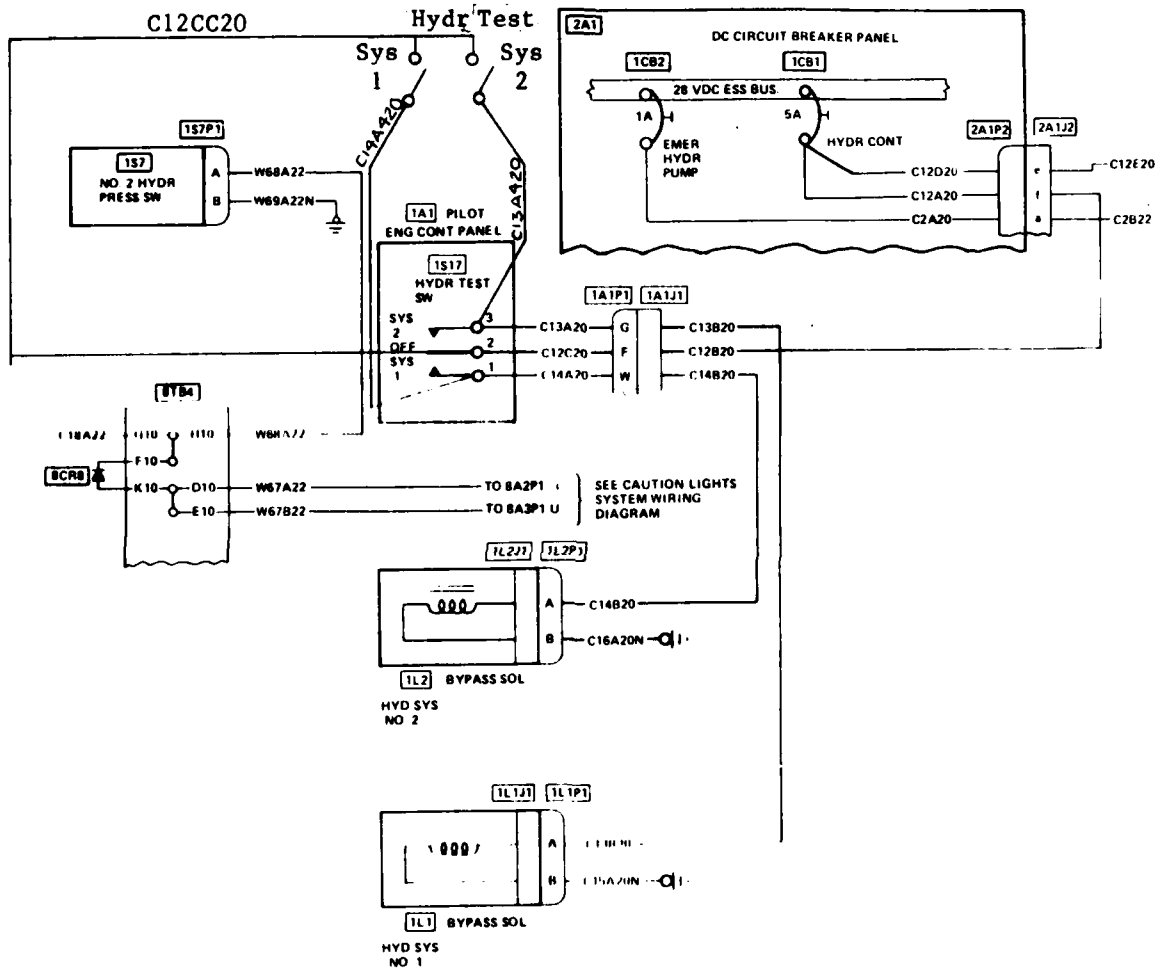


Figure 1. Non-standard Hydraulic Test Switches Wiring Diagram

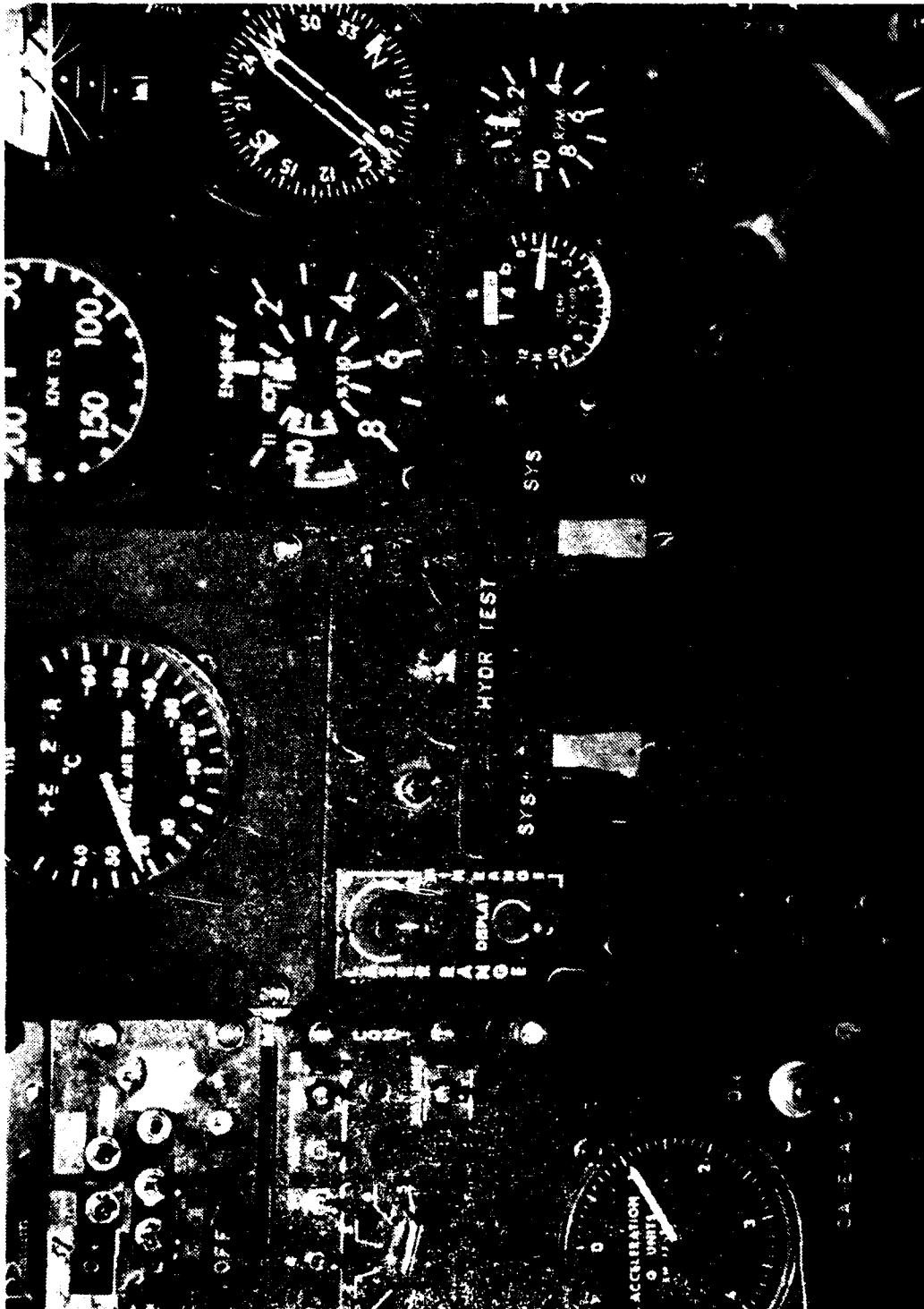
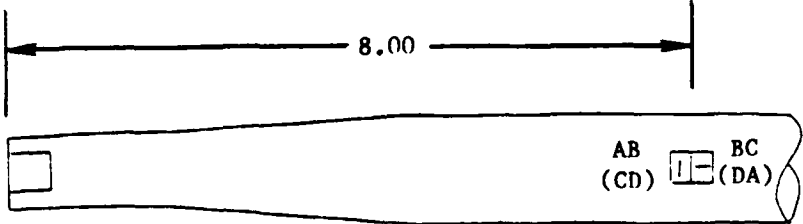


Photo 1. Non-standard Hydraulic Test Switches, Front Cockpit

Boost Tube
Collective



Gage Type: EA 06 125TB 35W

Resistance: 350Ω

Calibration Range: 0-2000 Pounds (Tension)

Figure 2. Collective Boost Tube Axial Load Instrumentation Installation



Photo 2. Cellulose Boost Tube Axial Load Test - Strain Gage Installation

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

PRETEST CHECKS AND CALIBRATIONS

1. The following pretest checks and calibrations were accomplished by USAAEFA personnel. The current pitot-static system calibrations, fuel cell calibrations, and weight and balance data were used.

Hydraulic System Check

2. The helicopter hydraulic systems were checked in accordance with (IAW) the maintenance manual (ref 5). A ground check with a hydraulic test stand and operational check utilizing helicopter power was accomplished.

Rigging Check

3. A collective control system rigging check was performed. IAW the MTF to determine collective control breakout force.

HYDR TEST Switches Operation

4. The non-standard HYDR TEST switches installed at the copilot gunner station were operationally checked in the same manner as the production HYDR TEST switch. Additionally, the installation was evaluated for electro-magnetic interference with other installed aircraft equipment and instrumentation.

CONTROL LIMITING ASSESSMENT

5. The No. 1 and/or No. 2 hydraulic system(s) were selected ON or OFF by use of the non-standard HYDR TEST switches in the front cockpit at a collective control position below the point where control limiting was likely to occur. The pilot in the rear cockpit operated all flight controls. Points at which control limiting occurred were noted and related to collective actuator output loads, airspeed, altitude, gross weight, rotor speed, normal load factor, engine torque, collective control position, collective control force and collective control input rate.

SIMULATED HYDRAULIC SYSTEM FAILURES

6. The objective of these tests was to determine if transition to a safe flight mode, as determined by the previous tests, could be made after a simulated single (No. 1 or No. 2) hydraulic system failure in an OGE hover or at the maximum airspeed for level

flight (V_H), as limited by maximum continuous power or the operator's manual limits. A major difference between these and the previous tests was that a hydraulic system could be disabled with the collective control at a position greater than the point at which control limiting occurs. Any characteristic of collective control to creep was noted. If downward collective creep was encountered, the test would be repeated and the effect of rotor speed reduction investigated. The test was first performed with the No. 1 hydraulic system only, then with the No. 2 hydraulic system only. The test was to be terminated if altitude could not be maintained because of collective control limiting, an aircraft limit was reached, aircraft handling qualities were unacceptable, or recovery was necessary.

MTF PROCEDURE

7. The procedures were performed using production switches and controls.

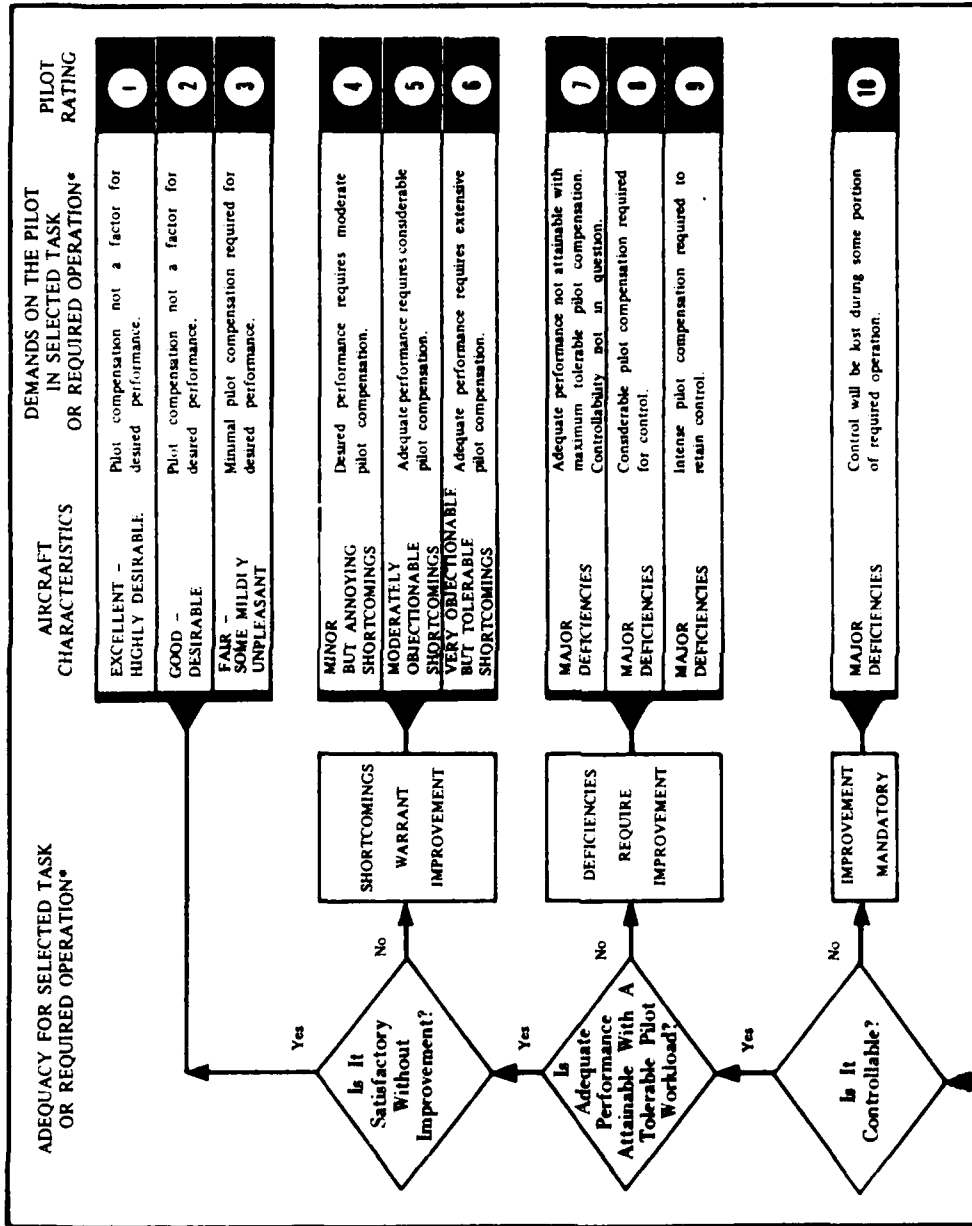
DEFINITIONS

Qualitative Rating Scale

8. A Handling Qualities Rating Scale was used to augment pilot comments and is presented as figure 1.

Deficiency

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



*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

APPENDIX E. TEST DATA

INDEX

<u>Figure</u>	<u>Figure No.</u>
Single Hydraulic Characteristics, Density Altitude Effects	1
Single Hydraulic Characteristics, Main Rotor Speed Effects	2
Single Hydraulic Characteristics, Gross Weight Effects	3
Single Hydraulic Characteristics, #1 and #2 Hydraulic System Comparison	4
Single Hydraulic Characteristics, Load Factor Effects	5
Dual Hydraulics OFF High Power Instability	6
Simulated Hydraulic Failure from OGE Hover	7 and 8
Simulated Hydraulic Failure from V_H	9 and 10

FIGURE 1
SINGLE HYDRAULICS CHARACTERISTICS
DENSITY ALTITUDE EFFECTS

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

GROSS WEIGHT (LB)	DENSITY ALTITUDE (FT)	LONGITUDINAL CG LOCATION (FS)	MAIN ROTOR SPEED (RPM)
7950-10120	1520-12140	197.6-200.3	310-325

□ 0-3000 FT DENSITY ALTITUDE COLLECTIVE LIMITING POINT
 ○ 5000-8000 FT DENSITY ALTITUDE COLLECTIVE LIMITING POINT
 △ 10000-12500 FT DENSITY ALTITUDE COLLECTIVE LIMITING POINT
 X DENOTES TEST POINT LIMITED BY TORQUE AND/OR TGT LIMITS

NOTES: 1. I DENOTES MINIMUM AND MAXIMUM OSCILLATORY PEAK
 2. #1 OR #2 HYDRAULIC SYSTEM DEPRESSURIZED

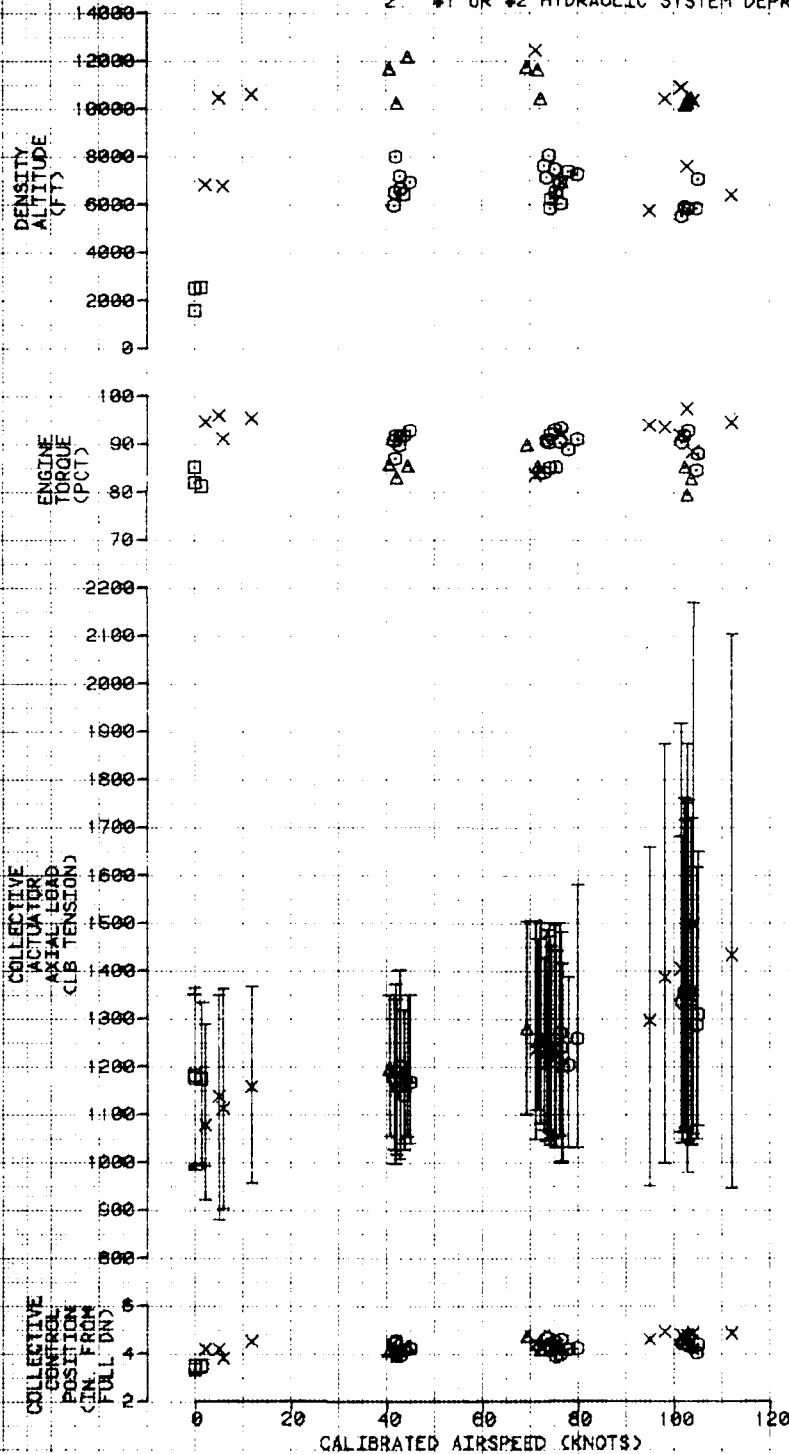


FIGURE 2
 SINGLE HYDRAULICS CHARACTERISTICS
 MAIN ROTOR SPEED EFFECTS
 AH-15 MODERNIZED COBRA (MC) USA S/N 69-16423

GROSS WEIGHT (LB) 7950-10120
 MAIN ROTOR SPEED (RPM) 307-325
 DENSITY ALTITUDE (FT) 1520-12140
 LONGITUDINAL CG LOCATION (FS) 197.6-200.3

□ 324 RPM (100%) MAIN ROTOR SPEED COLLECTIVE LIMITING POINT
 ○ 314 RPM (97%) MAIN ROTOR SPEED COLLECTIVE LIMITING POINT
 X DENOTES TEST POINT LIMITED BY TORQUE AND/OR TGT LIMITS

NOTES: 1. I DENOTES MINIMUM AND MAXIMUM OSCILLATORY PEAK
 2. #1 OR #2 HYDRAULIC SYSTEM DEPRESSURIZED

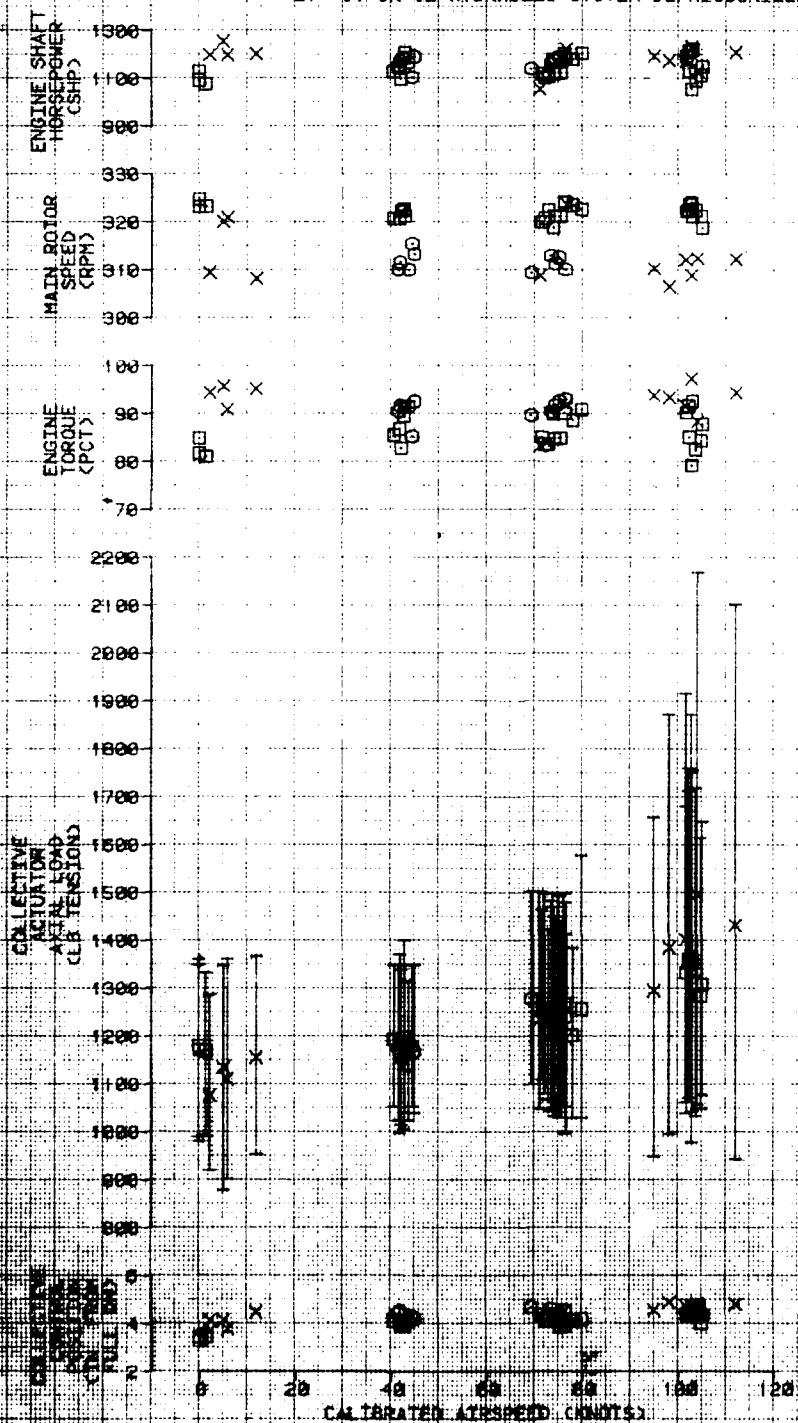


FIGURE 3
SINGLE HYDRAULICS CHARACTERISTICS
GROSS WEIGHT EFFECTS
 AH-15 MODERNIZED COBRA (MC) USA S/N 00-18423

GROSS WEIGHT (LB)	MAIN ROTOR SPEED (RPM)	DENSITY ALTITUDE (FT)	LONGITUDINAL CG LOCATION (FS)
7950-18120	310-325	1520-12140	197.6-200.3

□ 8500 LB TARGET GROSS WEIGHT, COLLECTIVE LIMITING POINT
 ○ 10000 LB TARGET GROSS WEIGHT, COLLECTIVE LIMITING POINT
 X DENOTES TEST POINT LIMITED BY TORQUE AND/OR TGT LIMITS

NOTES: 1. I DENOTES MINIMUM AND MAXIMUM OSCILLATORY PEAK
 2. #1 OR #2 HYDRAULIC SYSTEM DEPRESSURIZED

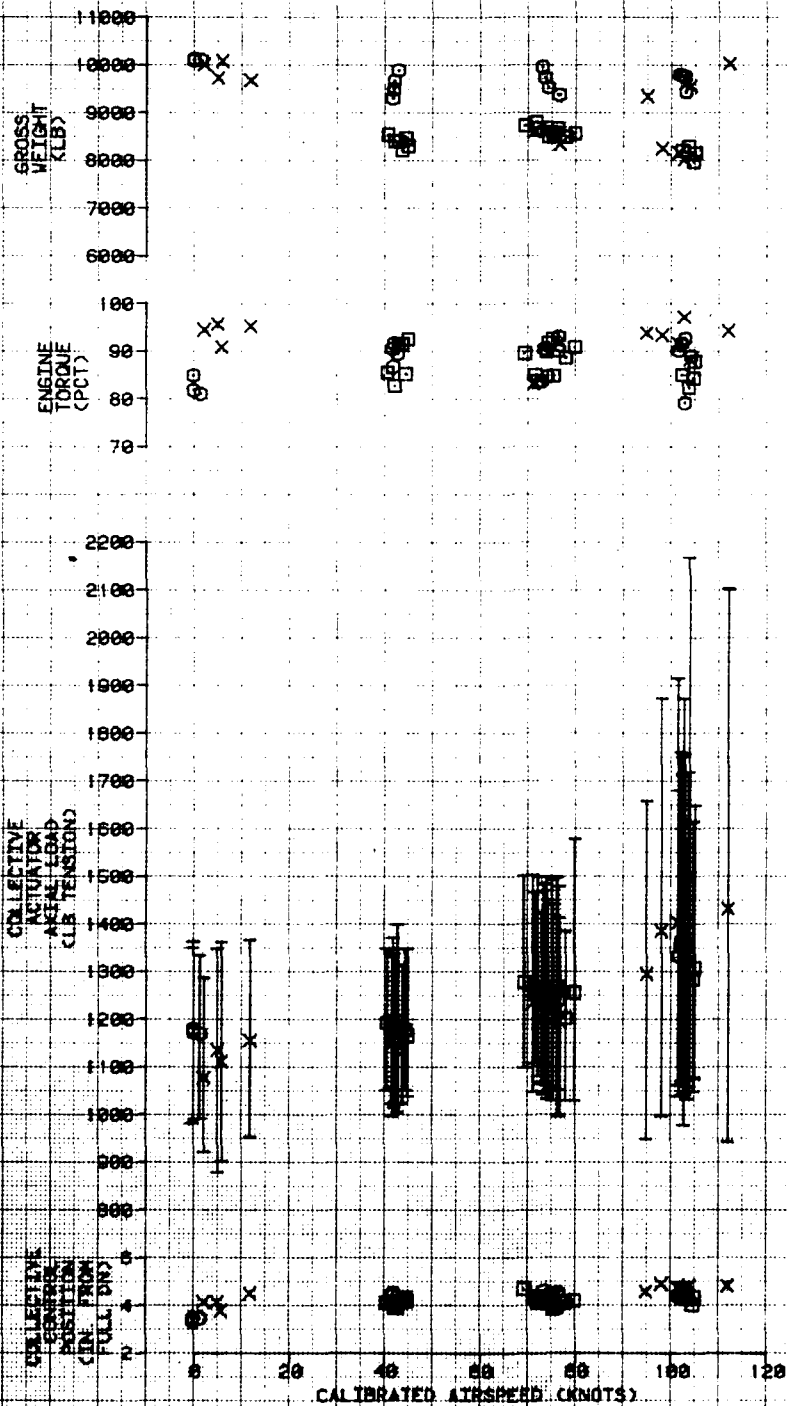


FIGURE 4
SINGLE HYDRAULICS CHARACTERISTICS
#1 & #2 HYDRAULIC SYSTEM COMPARISON
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

GROSS WEIGHT (LB) 7050-10120	DENSITY ALTITUDE (FT) 1520-12140	LONGITUDINAL CG LOCATION (FS) 197.6-200.3	MAIN ROTOR SPEED (RPM) 310-325
--	--	---	--

- #2 HYDRAULIC SYSTEM DEPRESSURIZED, LIMITING POINT
- #1 HYDRAULIC SYSTEM DEPRESSURIZED, LIMITING POINT
- #2 HYDRAULIC SYSTEM DEPRESSURIZED, TEST POINT LIMITED BY TORQUE AND/OR TGT LIMITS
- X #1 HYDRAULIC SYSTEM DEPRESSURIZED, TEST POINT LIMITED BY TORQUE AND/OR TGT LIMITS

NOTE I DENOTES MINIMUM AND MAXIMUM OSCILLATORY PEAK

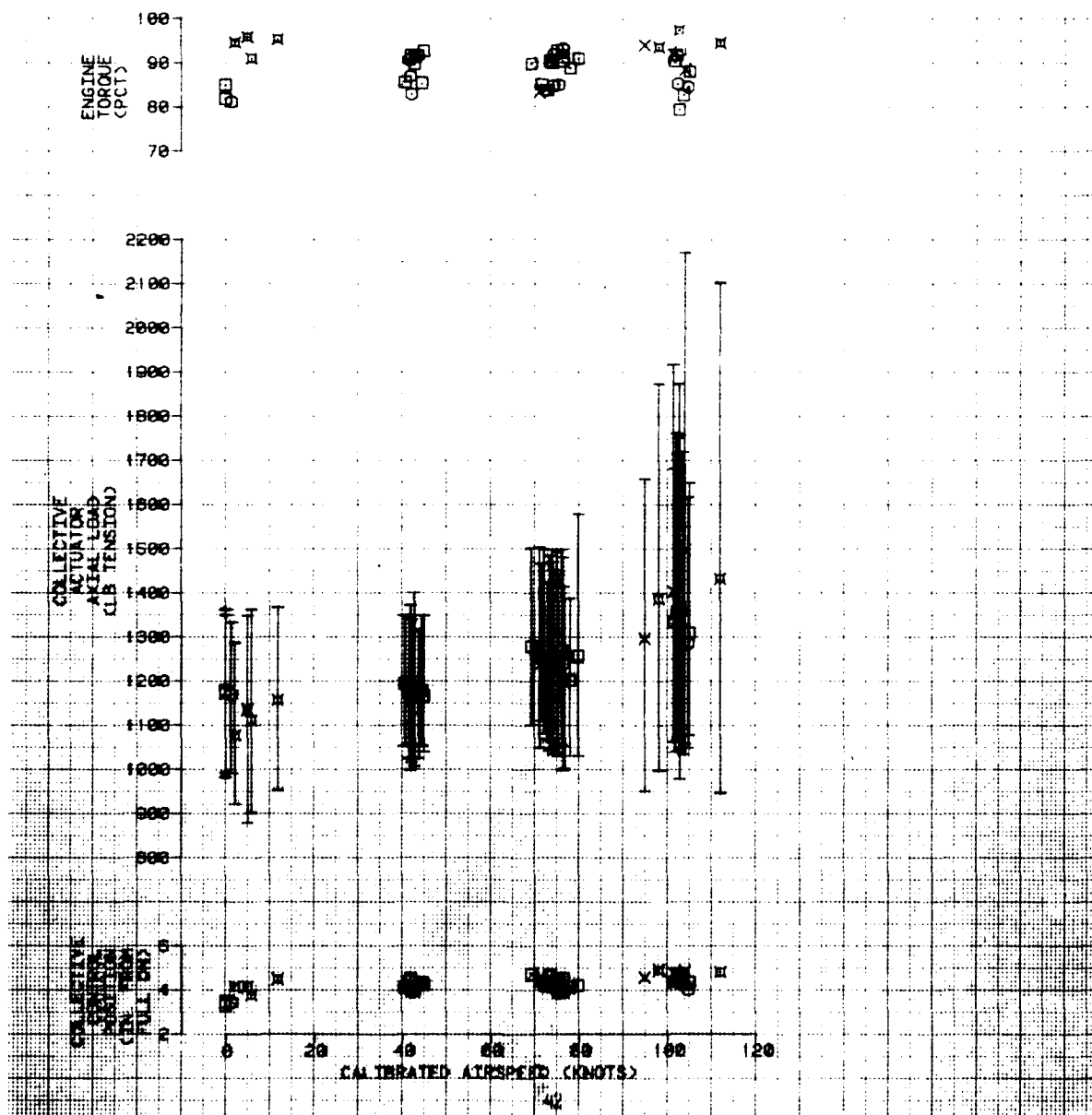


FIGURE 5
SINGLE HYDRAULICS CHARACTERISTICS
LOAD FACTOR EFFECTS
AH-1S MODERNIZED COBRA (MC) USA S/N 69-16423

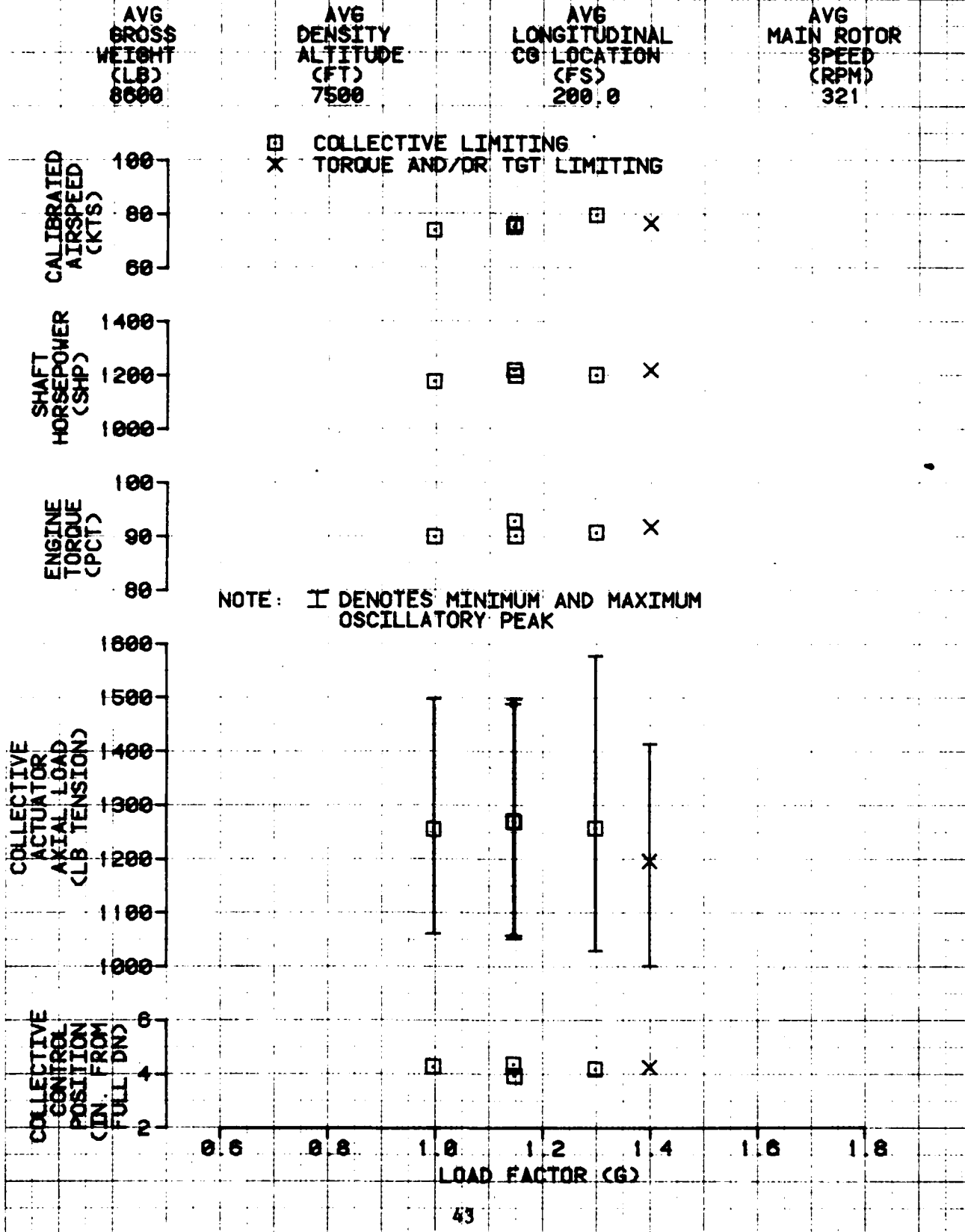


FIGURE 6
 DUAL HYDRAULICS OFF HIGH POWER INSTABILITY

NOTE NUMBER 1 & 2 HYDRAULICS OFF,
 EMERGENCY PUMP ON.

TRIM ROTOR CALIBRATED
 SPEED ALPSPEED
 (RPM) (FACTS) 70

TRIM ROTOR SPEED (RPM) 323

AVG DENSITY OAT 11.0

TRIM ALTITUDE (DEG C) 0.0

AVG CG LONG LAT 0.0

LOCATION (ECL) 0.0

AVG GROSS WEIGHT (LBS) 8120

LONG LAT 99.9

LOCATION (ECL) 0.0

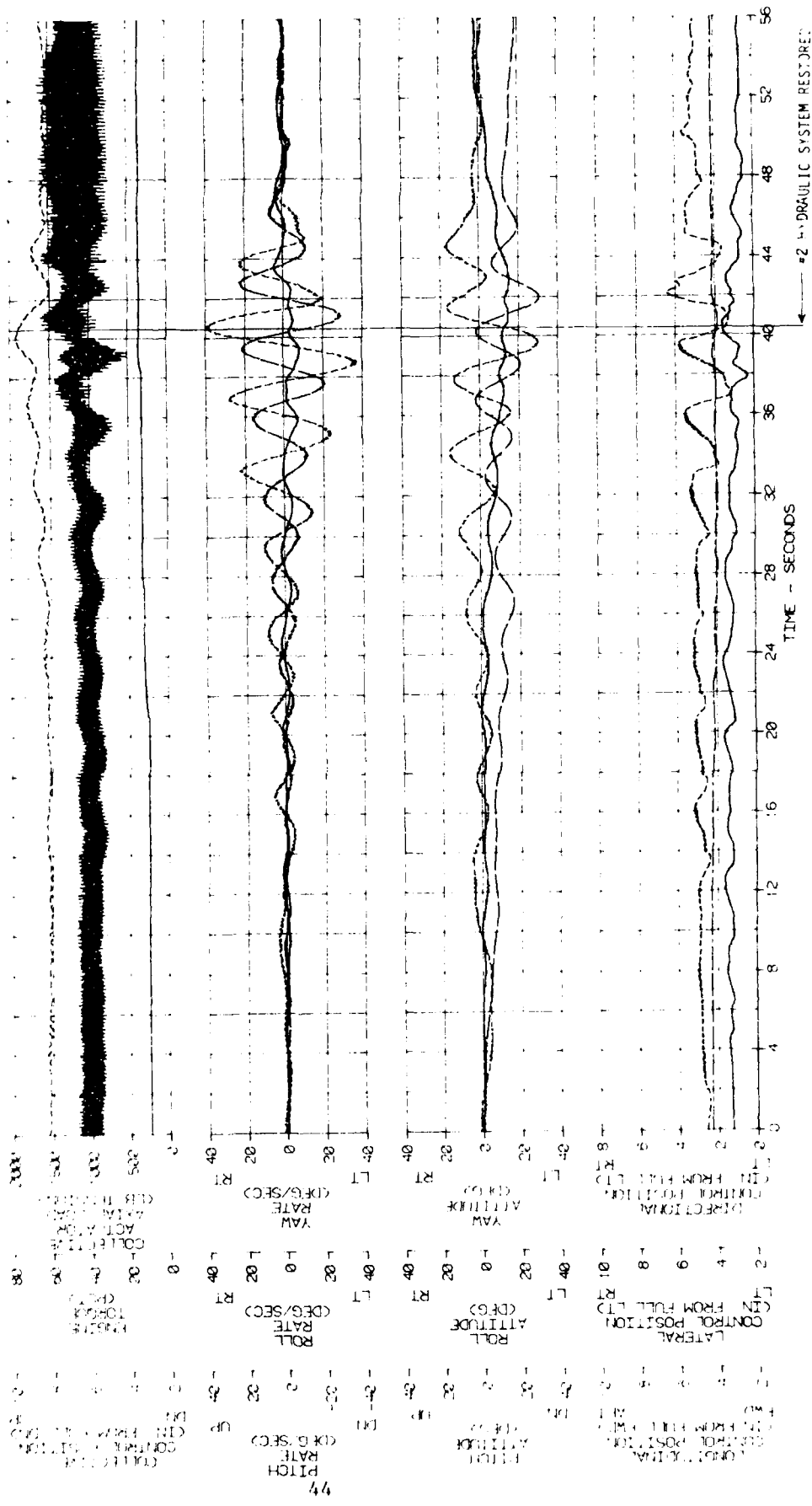


FIGURE 7
SIMULATED #1 HYDRAULIC FAILURE FROM OGE HOVER

NOTE: SIMULATED FAILURE OCCURS
AT TIME = 00 SECONDS

AVG GROSS WEIGHT (LB) 9650
AVG CG LONG (FSD) 197.9
AVG CG LAT (BL) 0.0
TRIM DENSITY ALTITUDE (FEET) 6640
TRIM DA (DEG) 10.2
TRIM CALIBRATED AIRSPEED (KNOTS) HOVER
TRIM SPEED (KNOTS) 30

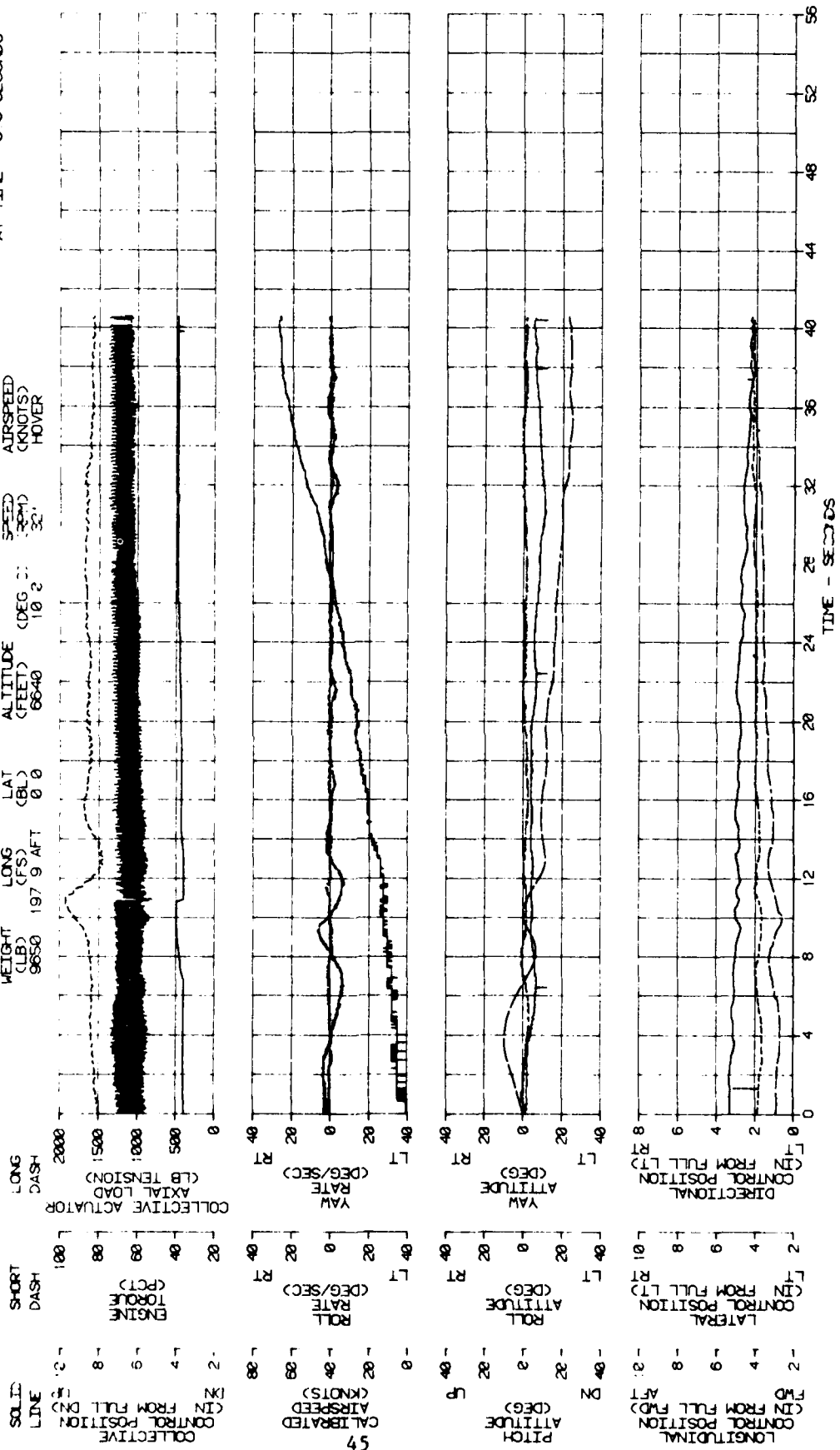


FIGURE 8
SIMULATED #2 HYDRAULIC FAILURE FROM CGE HOVER

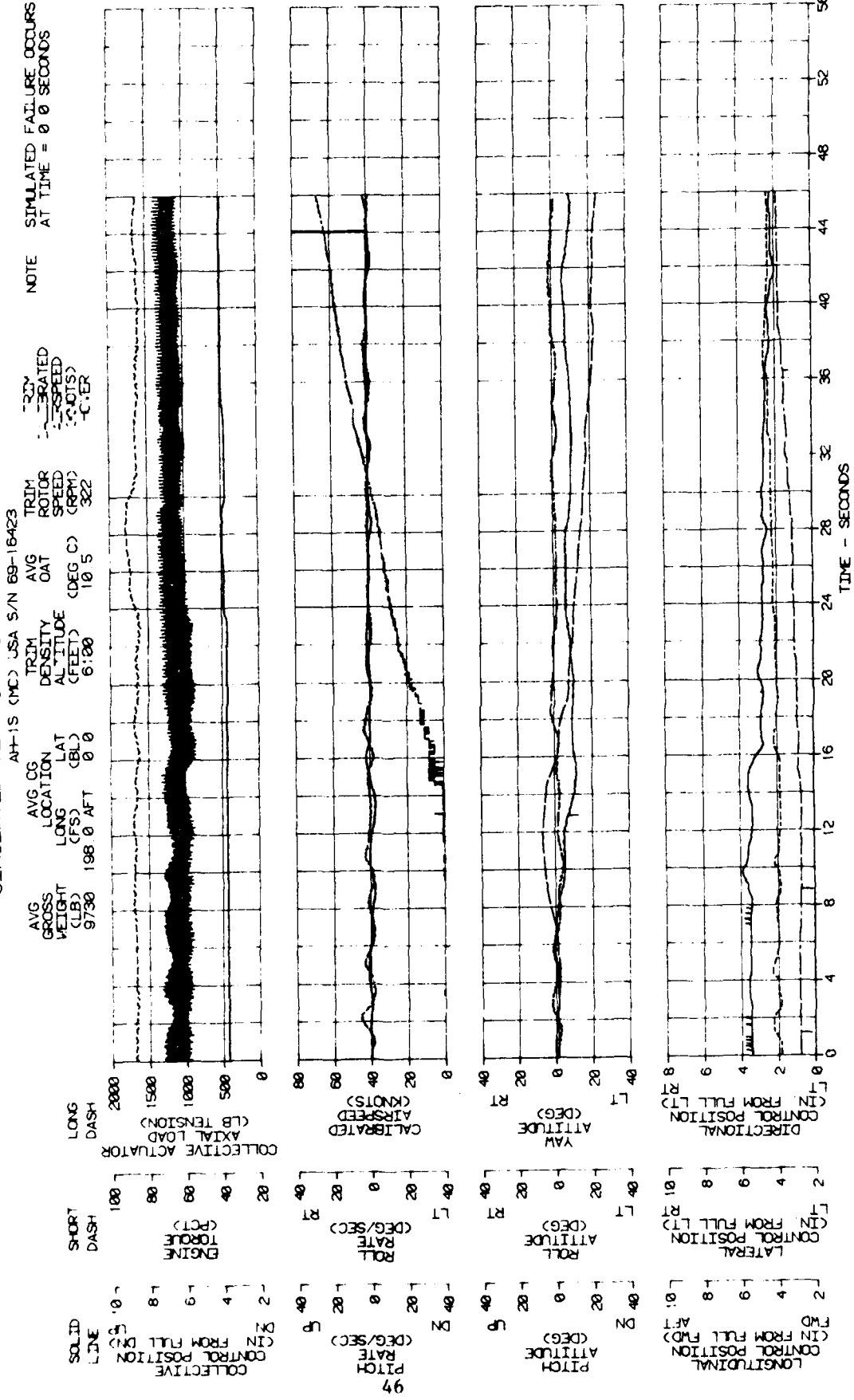


FIGURE 9
 SIMULATED #1 HYDRAULIC FAILURE FROM HIGH SPEED FLIGHT

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

AVG GROSS WEIGHT (LB)	9460	AVG CG LONG (F)	197.8	AVG OAT (DEG C)	10.5	TRIM CALIBRATED AIRSPEED (KNOTS)	117
TRIM DENSITY ALTITUDE (FEET)	6300	TRIM ROTOR SPEED (RPM)	321	NOTE: SIMULATED FAILURE OCCURS AT TIME = 0.0 SECONDS			
AVG CG LAT (BL)	0.0						

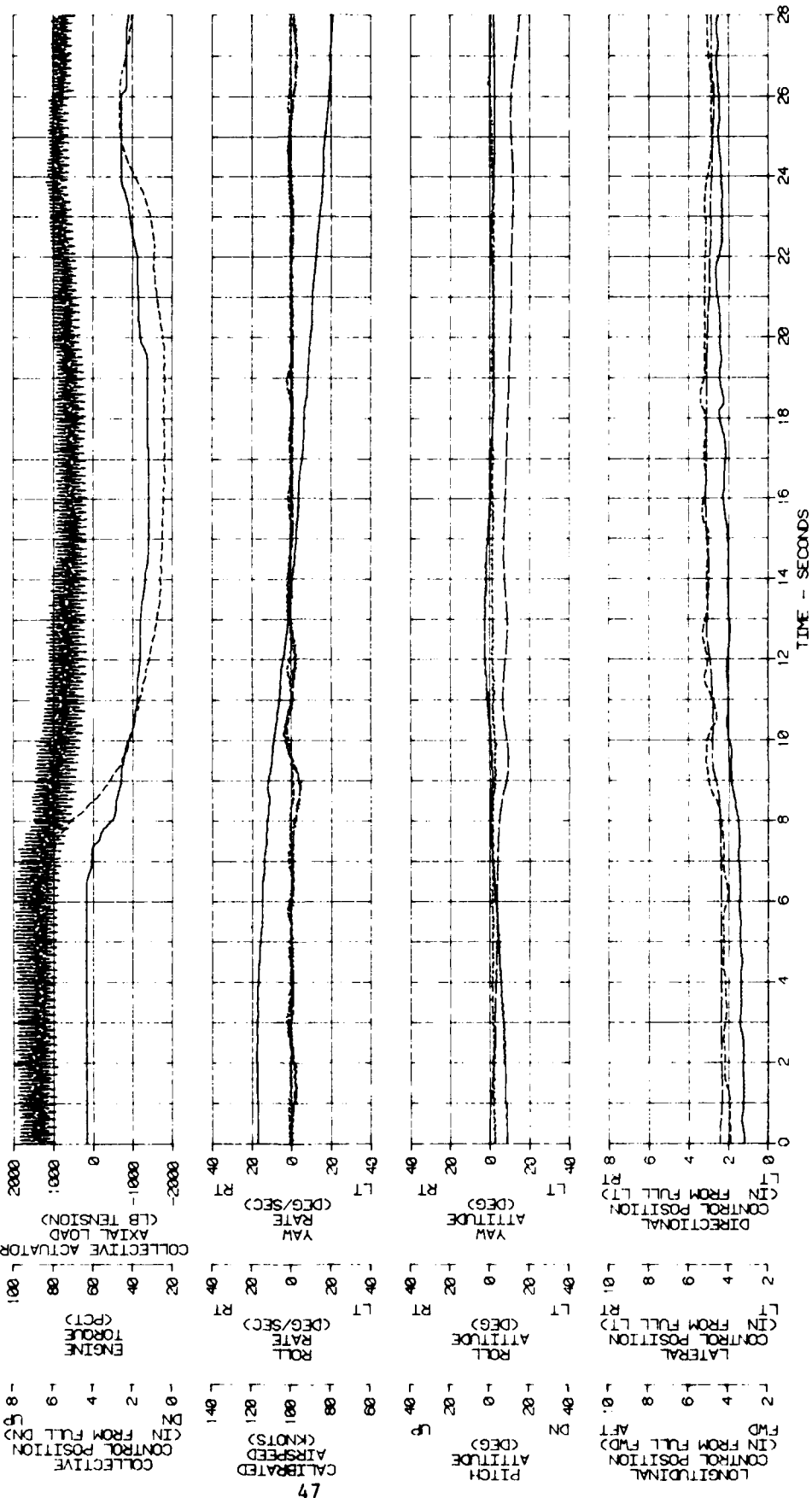


FIGURE 10
 SIMULATED #2 HYDRAULIC FAILURE FROM HIGH SPEED FLIGHT

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

NOTE
 SIMULATED FAILURE OCCURS
 AT TIME = 00 SECONDS

TRIM
 CALIBRATED
 AIRSPEED
 (KNOTS)
 118

TRIM
 ROTOR
 SPEED
 (RPM)
 321

AVG
 OAT
 (DEG C)
 10.5

TRIM
 DENSITY
 ALTITUDE
 (FEET)
 6200

AVG CG
 LOCATION
 LAT (BL)
 00

AVG
 GROSS
 WEIGHT
 (LB)
 9550

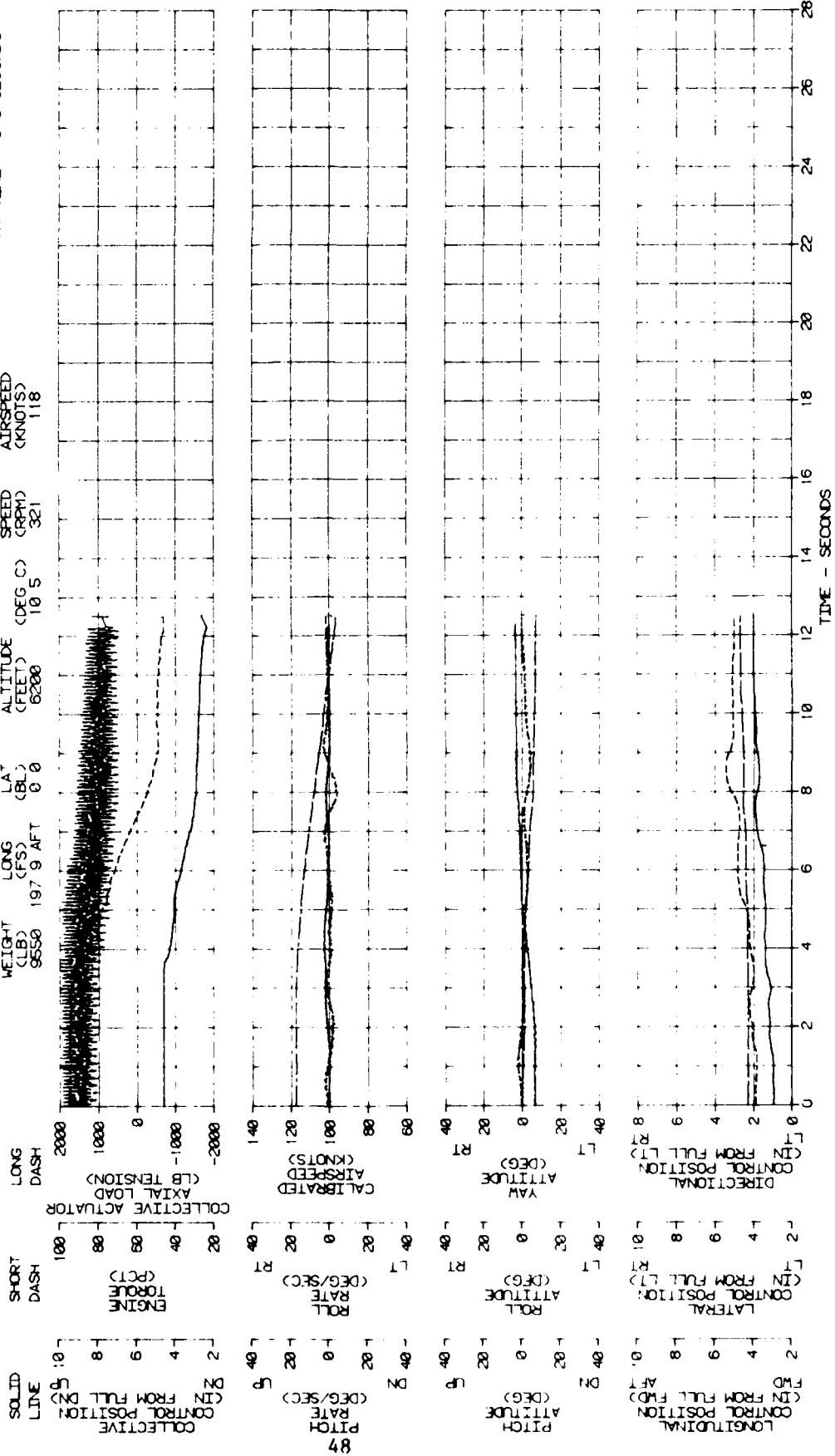
LONG
 DASH
 197.9 AFT

AVG
 GROSS
 WEIGHT
 (LB)
 9550

LONG
 DASH
 197.9 AFT

AVG
 GROSS
 WEIGHT
 (LB)
 9550

LONG
 DASH
 197.9 AFT



APPENDIX F. MAINTENANCE TEST FLIGHT PROCEDURES

1. HYDRAULIC SYSTEM #1 HOVER CHECK - Plan the test so that torque required to hover at 5 foot is approximately 80 percent. Stabilize at 5 foot hover, transfer collective and throttle control to the copilot. Pilot will place the hydraulic control switch to the #1 test position. Note illumination of the MASTER CAUTION and #2 HYDR PRESS lights. The PITCH and ROLL SCAS switches should disengage. Check that the cyclic and pedals move freely. If the collective control is above the limiting position when the single hydraulic system is selected, the pilot should select both hydraulic systems and land. A run on landing should be made and appropriate emergency procedure followed if hydraulic pressure is not restored to both systems. Copilot will gradually increase collective to 85 percent calibrated torque. The rate of collective movement should not exceed a rate necessary to produce a smooth, controlled moderate ascent. When 85 percent torque is reached, copilot will adjust collective to maintain a stabilized hover. Pilot place the HYDR TEST switch to the center (both) position. With hydraulic pressure restored to both systems control of collective and throttle will be transferred to the pilot. Pilot will reduce collective for a normal descent and landing. Reengage the pitch and roll SCAS channels when the No-Go lights are extinguished.

CAUTION

Regaining HYD SYS 1 with pedal force applied may result in excessive yaw rate or over-torque.

2. HYDRAULIC SYSTEM #2 HOVER CHECK - Stabilize at 5 foot hover, transfer collective and throttle control to the copilot. Pilot will place the HYDRAULIC CONTROL SWITCH to the #2 test position. Note illumination of the MASTER CAUTION and #1 HYDR PRESS lights. The yaw SCAS SWITCH should disengage. Check that the cyclic moves freely and that the pedals are stiff, but moveable. If the collective control is above the limiting position when the single hydraulic system is selected, the pilot should select both hydraulic systems and land. A run on landing should be made and appropriate emergency procedure followed if hydraulic pressure is not restored to both systems. Copilot will gradually increase collective to 85 percent torque. The rate of collective movement should not exceed a rate necessary to produce a smooth, controlled moderate ascent. When 85 percent torque is reached, copilot will adjust collective to maintain a stabilized hover. Pilot place the HYDR TEST SWITCH to the center (both) position at a stabilized OGE hover. With hydraulic pressure restored to both systems control of collective and throttle will be transfer-

red to the pilot. Pilot will reduce collective for a normal descent and landing. Reengage the yaw SCAS switch when the No-Go light is extinguished.

DISTRIBUTION

HQDA (DALO-AV, DALO-FDQ, DAMO-HRS, DAMA-PPM-T, DAMA-RA, DAMA-WSA)	6
US Army Materiel Command (AMCDE-SA, AMCDE-P, AMCQA-SA, AMCQA-ST)	4
US Army Training and Doctrine Command (ATCD-T, ATCD-B)	2
US Army Aviation Systems Command (AMSAV-8, AMSAV-ED, AMSAV-Q, AMSAV-MC, AMSAV-ME, AMSAV-L, AMSAV-N, AMSAV-GTD)	15
US Army Test and Evaluation Command (AMSTE-TE-V, AMSTE-TE-O)	2
US Army Logistics Evaluation Agency (DALO-LEI)	1
US Army Materiel Systems Analysis Agency (AMXSY-RV, AMXSY-MP)	8
US Army Operational Test and Evaluation Agency (CSTE-AVSD-E)	2
US Army Armor School (ATSB-CD-TE)	1
US Army Aviation Center (ATZQ-D-T, ATZQ-CDC-C, ATZQ-TSM-A, ATZQ-TSM-S, ATZQ-TSM-LH)	5
US Army Combined Arms Center (ATZL-TIE)	1
US Army Safety Center (PESC-SPA, PESC-SE)	2
US Army Cost and Economic Analysis Center (CACC-AM)	1
US Army Aviation Research and Technology Activity (AVSCOM) NASA/Ames Research Center (SAVRT-R, SAVRT-M (Library))	3
US Army Aviation Research and Technology Activity (AVSCOM) Aviation Applied Technology Directorate (SAVRT-TY-DRD SAVRT-TY-TSC (Tech Library))	2

US Army Aviation Research and Technology Activity (AVSCOM)	1
Aeroflightdynamics Directorate (SAVRT-AF-D)	
US Army Aviation Research and Technology Activity (AVSCOM)	1
Propulsion Directorate (SAVRT-PN-D)	
Defense Technical Information Center (FDAC)	2
US Military Academy, Department of Mechanics	1
(Aero Group Director)	
ASD/AFXT, ASD/ENF	2
US Army Aviation Development Test Activity (STEBG-CT)	2
Assistant Technical Director for Projects, Code: CT-24	
(Mr. Joseph Dunn)	2
6520 Test Group (ENML)	1
Commander, Naval Air Systems Command (AIR 5115B, AIR 5301)	3
Defense Intelligence Agency (DIA-DT-2D)	1
US Army Aviation Systems Command (AMCPM-CO)	4
US Army Aviation Systems Command (AMSAV-EIH)	1
US Army Aviation Systems Command (AMSAV-EP)	1
US Army Aviation Systems Command (AMSAV-EAA)	1
Commander, US Army Plant Representative Office, Bell	
Helicopter Textron (SAVBE-F)	1
Commander, US Army Plan Representative Office, Bell	
Helicopter Textron, Amarillo Division (SAVBE-O)	1