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PERFORMANCE AND HANDLING QUALITIES EVALUATION - AG-1G HELICOPTER WITH LOW REFLECTIVE INFRARED/OPTICAL PAINT

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Army Aviation Engineering Flight Activity
Edwards Air Force Base, California

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PERFORMANCE AND HANDLING QUALITIES EVALUATION AH-1G HELICOPTER WITH LOW REFLECTIVE INFRARED/OPTICAL PAINT

FINAL REPORT

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The performance and handling qualities of an AH-1G helicopter were evaluated in the basic paint configuration, with the fuselage and main and tail rotors painted with a low reflective infrared (IR)/optical paint (FSN 8010-083-6588), and in a modified IR/optical paint configuration in which the tail rotor blades and the main rotor leading edge were stripped of the IR/optical paint. Flight tests were conducted by the United States Army Aviation Engineering Flight Activity at Edwards

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20. Abstract

Air Force Base, California, between 27 November 1974 and 10 April 1975. Twenty-five flights were flown for a total of 24.7 productive flight hours. Performance testing was limited to hover, level flight, and autorotational descent. Handling qualities were qualitatively evaluated throughout the conduct of the test program. Additionally, maneuvering stability was quantitatively evaluated in the IR/optical paint configuration and compared with results from previous reports. Application of the IR/optical paint reduced the out-of-ground-effect hover capability by 340 pounds (which with the added paint weight reduced the payload by 361 pounds) and the maximum airspeed for level flight by 6 knots true airspeed at sea-level, standard-day conditions. The minimum operational rotor speed of 294 rpm could not be maintained down to sea-level standard-day conditions at light gross weights during autorotational descents. Present maintenance test flight procedures for determining autorotational rotor speed limits should be reevaluated in order to ensure detection of this performance characteristic. The performance degradations were significantly reduced in the modified IR/optical paint configuration. Handling qualities were essentially the same for all configurations. If the full IR/optical paint configuration is fielded, further testing should be conducted.

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INTRODUCTION

BACKGROUND

1. The Aircraft Survivability Equipment Product Manager has procured a low reflective infrared (IR)/optical paint (FSN 8C10-083-6588). The results of other tests indicate the paint is effective in reducing the IR signature of an aircraft. The United States Army Aviation Engineering Flight Activity (USAAEFA) was directed by the United States Army Aviation Systems Command (AVSCOM) to determine the effects of this low reflective IR/optical paint on AH-1G performance and handling qualities (ref 1, app A, as modified by refs 2 through 6) prior to painting the fleet.

TEST OBJECTIVE

2. The objective of this test was to evaluate the effects of the low reflective IR/optical paint on the performance and handling qualities of the AH-1G helicopter.

DESCRIPTION

3. The test helicopter, serial number 71-20985, was a production AH-1G manufactured by Bell Helicopter Company (BHC) of Fort Worth, Texas. The AH-1G is a single-main-rotor attack helicopter. Distinctive features include a narrow fuselage, small stub wings with four external stores stations, an integral chin turret capable of mounting two weapons (not installed for this test), and skid-type landing gear. Tandem seating is provided for a crew of two. The main rotor is a two-bladed, semirigid, teetering rotor. The aircraft was modified to incorporate a Model 212 tail rotor. The aircraft is powered by a Lycoming T53-L-13 engine, flat rated to 1100 shaft horsepower (shp) by the main transmission. The flight control system is a positive mechanical hydraulically-boosted irreversible system. A three-axis limited authority stability and control augmentation system (SCAS) employs electrohydraulic actuators in series with the flight control mechanical linkages. A more detailed description of the AH-1G is contained in the operator's manual (ref 7, app A).

4. The low reflective IR/optical paint was air-sprayed over the existing paint. This IR/optical paint is specially formulated to reduce IR solar reflections on the spectral band pass of all currently identified IR-seeking missiles. It is also designed to have a low visual gloss to aid in visual contrast reduction. Further details of the test helicopter, the Model 212 tail rotor, and the IR/optical paint are contained in appendix B.

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TEST SCOPE

5. A limited performance and handling qualities evaluation of the AH-1G helicopter painted with low reflective IR/optical paint was conducted at Edwards Air Force Base, California, between 27 November 1974 and 10 April 1975. The test program was comprised of 25 flights for a total of 33.7 flight hours, 24.7 of which were productive. Forward flight performance tests were conducted in the heavy Hog armament configuration (two XM159C pods on each wing), and hover performance and handling qualities tests were conducted in the clean armament configuration (no external stores). An instrumented cargo hook was installed for tethered hover tests and was removed and the fuselage cover plate reinstalled for forward flight tests. The flight envelope and operating limits prescribed in the operator's manual and the safety-of-flight release (ref 8, app A) were observed during this evaluation. Table 1 is a summary of the test conditions. Base-line data were collected first, the aircraft was painted, and the tests repeated. A modified IR/optical paint configuration, in which the IR/optical paint was stripped from the entire tail rotor and the leading edge of the main rotor (para 5, app B), then was tested.

TEST METHODOLOGY

6. Engineering flight test techniques outlined in Army Materiel Command Pamphlet AMCP 706-204 (ref 9, app A) were used in conducting the performance tests. Handling qualities tests were conducted in accordance with Naval Air Test Center flight test manual FTM No. 101 (ref 10). All tests were flown at zero sideslip. The flight test data were obtained from test instrumentation displayed on the pilot and copilot/gunner panels and recorded on magnetic tape via pulse code modulation (PCM) encoding. A detailed listing of the test instrumentation is given in appendix C. Data reduction was accomplished using USAAEFA computer facilities. The test techniques and data analysis methods used are described in appendix D.

Table 1. Test Conditions.

Test	Gross Weight (lb)	Center-of-Gravity Location (in.)	Rotor Speed (rpm)	Density Altitude (ft)	True Airspeed (kt)	Paint Configuration
Hover performance[1]	7500 to 10,540[2]	199.7 (aft)	294 to 324	560	--	Basic
						IR/optical paint
						Modified IR/optical paint
Level flight performance[3]	7720 to 9100	199.4 (aft)	324	5610 to 9640	30 to 148	Basic
				5220 to 9480	50 to 145	IR/optical paint
				5280 to 7740	50 to 130	Modified IR/optical paint
Autorotational descent[3]	7900 to 8100	199.4 (aft)	330 to 294	6650 to 2930	70	Basic
				5250 to 2690	70	IR/optical paint
				8930 to 3500	70	Modified IR/optical paint
Maneuvering stability[1]	7700 to 8100	197.9 (aft)	324	4850 to 5200	110 to 139	IR/optical paint

[1]Clean configuration.
[2]Gross weight and cable tension.
[3]Heavy Hog configuration.

RESULTS AND DISCUSSION

GENERAL

7. The performance and handling qualities of the AH-1G helicopter were evaluated in the basic paint configuration, with the fuselage and main and tail rotors painted with IR/optical paint (IR/optical paint configuration), and in the modified IR/optical paint configuration, in which the tail rotor blades and the main rotor blade leading edge (to 20 percent chord) were stripped of the IR/optical paint. Performance testing was limited to hover, level flight, and autorotational descent. Handling qualities were qualitatively evaluated throughout the conduct of the test program. Additionally, maneuvering stability was quantitatively evaluated in the IR/optical paint configuration and the results compared with those of other tests. Application of the IR/optical paint reduced the out-of-ground-effect (OGE) hover capability by 340 pounds and the maximum airspeed for level flight (V_H) by 6 knots true airspeed (KTAS) at sea-level, standard-day conditions. Missions requiring a higher density altitude OGE hover capability will incur a significant payload reduction with the IR/optical painted tail rotor. The minimum operational rotor speed of 294 rpm could not be maintained down to sea-level, standard-day conditions at light gross weights during autorotational descents. The performance characteristics may not be detectable with existing maintenance test flight procedures. The performance degradations were significantly reduced in the modified IR/optical paint configuration. Handling qualities were essentially the same for all paint configurations.

Hover Performance

8. The hover performance of the AH-1G helicopter in each configuration was determined at the conditions shown in table 1. The tethered hover and free flight test techniques were used to determine the 100-foot skid height OGE hover performance characteristics. A summary of hover performance is shown in figures 1, 2, and 3 of appendix E. Nondimensional hover performance data are presented in figures 4 through 6. Summary hovering performance was based on power available, as presented in figure 7.

9. A comparison of hover performance summaries for a standard day at sea level shows that the IR/optical paint application caused a reduction in hover performance of approximately 340 pounds (which with the added paint weight reduced the payload by 361 pounds). In the modified IR/optical paint configuration, the performance losses were reduced to approximately 60 pounds (81 pounds of payload).

10. Above an altitude of 4800 feet, the standard-day OGE hover performance of the AH-1G in the IR/optical paint configuration is limited by the 10-percent directional control margin of military specification MIL-H-8501A (ref 11, app A). This limitation occurs at an altitude of approximately 7900 feet for the aircraft

with a nonIR/optical painted tail rotor (basic and modified IR/optical paint configurations). Missions requiring a higher density altitude OGE hover capability will incur a significant payload reduction with the IR/optical painted tail rotor. For example, at 8000 feet density altitude, this reduction is approximately 800 pounds. If the IR/optical paint configuration is fielded, further testing should be conducted.

Level Flight Performance

11. Level flight performance characteristics were determined for all configurations at the conditions shown in table 1. The basic AH-1G level flight performance is summarized in figure 8, appendix E. Figures 9 through 13 depict the level flight power required and the specific range curves for the basic AH-1G. The corresponding data for the full and modified IR/optical paint configurations are shown in figures 14 through 19 and 20 through 22, respectively. Computed level flight power-required characteristics for all configurations at 9500 pounds gross weight, sea-level, standard-day conditions, are shown for direct comparison in figure 23. Application of the IR/optical paint reduced V_H by 6 KTAS. The minimum level flight power required increased by 54 shp. With the modified IR/optical paint configuration, V_H was reduced by 2 KTAS and the minimum level flight power required increased by 12 shp. For the basic IR/optical paint configuration, 99 percent maximum specific range (based on fuel flow curves, ref 12, app A) at 9500 pounds gross weight, standard-day, sea-level conditions, was 0.190 nautical air miles per pound of fuel (NAMPP). This was reduced to 0.180 NAMPP for the full IR/optical paint configuration and 0.186 NAMPP for the modified IR/optical paint configuration.

Autorotational Descent Performance

12. The autorotational descent performance of the AH-1G helicopter was determined at the conditions shown in table 1. Autorotational characteristics as a function of gross weight are summarized in figure 24, appendix E. Data are presented for the minimum density altitude to maintain rotor speed with full-down collective. At a given gross weight, there will be a minimum density altitude below which a constant rotor speed cannot be maintained with the collective pitch control on the bottom stop. For the IR/optical paint configuration at a given gross weight, the density altitude for full-down collective and 324 rpm rotor speed was 1800 feet higher than the altitude for the basic configuration. The significant aspect of this degradation was that at light gross weights (less than 7600 pounds), the minimum operational rotor speed of 294 rpm could not be maintained down to sea-level, standard-day conditions. This performance characteristic may not be detectable with existing maintenance test flight procedures. It is recommended that present maintenance test flight procedures for determining autorotational rotor speed limits be reevaluated. The increase in the density altitude for full-down collective for the modified IR/optical paint configuration was 300 feet higher than for the basic configuration.

13. The rates of descent for the IR/optical paint and modified IR/optical paint configurations of 70 knots calibrated airspeed (KCAS) were, respectively, 190 feet per minute (ft/min) and 80 ft/min greater than for the basic configuration.

HANDLING QUALITIES

14. The handling qualities of the AH-1G helicopter were qualitatively evaluated in the basic, IR/optical paint, and modified IR/optical paint configurations throughout the conduct of the test program. Within the scope of this test, the AH-1G handling qualities were the same for all paint configurations.

15. Maneuvering stability characteristics for the IR/optical paint configuration were quantitatively evaluated at the conditions shown in table 1. Steady turns and sudden pull-ups were conducted. Results are depicted in figures 25 and 26, appendix E. The longitudinal control required to achieve normal acceleration was greater than that presented for the basic AH-1G in the AH-1G Phase D report (ref 13, app A). However, comparison with other reports, specifically the AH-1G Phase B report (ref 14) and the AH-1Q improved Cobra armament system Army Preliminary Evaluation (ref 15), indicates essentially the same longitudinal cyclic variation with normal acceleration. The maneuvering stability characteristics are essentially unchanged with the application of IR/optical paint.

VIBRATION

16. Vibration data were recorded during level flight performance tests. Three-axis vibration data were recorded at the cg. Although spectral analysis was not available, a visual comparison of trace characteristics showed no discernible differences between the basic, IR/optical paint, and modified IR/optical paint configurations.

CONCLUSIONS

17. The following conclusions were reached upon completion of testing:

a. The application of IR/optical paint degrades aircraft performance in all areas tested (paras 10 through 13).

b. The performance losses were significantly reduced in the modified IR/optical paint configuration (paras 10 through 13).

c. Present maintenance test flight procedures are not adequate to ensure that rotor speed can be maintained within operational limits during autorotations at light gross weight (para 12).

d. Within the scope of this evaluation, the IR/optical paint application did not noticeably affect aircraft handling qualities or vibrations (paras 14 and 15).

RECOMMENDATIONS

18. If the full IR/optical paint configuration is fielded, further testing should be conducted (para 10).

19. The adequacy of present maintenance test flight procedures should be reevaluated to ensure that safe autorotational rotor speeds can be maintained (para 12).

APPENDIX A. REFERENCES

1. Letter, AVSCOM, AMSAV-EFT, 11 October 1974, subject: AH-1G Low Reflective IR/Optical Paint Airworthiness Evaluation.

2. Letter, AVSCOM, AMSAV-EFT, 4 November 1974, subject: AH-1G Low Reflective IR/Optical Paint Airworthiness Evaluation (Program Modification).

3. Message, AVSCOM, AMSAV-EFT, 072321Z December 1974, subject: AH-1G Low Reflective IR/Optical Paint Airworthiness Evaluation (Program Modification).

4. Message, AVSCOM, AMSAV-EFT, 250044Z December 1974, subject: AH-1G Low Reflective IR/Optical Paint Airworthiness Evaluation (Program Modification).

5. Message, AVSCOM, AMSAV-EFT, 010244Z January 1975, subject: AH-1G Low Reflective IR/Optical Paint Airworthiness Evaluation (Program Modification).

6. Message, AVSCOM, AMSAV-EFT, 240011Z January 1975, subject: AH-1G Low Reflective IR/Optical Paint Airworthiness Evaluation (Program Modification).

7. Technical Manual, TM 55-1520-221-10, *Operator's Manual, Army Model AH-1G Helicopter*, 19 June 1971, with Change 10, 2 April 1974.

8. Message, AVSCOM, AMSAV-EFT, 270744Z November 1974, subject: Safety-of-Flight Release (SOFR) for Low Reflective IR/Optical Paint Configured AH-1G 71-20985.

9. Pamphlet, Army Materiel Command, AMCP 706-204, *Engineering Design Handbook, Helicopter Performance Testing*, August 1974.

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

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, USAASTA, No. 66-06, *Engineering Flight Test, AH-1G Helicopter (HueyCobra), Phase D, Part II, Performance*, April 1970.

13. Final Report, USAASTA, No. 66-06, *Engineering Flight Test, AH-1G Helicopter (HueyCobra), Phase D, Part I, Stability and Control*, April 1970.

14. Final Report, USAASTA, No. 66-06, *Engineering Flight Test, AH-1G Helicopter (HueyCobra), Phase B, Part I*, January 1968.

15. Final Report, USAASTA, No. 72-18, *Army Preliminary Evaluation, Improved Cobra Armament System*, December 1972.

APPENDIX B. DESCRIPTION

1. The test helicopter, serial number 71-20985, was a production AH-1G manufactured by BHC. The AH-1G is a single-main-rotor attack helicopter. Distinctive features include a narrow fuselage, small stub wings with four external stores stations, an integral chin turret capable of mounting two barrel-type weapons (not installed for this test), and skid-type landing gear. Tandem seating is provided for a crew of two. The main rotor is a two-bladed, semirigid, teetering rotor. The aircraft was modified to incorporate a BHC Model 212 tail rotor, which is described in paragraph 2. The aircraft is powered by a Lycoming T53-L-13 engine, flat rated to 1100 shp by the main rotor transmission. The flight control system is a positive mechanical hydraulically-boosted irreversible system. A three-axis limited authority SCAS employs electrohydraulic actuators in series with the flight control mechanical linkages.

2. The BHC Model 212 tail rotor is a two-bladed, delta-three hinge type employing a flex-beam yoke. Location, power source, and controls are essentially the same as the Model 801 tail rotor. The tail rotor was rigged for 16.4 degrees full left pedal to 12.2 degrees full right.

3. The paint supplied for these tests is a low reflective olive-drab acrylic lacquer, FSN 8010-08[illegible]-6588, specified by military specification MIL-L-46159. It is specially formulated to reduce IR solar reflections in the spectral band pass of all currently identified IR-seeking missiles. It is also designed to have a low visual gloss to aid in visual contrast reduction.

4. The IR/optical paint was applied by overspraying the existing paint. The fuselage, main and tail rotors, and XM159C rocket pods were sprayed. Main and tail rotor control linkages and mast were not painted. Photos 1 and 2 show the paint application.

5. The modified IR/optical paint configuration was achieved by stripping the IR/optical paint from the entire surface of the tail rotor blades and the leading edge of the main rotor blades. The paint was stripped back 5 inches along the main rotor chord over the entire span. Photo 3 shows the configuration.

Photo 1. AH-1G Helicopter With Painted Tail Rotor Blades.

Photo 2. AH-1G Helicopter With Painted Main Rotor Blades.

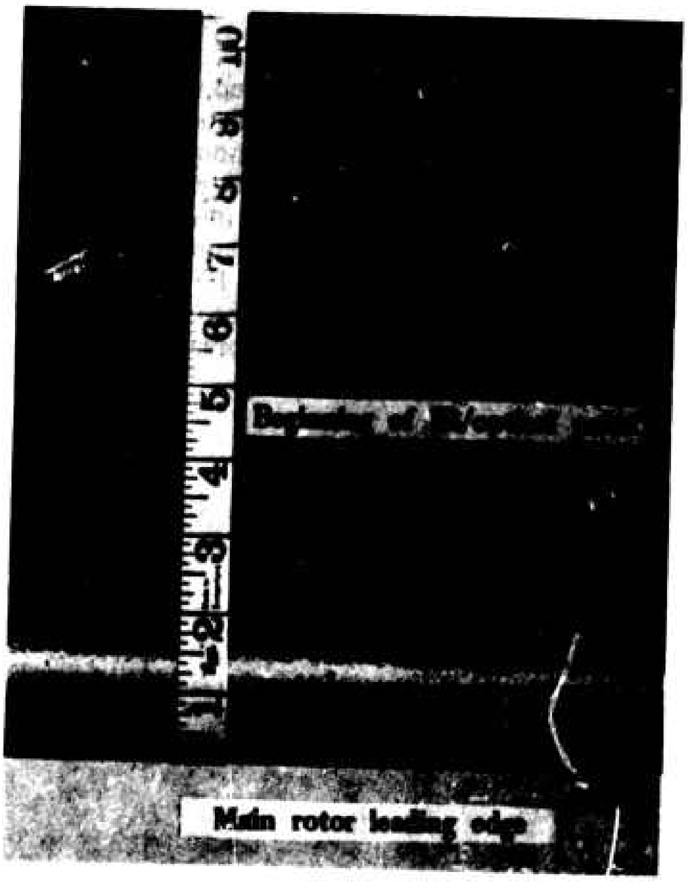


Photo 3. AH-1G Helicopter With Stripped Main Rotor Blade.

APPENDIX C. INSTRUMENTATION

The test instrumentation was calibrated, installed, and maintained by the Data Systems Office of USAAEFA. A test boom was mounted on the nose of the aircraft and the following sensors were mounted on the boom: a swiveling pitot-static head, a sideslip vane, and an angle-of-attack vane. A total-temperature sensor was mounted aft of the test boom on the underside of the aircraft nose section (fuselage station (FS) 53). Fittings for installation of a trailing bomb airspeed calibration system were installed on the left side of the fuselage at FS 90. Data were obtained from calibrated sensitive instrumentation and were recorded on magnetic tape and/or displayed in the cockpit. The following list is a breakdown of the instrumentation utilized during this evaluation.

Pilot Panel

Airspeed (boom)
Altitude (boom)
Main rotor speed
Sideslip angle
Vertical speed (ship's system)
Engine output shaft torque

Engineer Panel

Airspeed (boom)
Altitude (boom)
Main rotor speed
Total outside air temperature
Tether cable tension
Fuel consumed
Engine output shaft torque

Magnetic Tape

Airspeed (boom)
Altitude (boom)
Engine output shaft torque
Main rotor speed
Fuel consumed
Total outside air temperature
Sideslip angle
Pitch attitude
Roll attitude
Tether cable tension

Control positions:
- Longitudinal cyclic
- Lateral cyclic
- Pedal
- Collective

Longitudinal control force
Center-of-gravity normal acceleration
Time code
Pilot event
Engineer event
Vibration accelerometers:
- Center-of-gravity vertical (FS 197.50, BL* 12.75, WL** 36.92)
- Center-of-gravity lateral (FS 197.50, BL 12.75, WL 36.92)
- Center-of-gravity longitudinal (FS 197.50, BL 12.75, WL 36.92)

*BL: Buttline
**WL: Water line

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

TEST TECHNIQUES

Aircraft Weight and Balance

1. The test aircraft was weighed on sensitive electronic scales in the basic configuration after test instrumentation was installed and with the helicopter fully serviced. The fuel load for each test flight was determined prior to engine start and following engine shutdown by using a calibrated external sight gage to determine fuel volume and by measuring the fuel specific gravity. Fuel used in flight was recorded by a sensitive fuel-consumed counter and cross-checked with readings taken from the sight gage after each flight. Aircraft gross weight and cg were controlled by installing ballast in 25-pound increments in the tail boom (FS 472), under the pilot seat (FS 135), and/or in the battery compartment (FS 43).

Hover Performance

2. Hover performance parameters were determined using the tethered and free flight hover techniques as described in AMCP 706-204. With the aircraft tethered to the ground by a steel cable, engine torque was varied from that required to maintain a minimum 200-pound cable tension to the maximum, defined either by a maximum torque limit or by reaching topping power. (For this test, topping power was determined by an inability to maintain the desired rotor speed.) This torque range was repeated for main rotor speeds of 294, 314, and 324 rpm. During the test, the aircraft was maintained in a position to keep the cable vertical with respect to the ground, through voice or hand signals from two observers located to observe the longitudinal and lateral position of the helicopter. Atmospheric pressure, temperature, and wind velocity were recorded from a ground weather station. All hover tests were conducted with wind velocity less than 3 knots. All data were recorded on magnetic tape in 15- to 30-second data records backed up by hand-recorded cockpit data.

Level Flight Performance

3. Level flight performance parameters were determined utilizing the constant weight to density (W/ρ) ratio technique described in AMCP 706-204. This method allows the entire test to be flown at a constant value of the nondimensional parameter thrust coefficient (C_T) defined below. In flight the aircraft was stabilized at airspeeds between 40 KTAS and V_H as limited by engine power available. The altitude for each test point was determined from current aircraft weight and ambient density (determined from pressure altitude and ambient temperature). All test points were flown at 324 rpm. The helicopter was stabilized at each test condition for at least 2 minutes.

Autorotational Descent Performance

4. Autorotational descent performance tests were conducted by stabilizing the aircraft in an autorotational descent at constant airspeed and constant rotor speed or full-down collective. Rotor speed was maintained by adjusting collective position until the density altitude-gross weight condition was achieved in which the collective was on the bottom stop. When this condition was reached, rotor speed was allowed to decrease with altitude.

Maneuvering Stability

5. Maneuvering stability tests were conducted by first stabilizing the helicopter in 1g level flight at the desired airspeed and recording the trim condition. The load factor was increased by stabilizing the helicopter at increasing bank angles in left and right turns. Airspeed and collective were maintained constant and altitude allowed to decrease. Additionally, sudden pull-ups were conducted by initiating a dive from a higher altitude and lower airspeed than the trim conditions. As the trim airspeed was approached, the longitudinal cyclic was displaced aft and the aircraft allowed to pitch up through the horizon. Data were recorded with the aircraft at approximately zero pitch attitude.

DATA ANALYSIS

Hover Performance

6. Test data from the PCM flight tape were calibrated and converted to dimensional engineering units. This dimensional data were then converted to the nondimensional parameters power coefficient (C_P) and C_T by use of the following equations:

$$C_T = \frac{GRWT}{\rho A (\Omega R)^2} \quad (1)$$

and

$$C_P = \frac{SHP \times 550}{\rho A (\Omega R)^3} \quad (2)$$

Where:

ρ = Ambient density - determined from ground barometric pressure, ambient temperature, and hover height ($slug/ft^3$)

A = AH-1G rotor disc geometric area (ft^2)

Ω = Main rotor speed (radians/sec)

R = Main rotor radius (ft)

GRWT = Thrust - determined from helicopter engine start gross weight, fuel consumed, and tether cable tension (lb)

SHP = Engine output shaft power - determined from main rotor speed and engine output shaft torque

7. A plot of the variation of C_P with C_T was then constructed and a line was faired through the data points. Use of the nondimensional hover performance plots allows a direct comparison of the power required to hover at a given thrust level. The summary hover performance was calculated by use of these nondimensional plots and the power available presented in figure 7, appendix E.

Level Flight Performance

8. Test day level flight power was corrected to standard-day conditions by the following relation:

$$SHP_s = SHP_t \times \frac{\rho_s}{\rho_t} \qquad (3)$$

Where:

ρ_t = Test day ambient density

ρ_s = Standard-day average density for the flight

The data were then generalized to nondimensional coefficients of C_P, C_T, and μ through the following relationships:

$$V_T = \frac{V_c}{\sqrt{\sigma}} \qquad (4)$$

$$\mu = \frac{1.689\ V_T}{\Omega R} \qquad (5)$$

Where:

V_c = Calibrated airspeed - determined from indicated airspeed by applying instrument error and pitot-static system error corrections (kt)

V_T = True airspeed (kt)

σ = Air density ratio

Curves defined by the power required as a function of airspeed were plotted nondimensionally as C_P versus μ for a constant value of C_T. For each level flight performance test flown, these curves were then cross-plotted as C_T versus C_P for constant μ value, which allows determination of the power required as a function of airspeed for any value of C_T.

9. The specific NAMPP range data were derived from the test level flight power required and specification engine fuel flow data obtained from figure 114 of USAASTA Final Report No. 66-06.

<u>Autorotational Descent Performance</u>

10. Collective position, rotor speed, and tapeline rate of descent were plotted as a function of density altitude. The altitude at which the bottom collective stop was reached was the minimum altitude for full-down collective for the test gross weight. At lower gross weight-density altitude conditions in which rotor speed could not be maintained with full-down collective, the slope of rotor speed versus density was calculated. The altitude for full-down collective was then determined by extrapolating back to the desired rotor speed. The second method is required at light gross weights because a constant rotor speed could not be maintained at full-down collective. Rotor speed decay versus density altitude, at constant collective, is linear, providing a slope which can be used to determine the relation of the two parameters at various values of either one. Tapeline rate of descent was calculated by the following relationships:

$$R/D_t = \frac{dH_P}{dt} \quad (6)$$

$$R/D_{TL} = R/D_t \times \frac{T_t}{T_s} \quad (7)$$

Where:

$\frac{d}{dt}$ = First derivative with respect to time

R/D_t = Test-day rate of descent

R/D_{TL} = Tapeline rate of descent

Hp = Pressure altitude

T_t = Test-day temperature

T_s = Standard-day temperature

APPENDIX E. TEST DATA

INDEX

FIGURE 1
SUMMARY OGE POWER/PERFORMANCE
AH-1G USA S/N 71-20985
MILITARY POWER AVAILABLE
BASIC CONFIGURATION

NOTES:
1. SHP OBTAINED FROM FIGURE 7.
2. WINDS LESS THAN 3 KNOTS.
3. ROTOR SPEED = 324 RPM.
4. BROKEN LINE DEPICTS 10 PERCENT DIRECTIONAL CONTROL MARGIN (MIL-H-8501A).
5. HOVER DATA OBTAINED FROM FIG. 4.

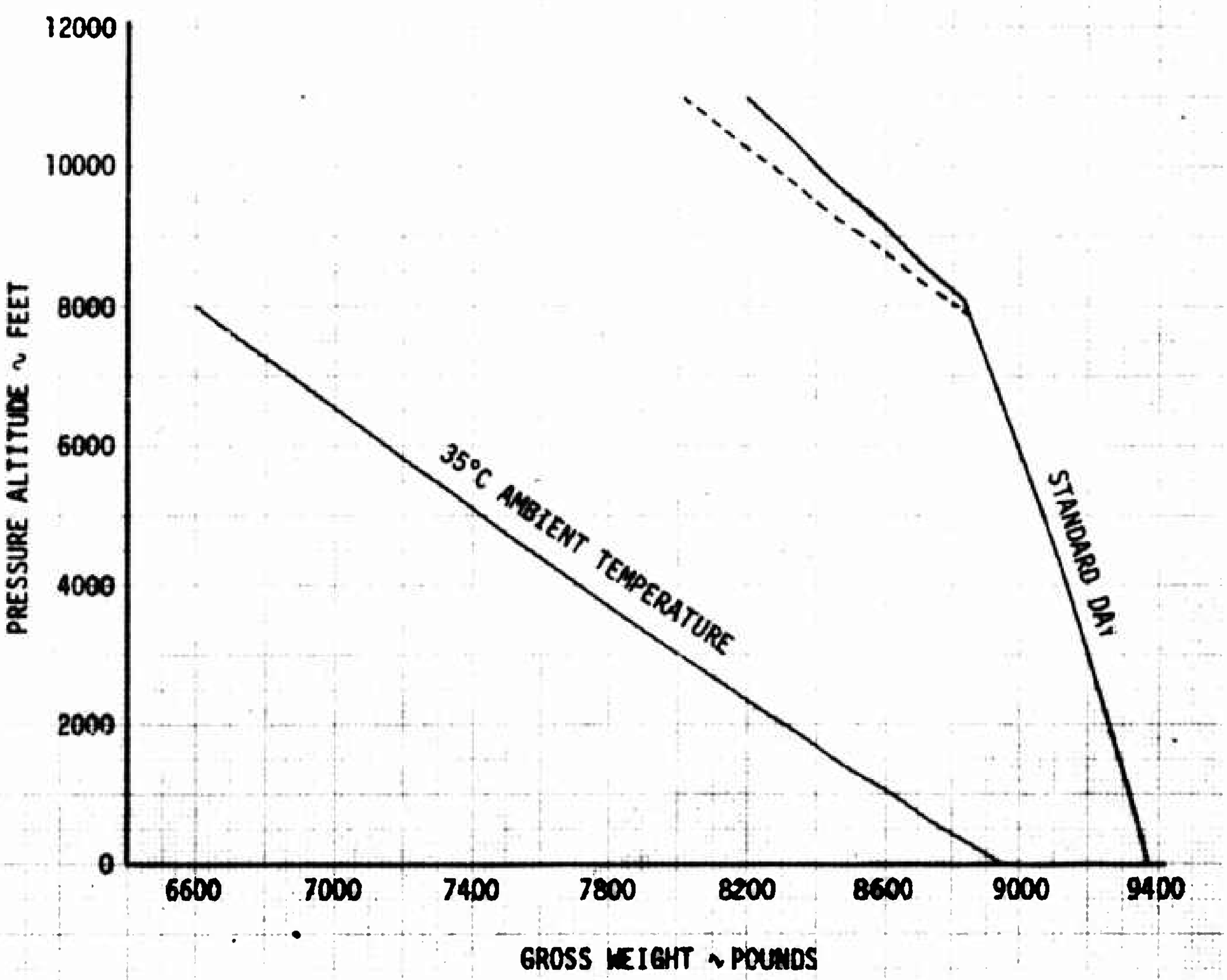


FIGURE 2

[illegible]

[illegible]

[illegible] POWER AVAILABLE

[illegible] PAINT CONFIGURATION

NOTES:
1. SHP OBTAINED FROM FIGURE 7.
2. WINDS LESS THAN 3 KNOTS.
3. ROTOR SPEED = 324 RPM.
4. BROKEN LINE DEPICTS 10 PERCENT DIRECTIONAL CONTROL MARGIN (MIL-H-8501A).
5. HOVER DATA DERIVED FROM FIG. 5.

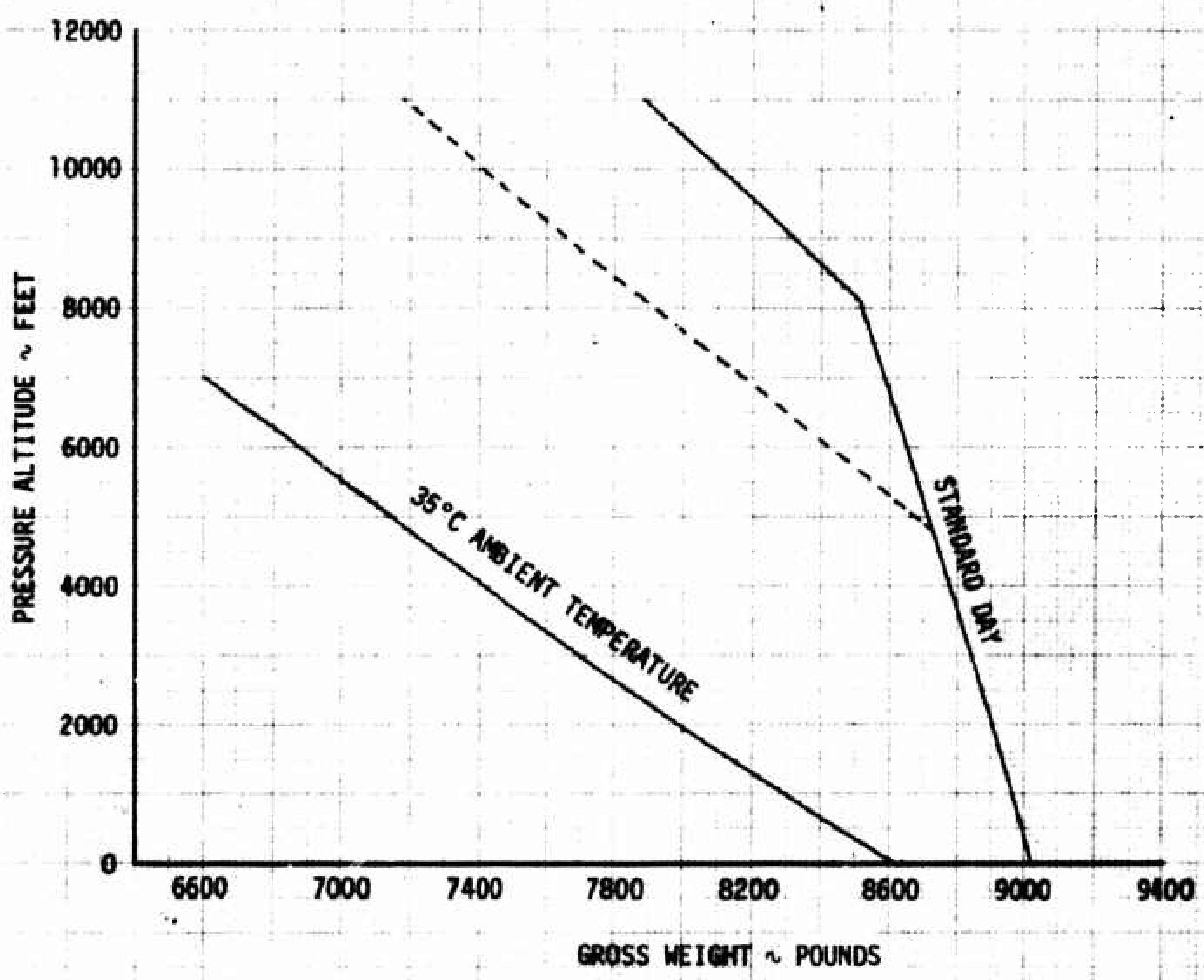


FIGURE 3

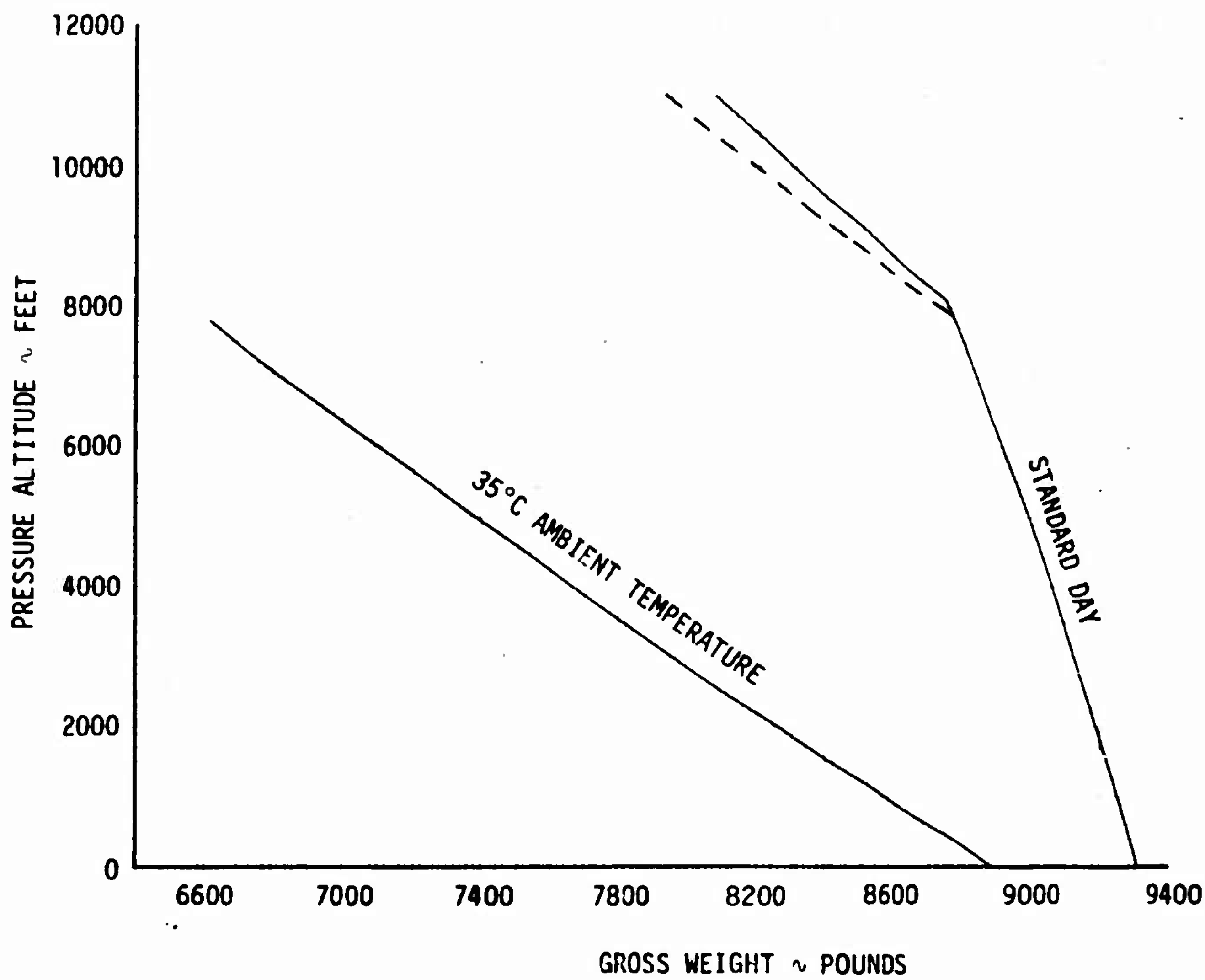
SUMMARY OGE HOVER PERFORMANCE

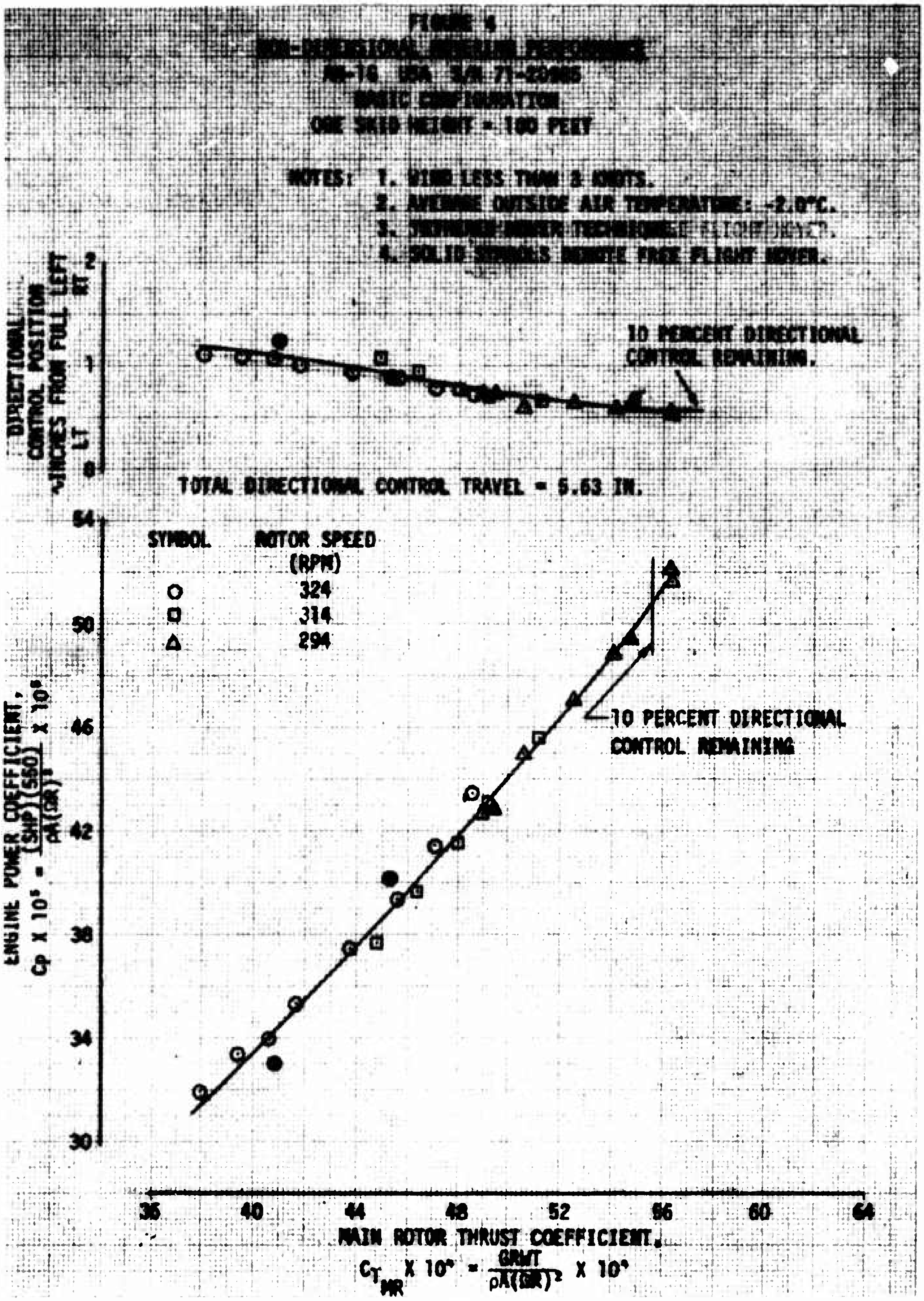
AH-1G USA S/N 71-20985

MILITARY POWER AVAILABLE

MODIFIED IR/OPTICAL PAINT CONFIGURATION

NOTES:
1. SHP OBTAINED FROM FIGURE 7.
2. WINDS LESS THAN 3 KNOTS.
3. ROTOR SPEED = 324 RPM.
4. BROKEN LINE DEPICTS 10 PERCENT DIRECTIONAL CONTROL MARGIN (MIL-H-8501A).
5. HOVER DATA OBTAINED FROM FIG. 6.




NOTES:
2. AVERAGE OUTSIDE AIR TEMPERATURE: -2.0°C.
4. SOLID SYMBOLS DENOTE FREE FLIGHT HOVER.
DIRECTIONAL CONTROL POSITION ~INCHES FROM FULL LEFT
LT
RT
10 PERCENT DIRECTIONAL CONTROL REMAINING.
TOTAL DIRECTIONAL CONTROL TRAVEL = 5.63 IN.
SYMBOL
ROTOR SPEED (RPM)
324
314
294
10 PERCENT DIRECTIONAL CONTROL REMAINING
ENGINE POWER COEFFICIENT,
$C_P \times 10^5 = \frac{(SHP)(550)}{\rho A(\Omega R)^3} \times 10^5$
MAIN ROTOR THRUST COEFFICIENT,
$C_{T_{MR}} \times 10^4 = \frac{GRWT}{\rho A(\Omega R)^2} \times 10^4$

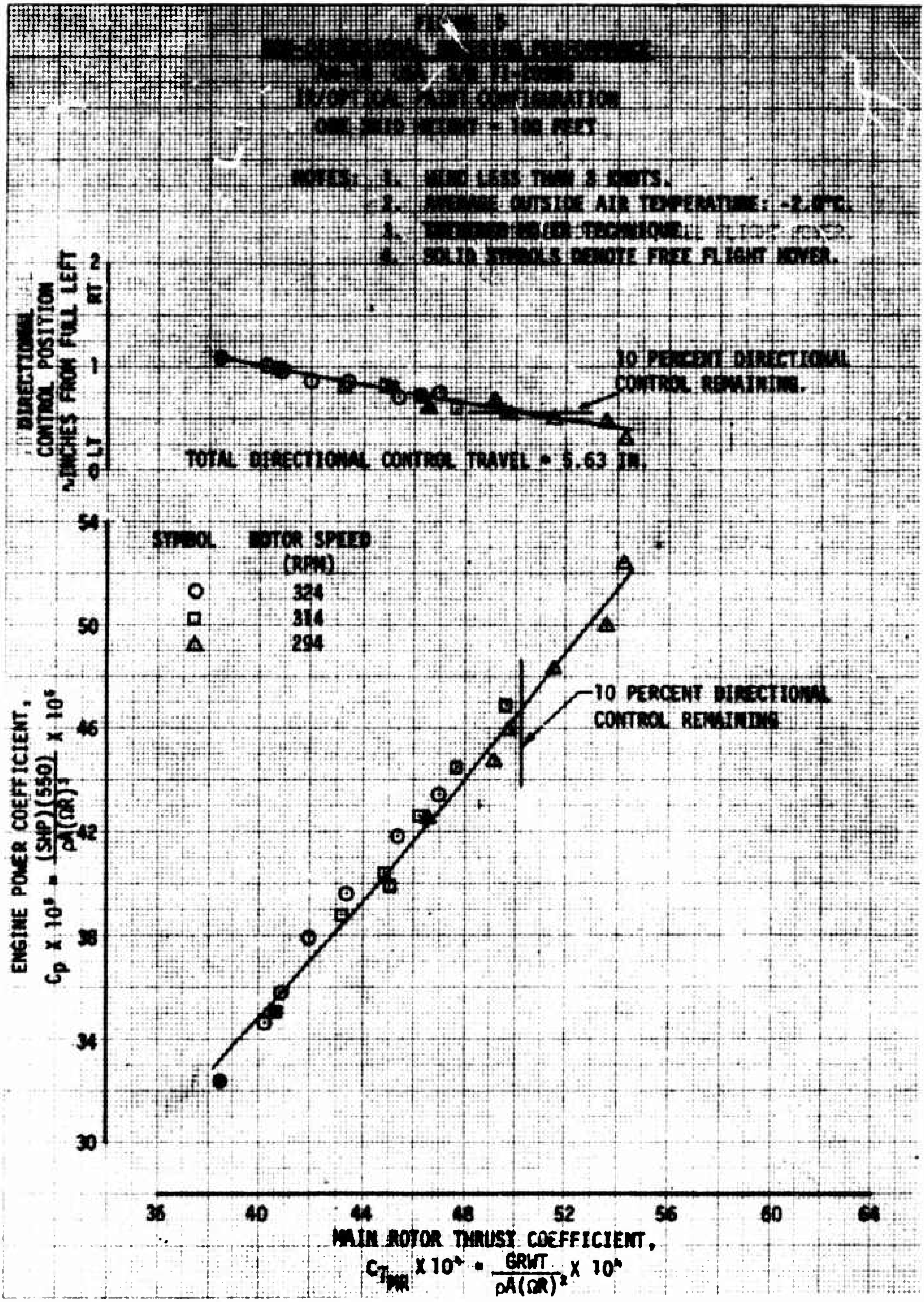
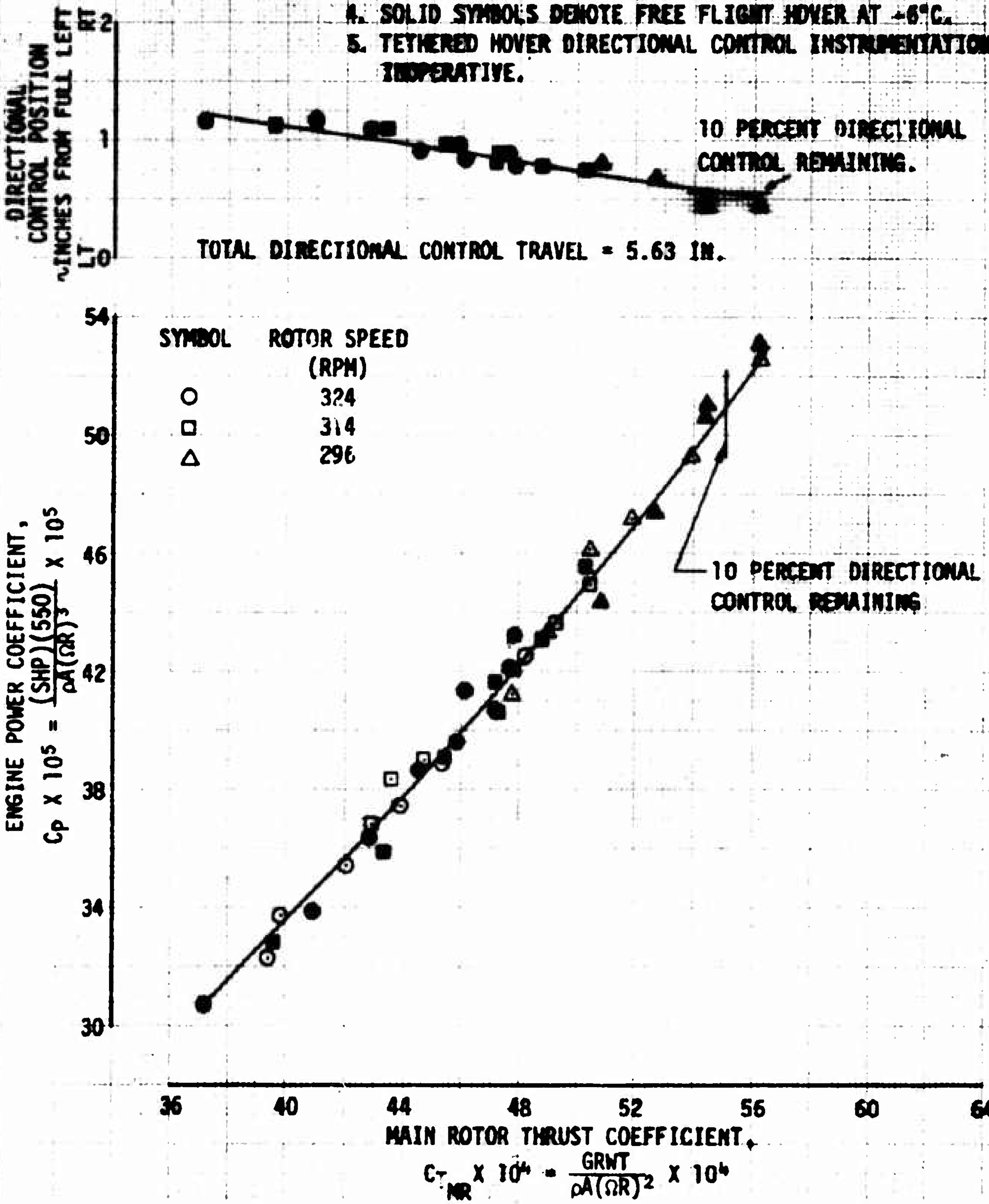
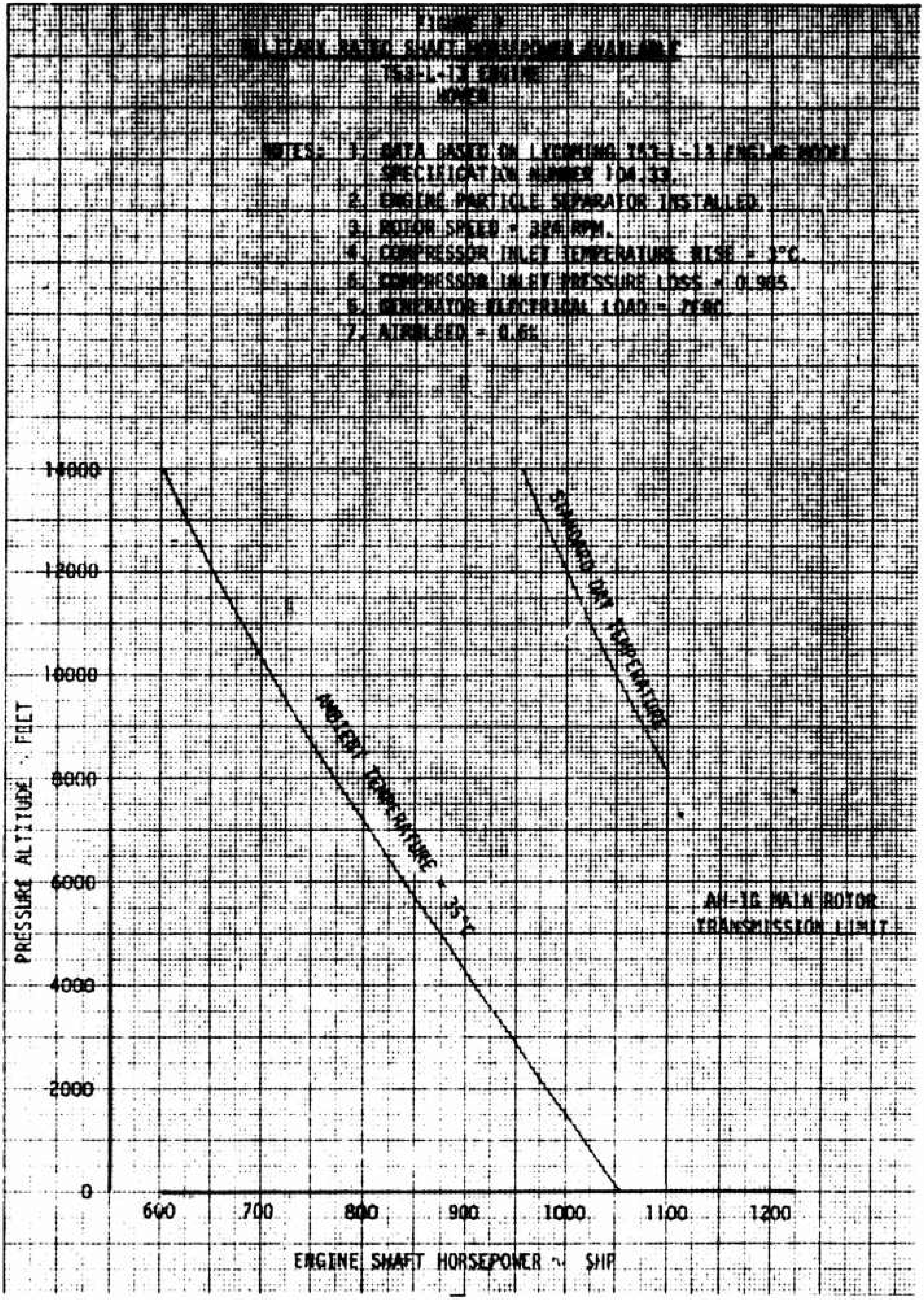

CONFIGURATION
NOTES:
AIR TEMPERATURE
4. SOLID SYMBOLS DENOTE FREE FLIGHT HOVER.
DIRECTIONAL CONTROL POSITION ~ INCHES FROM FULL LEFT
RT
LT
10 PERCENT DIRECTIONAL CONTROL REMAINING.
TOTAL DIRECTIONAL CONTROL TRAVEL = 5.63 IN.
SYMBOL
ROTOR SPEED (RPM)
324
314
294
10 PERCENT DIRECTIONAL CONTROL REMAINING
ENGINE POWER COEFFICIENT,
MAIN ROTOR THRUST COEFFICIENT,

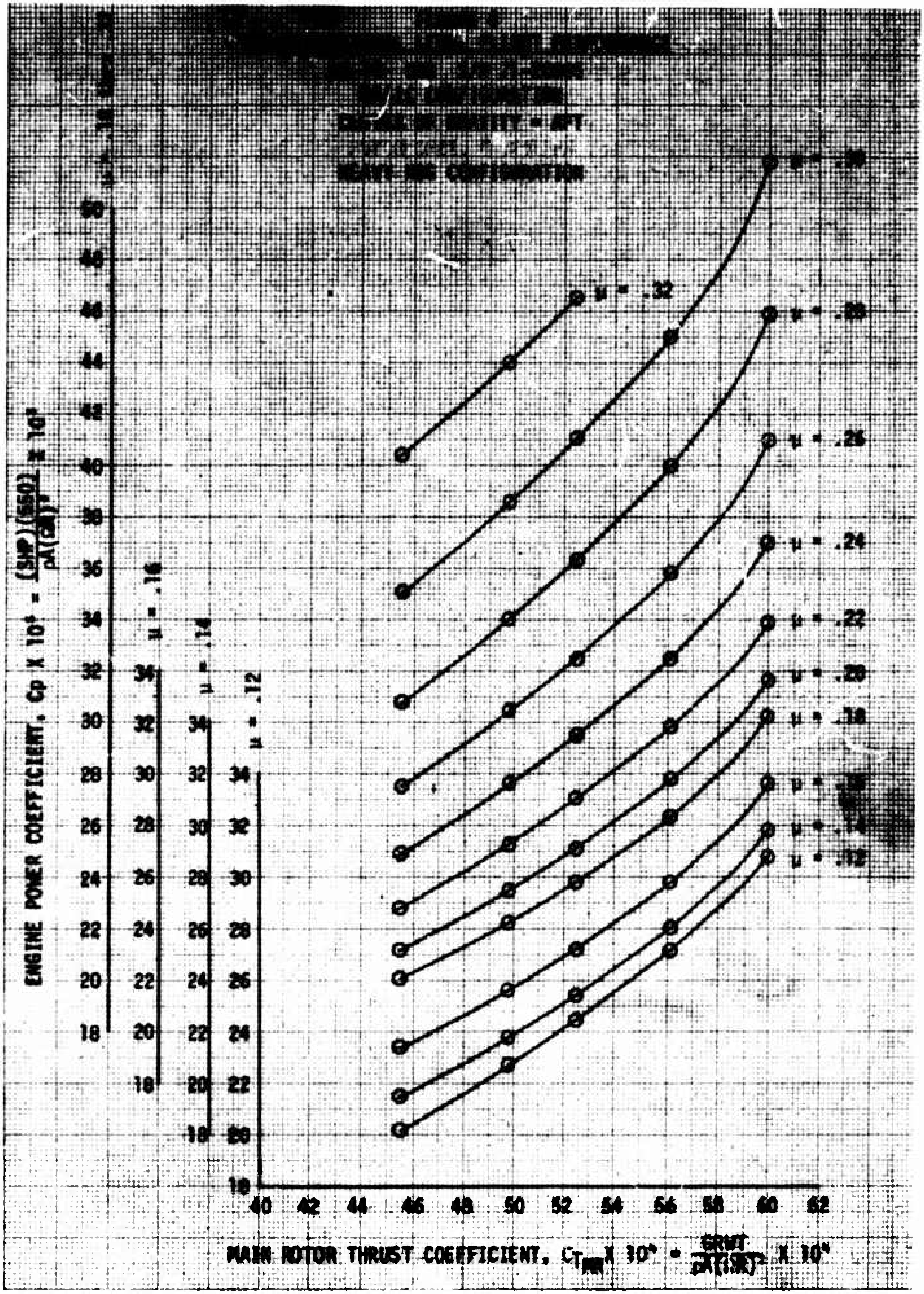
FIGURE 6
NONDIMENSIONAL HOVERING PERFORMANCE
AH-1G USA S/N 71-20985
MODIFIED IR/OPTICAL PAINT CONFIGURATION
ONE SKID HEIGHT = 100 FEET

NOTES:
1. WIND LESS THAN 3 KNOTS.
2. AVERAGE OUTSIDE AIR TEMPERATURE: -2.0°C.
3. TETHERED HOVER TECHNIQUE. [illegible]
4. SOLID SYMBOLS DENOTE FREE FLIGHT HOVER AT -6°C.
5. TETHERED HOVER DIRECTIONAL CONTROL INSTRUMENTATION INOPERATIVE.





T53-L-13 ENGINE
NOTES:
2. ENGINE PARTICLE SEPARATOR INSTALLED.
4. COMPRESSOR INLET TEMPERATURE RISE = 1°C.
PRESSURE ALTITUDE ~ FEET
14000
12000
10000
8000
6000
4000
2000
0
600
700
800
900
1000
1100
1200
ENGINE SHAFT HORSEPOWER ~ SHP
STANDARD DAY TEMPERATURE
AMBIENT TEMPERATURE = 35°C
AH-1G MAIN ROTOR
TRANSMISSION LIMIT



ENGINE POWER COEFFICIENT, Cp X 10⁴ = (SHP)(550) / ρA(ΩR)³ X 10⁴
MAIN ROTOR THRUST COEFFICIENT, $C_{T_{MR}}$ X 10⁴ = GRWT / ρA(ΩR)² X 10⁴
μ = .32
μ = .28
μ = .26
μ = .24
μ = .22
μ = .20
μ = .18
μ = .16
μ = .14
μ = .12
40 42 44 46 48 50 52 54 56 58 60 62
18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50

FIGURE 9

LEVEL FLIGHT PERFORMANCE

AH-1G USA S/N 71-20985

BASIC CONFIGURATION

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	AVG C_T	ARMAMENT CONFIGURATION
7720	5680	6.5	195.6 (AFT)	323	0.004557	HEAVY HOG

NOTE: FUEL FLOW DATA OBTAINED FROM FIG. 116 REF 11 ARP A.

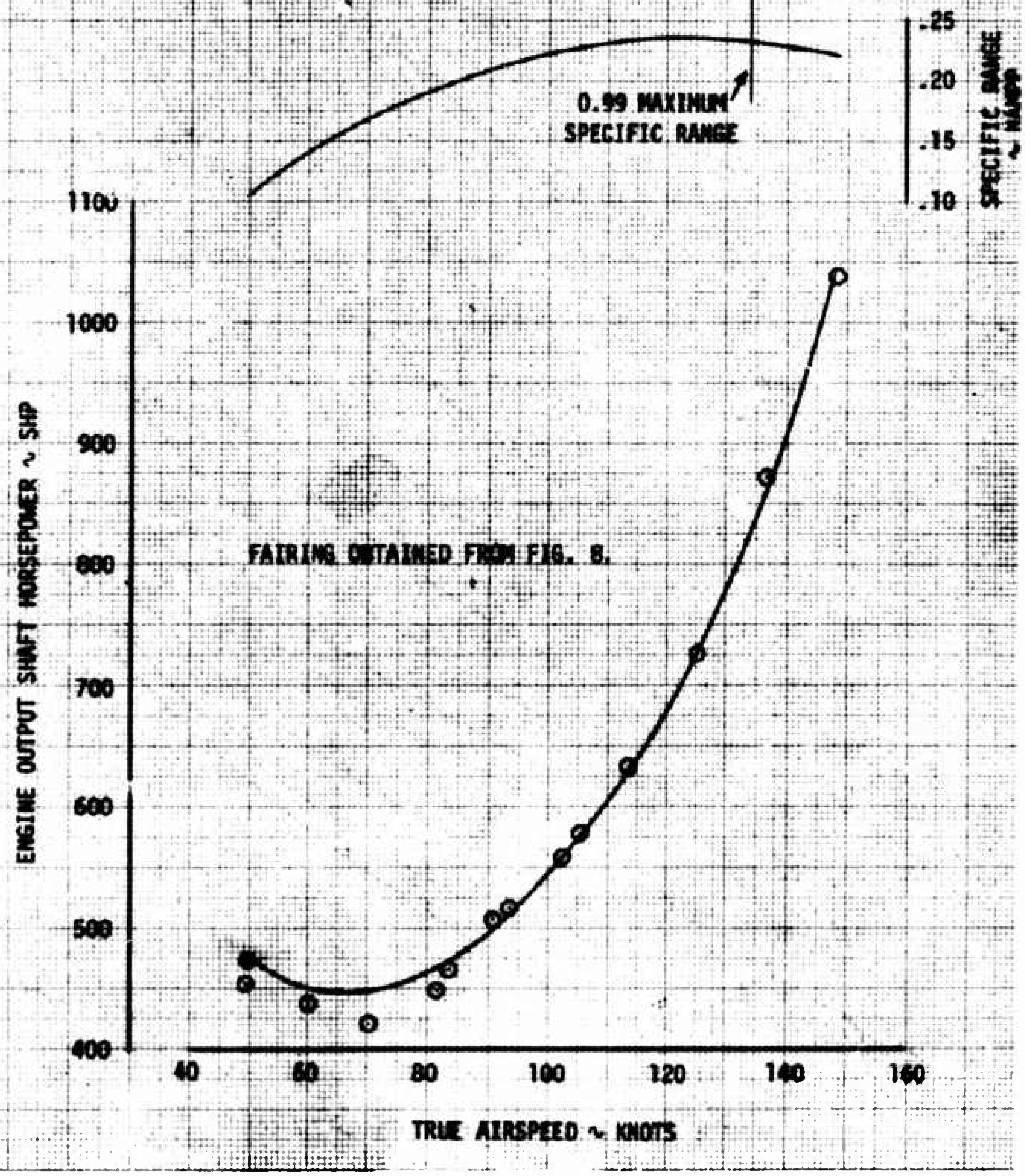


FIGURE 10
LEVEL FLIGHT PERFORMANCE
AH-1G USA S/N 71-20985
BASIC CONFIGURATION

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	AVG C_T	ARMAMENT CONFIGURATION
8300	6340	3.0	199.5(AFT)	324	0.004981	HEAVY HOG

NOTE: FUEL FLOW DATA OBTAINED FROM FIG. 116, REF 11, APP A.

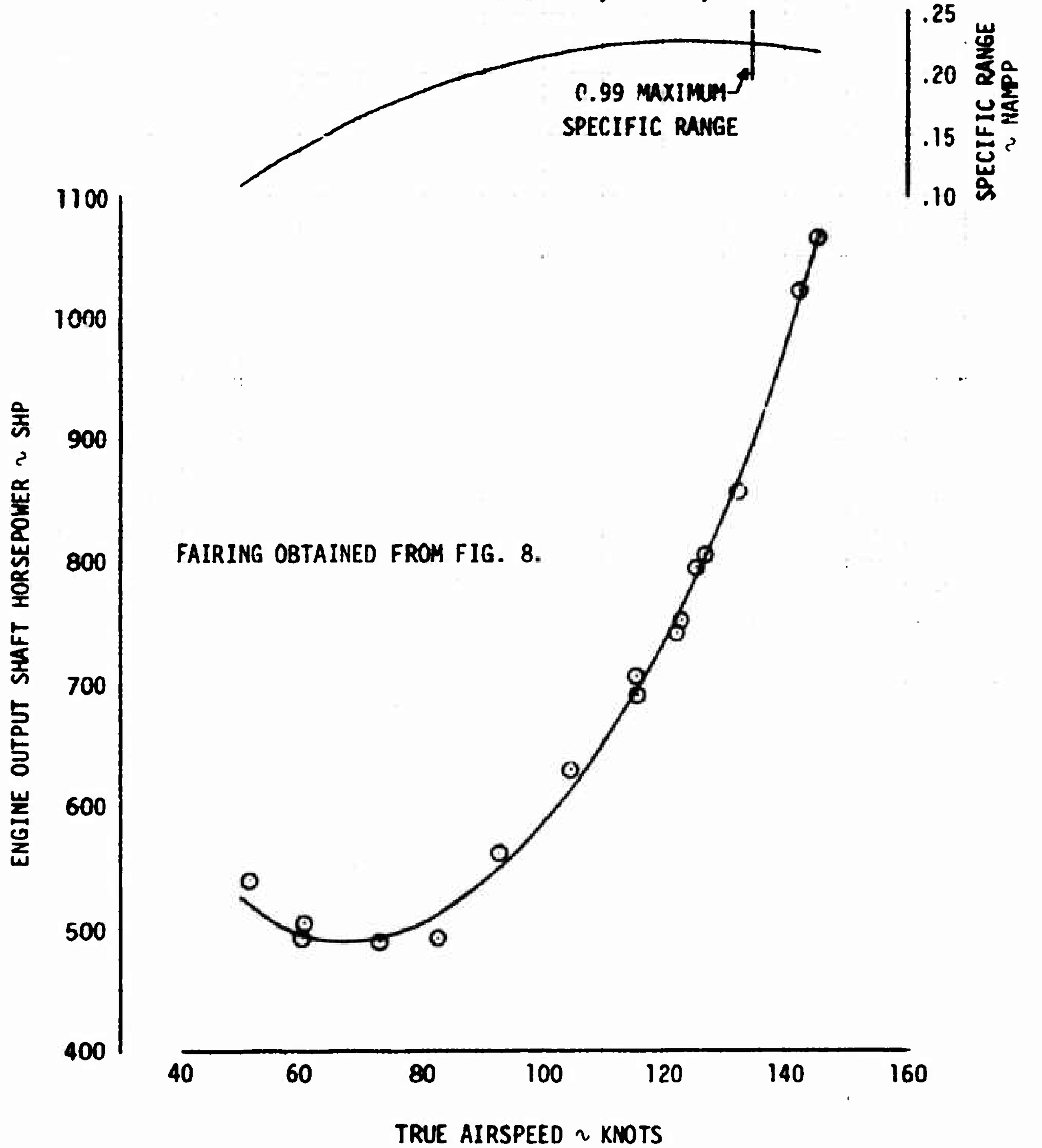


FIGURE 11
LEVEL FLIGHT PERFORMANCE
AH-1S USA S/N 71-20905
BASIC CONFIGURATION

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	AVG C_T	ARMAMENT CONFIGURATION
8970	5700	9.0	199.4(AFT)	325	0.005251	HEAVY HOG

NOTE: FUEL FLOW DATA OBTAINED FROM FIG. 116, REF 11, APP A.

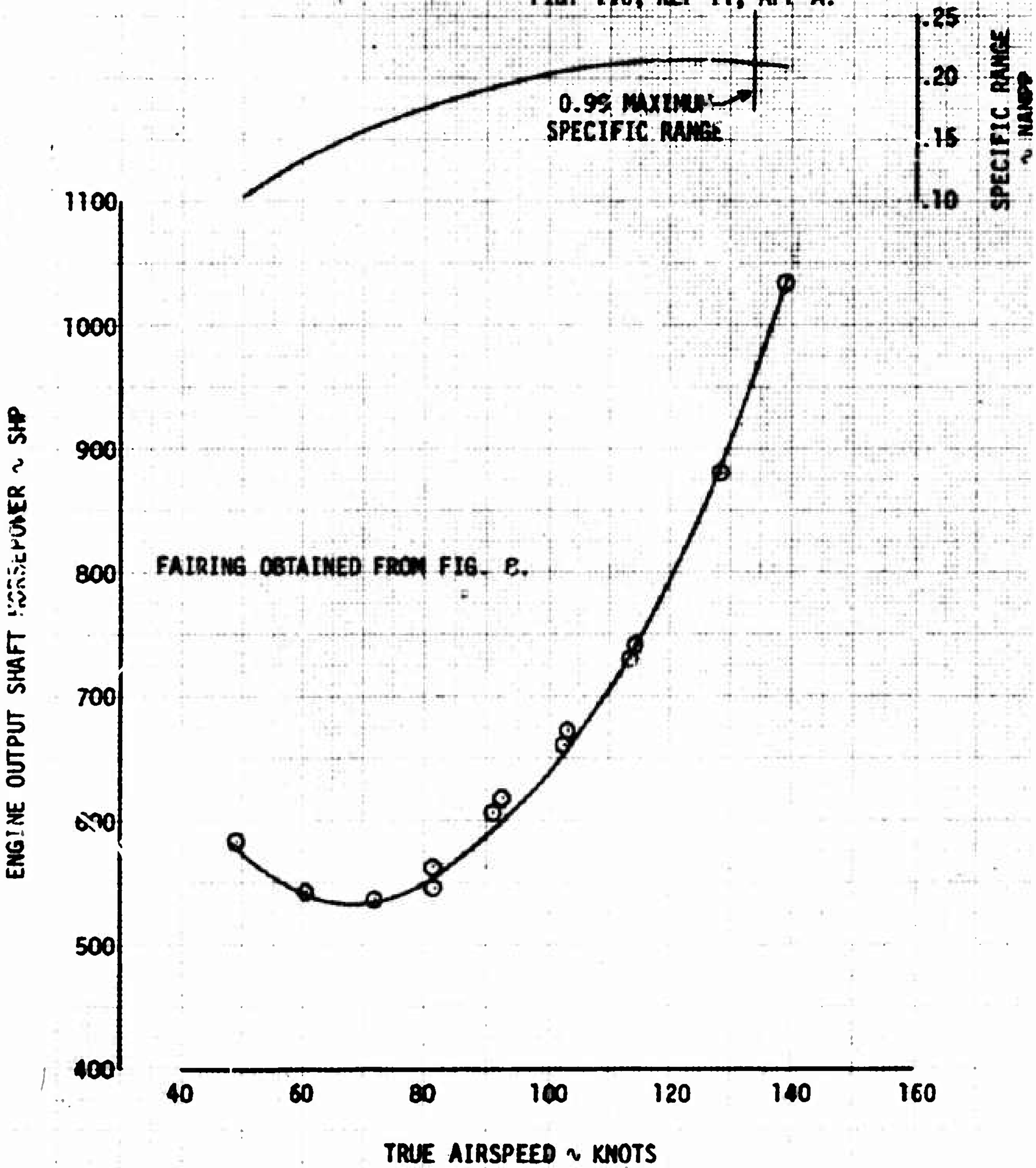


FIGURE 12
LEVEL FLIGHT PERFORMANCE
AH-1G USA S/N 71-20985
BASIC CONFIGURATION

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	AVG C_T	ARMAMENT CONFIGURATION
8840	8360	5.5	199.4(AFT)	325	0.005613	HEAVY HOG

NOTE: FUEL FLOW DATA OBTAINED FROM FIG. 116, REF 11, APP A.

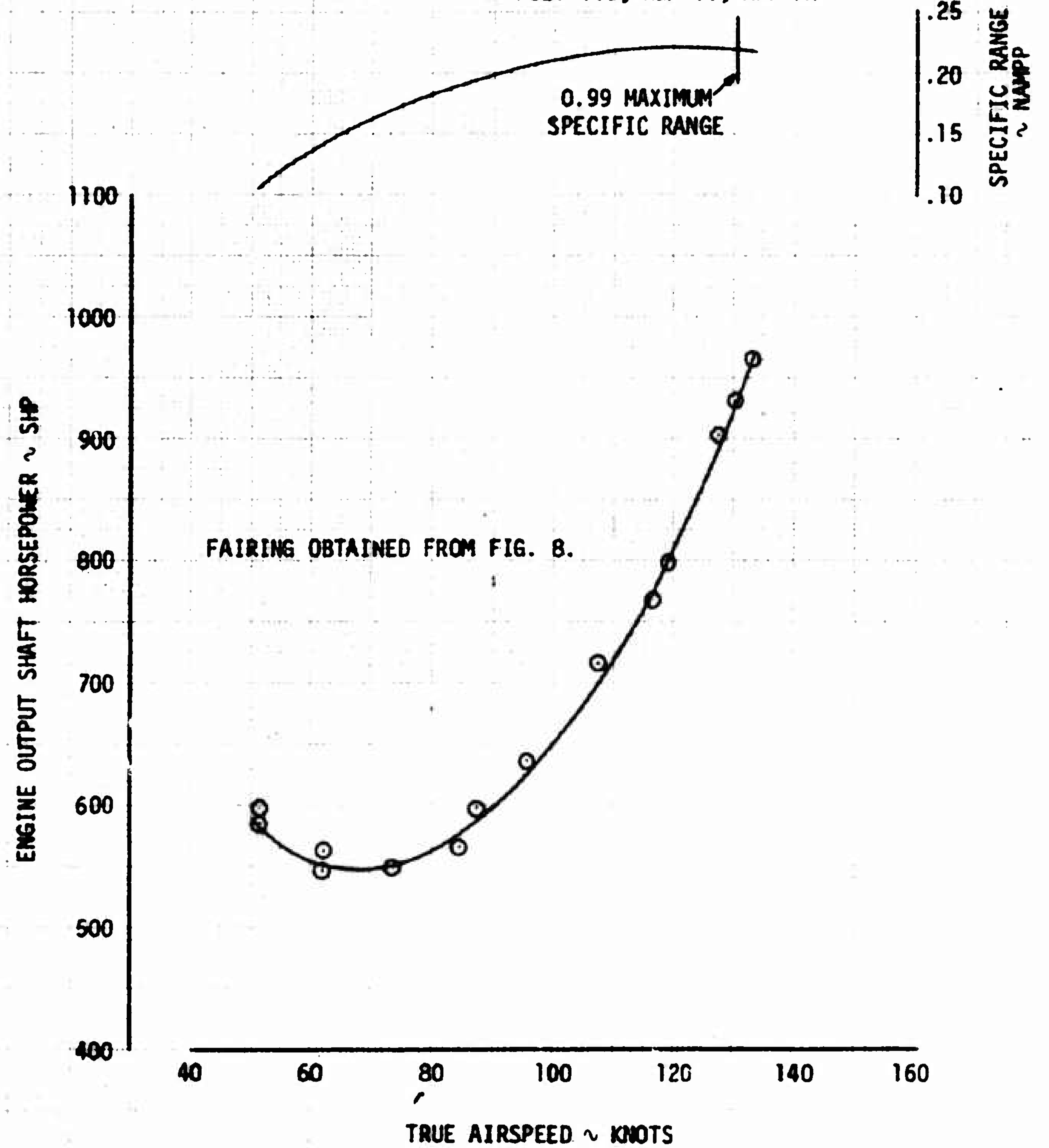


FIGURE 19
LEVEL FLIGHT PERFORMANCE
AH-1G USA S/N 71-20985
BASIC CONFIGURATION

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	AVG C_T	ARMAMENT CONFIGURATION
9050	9640	5.5	199.4(AFT)	324	0.006005	HEAVY HOG

NOTE: FUEL FLOW DATA OBTAINED FROM FIG. 116, REF 11, APP A.

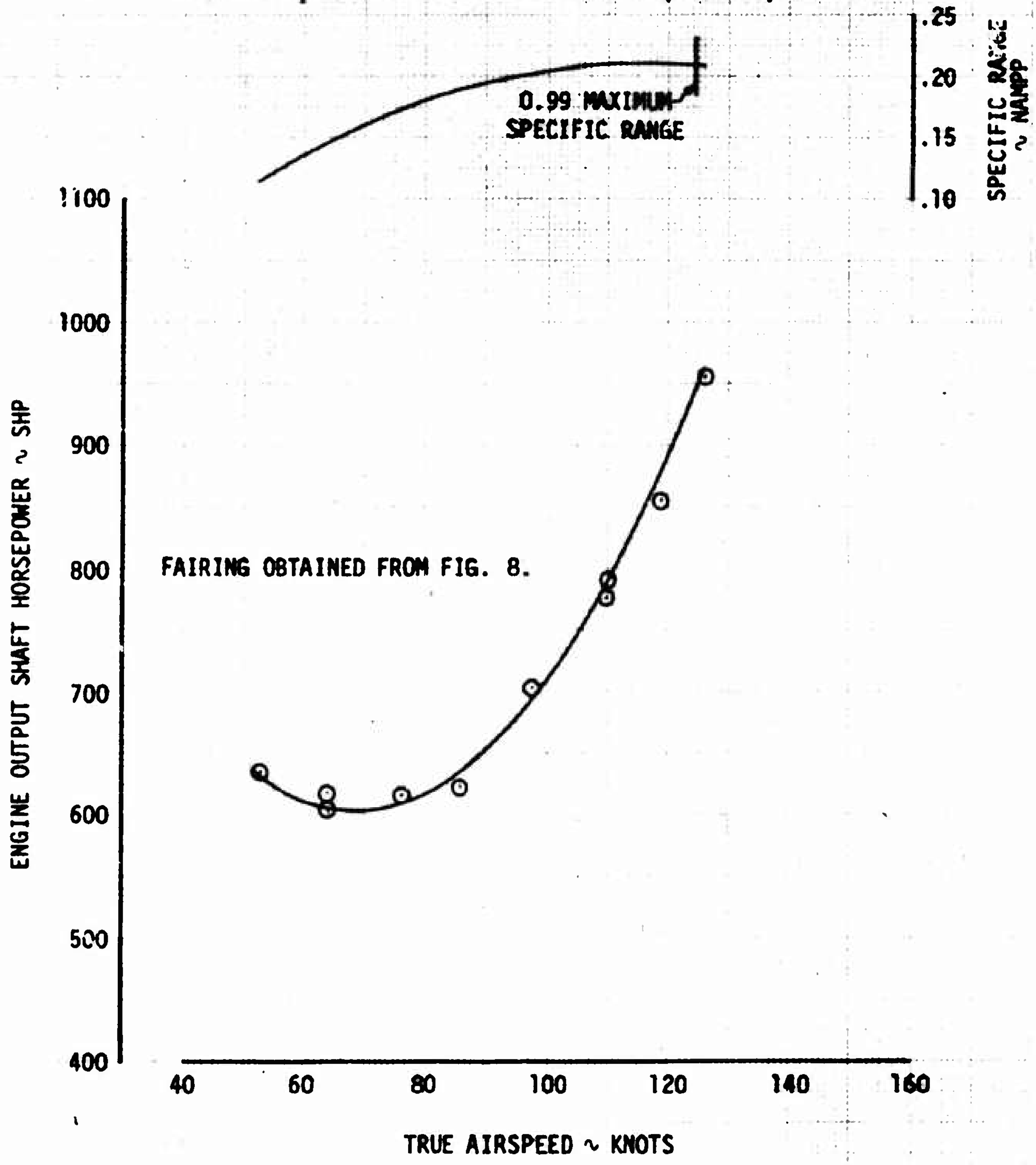


FIGURE 14

NON-DIMENSIONAL LEVEL FLIGHT PERFORMANCE

AH-1G USA S/N 71-20985

IR/OPTICAL PAINT CONFIGURATION

CENTER OF GRAVITY = AFT

HEAVY HOG CONFIGURATION

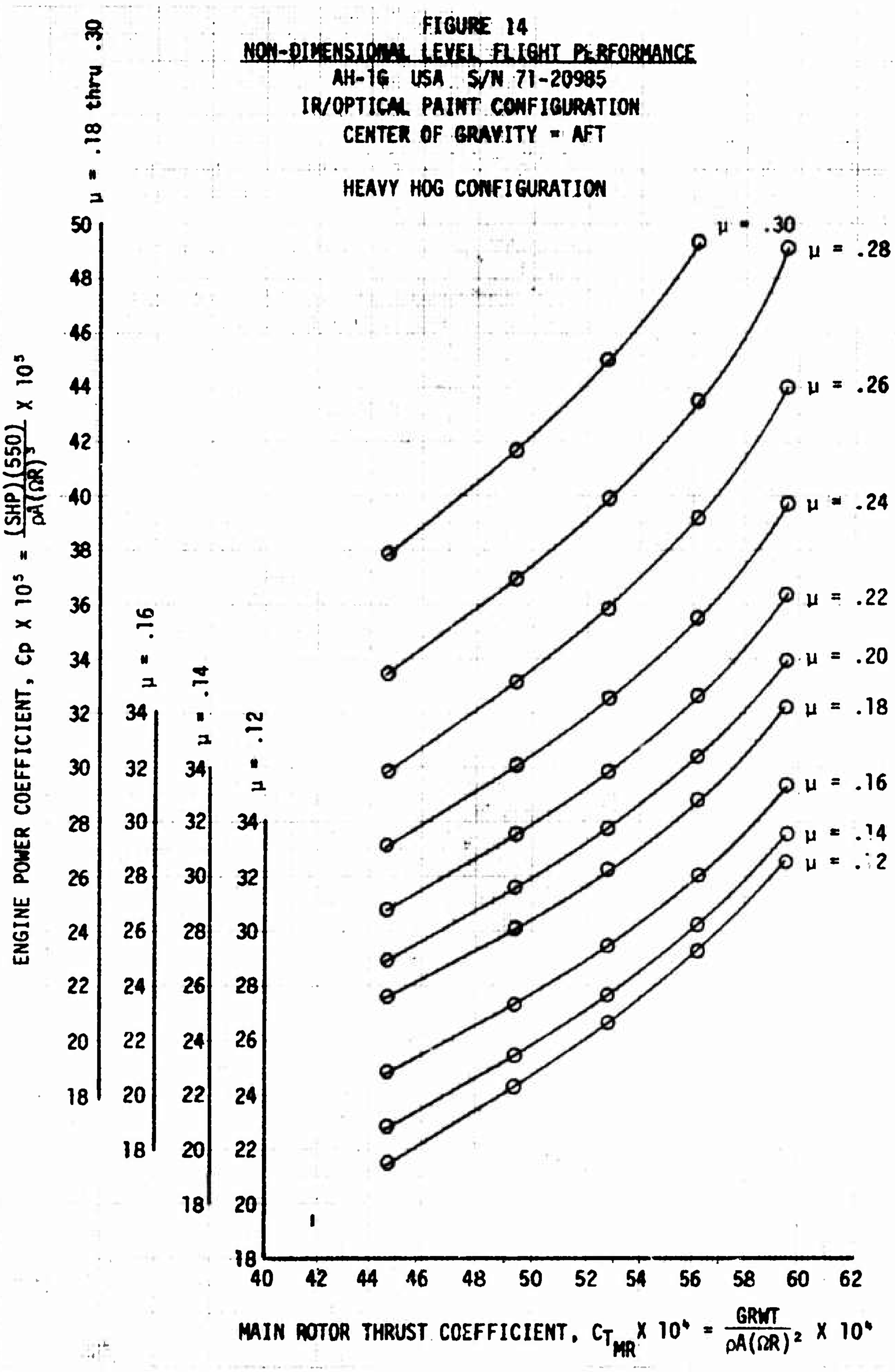


FIGURE 15
LEVEL FLIGHT PERFORMANCE
AH-1G USA S/N 71-20985
IR/OPTICAL PAINT CONFIGURATION

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	AVG C_T	ARMAMENT CONFIGURATION
7710	5220	3.0	199.5(AFT)	324	0.004473	HEAVY HOG

NOTE: FUEL FLOW DATA OBTAINED FROM FIG. 116, REF 11, APP A.

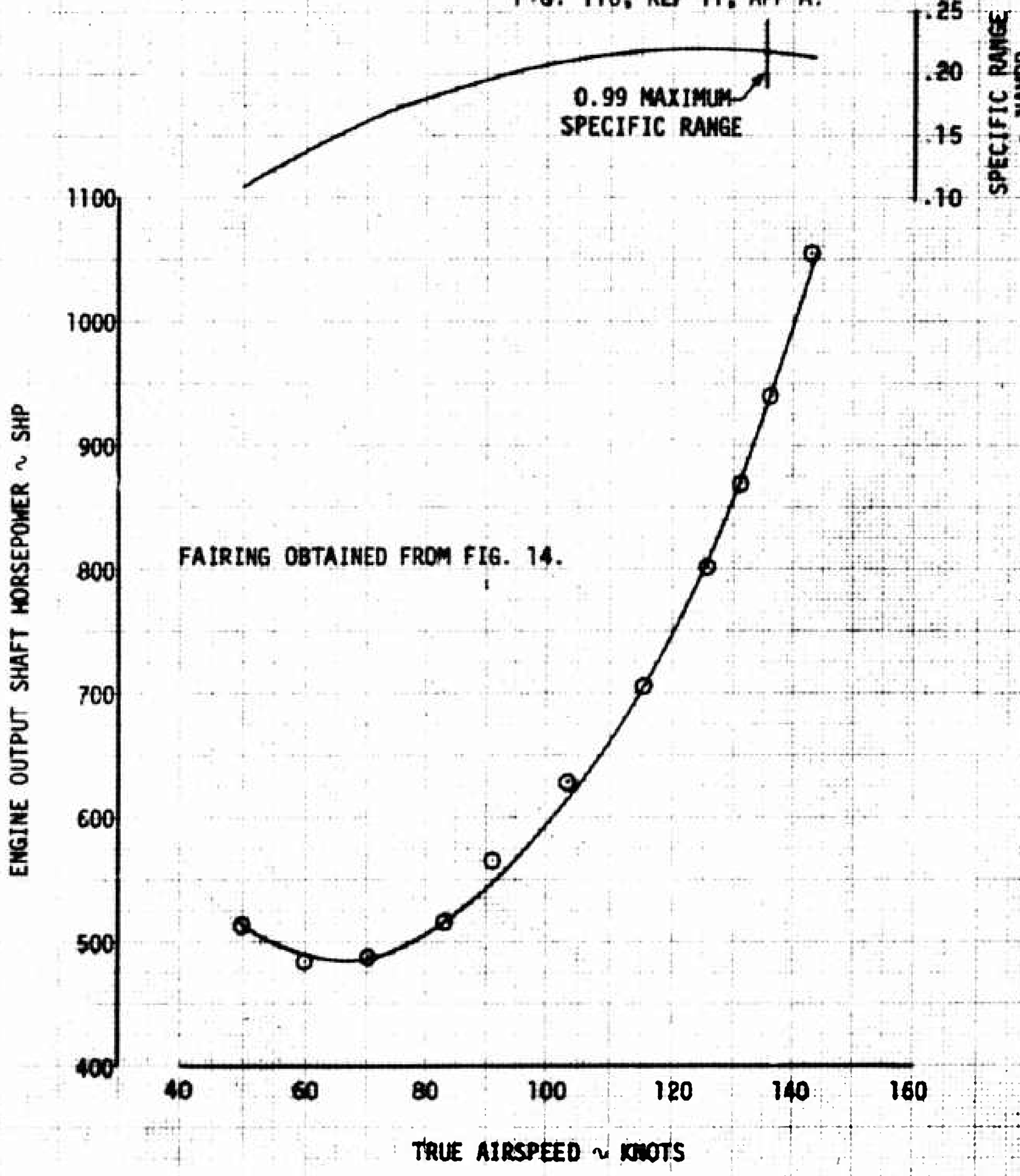
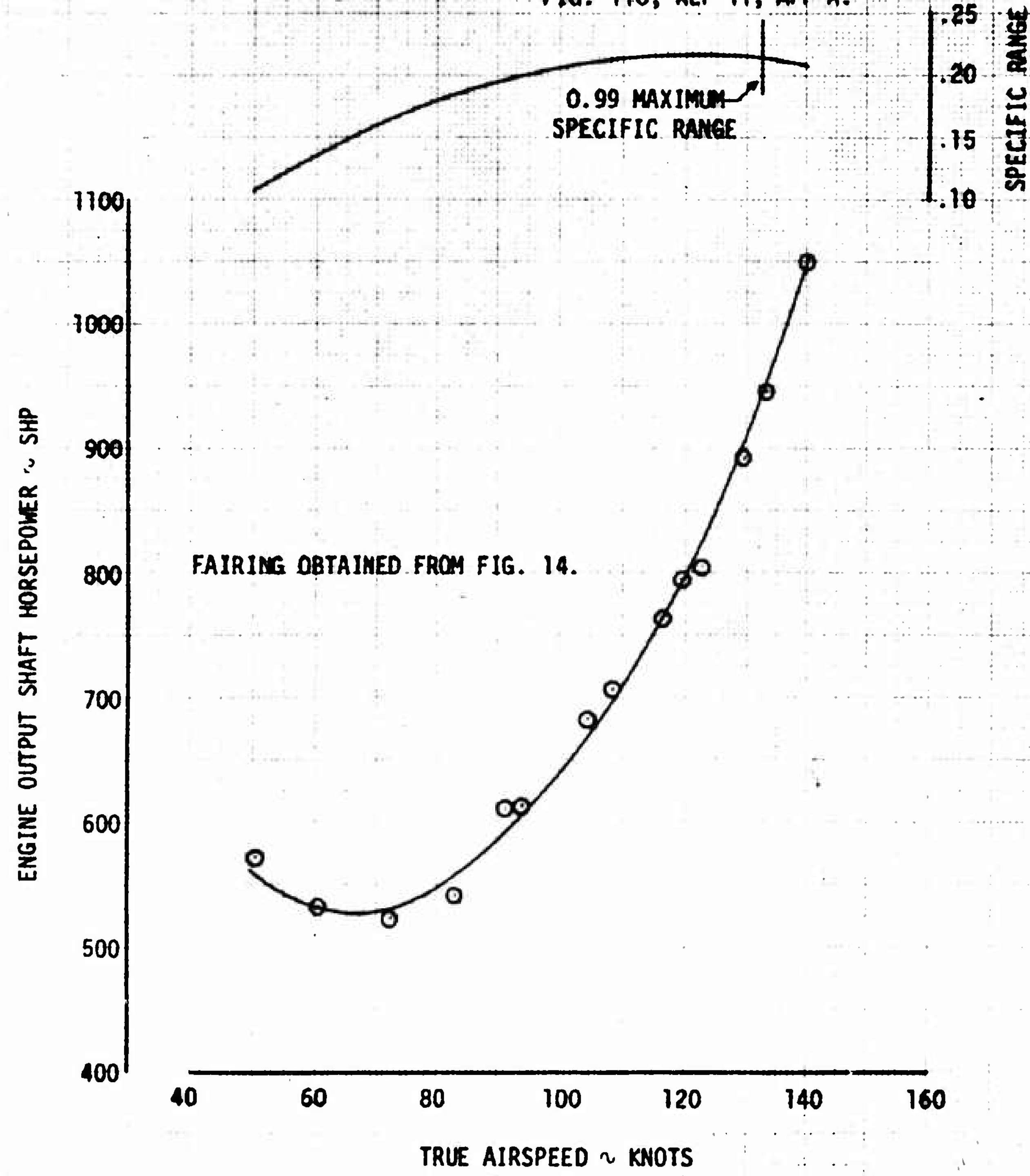
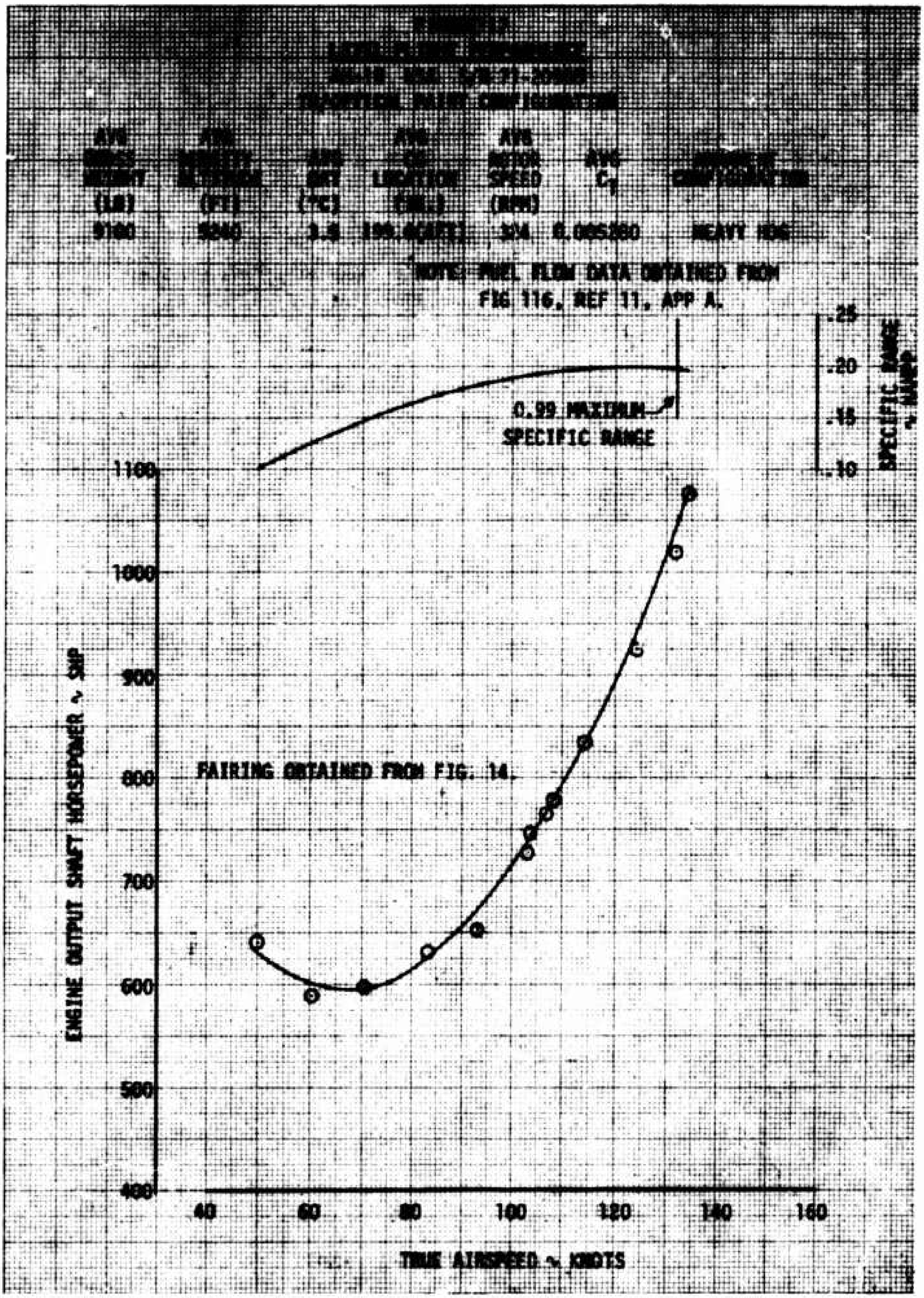


FIGURE 16
LEVEL FLIGHT PERFORMANCE
AH-1G USA S/N 71-20985
IR/OPTICAL PAINT CONFIGURATION

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	AVG C_T	ARMAMENT CONFIGURATION
8280	6320	1.0	199.6(AFT)	325	0.004937	HEAVY HOG

NOTE: FUEL FLOW DATA OBTAINED FROM FIG. 116, REF 11, APP A.




(LB)
(°C)
9100
3.5
SPEED
(RPM)
324
HEAVY HOG
NOTE: FUEL FLOW DATA OBTAINED FROM
FIG 116, REF 11, APP A.
0.99 MAXIMUM
SPECIFIC RANGE
SPECIFIC RANGE
FAIRING OBTAINED FROM FIG. 14
ENGINE OUTPUT SHAFT HORSEPOWER ~ SHP
TRUE AIRSPEED ~ KNOTS
.25
.20
.15
.10
1100
1000
900
800
700
600
500
400
40
60
80
100
120
140
160

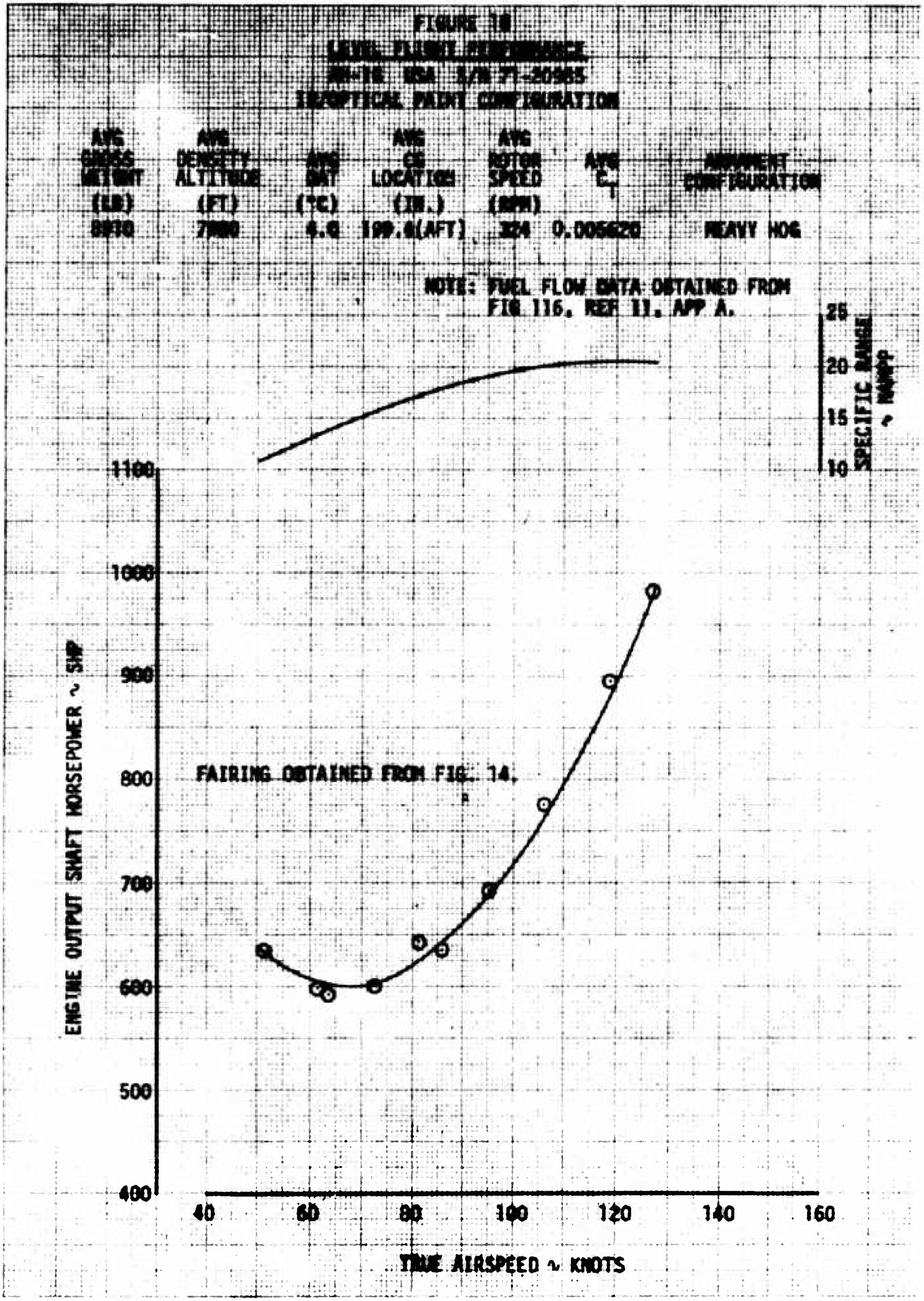
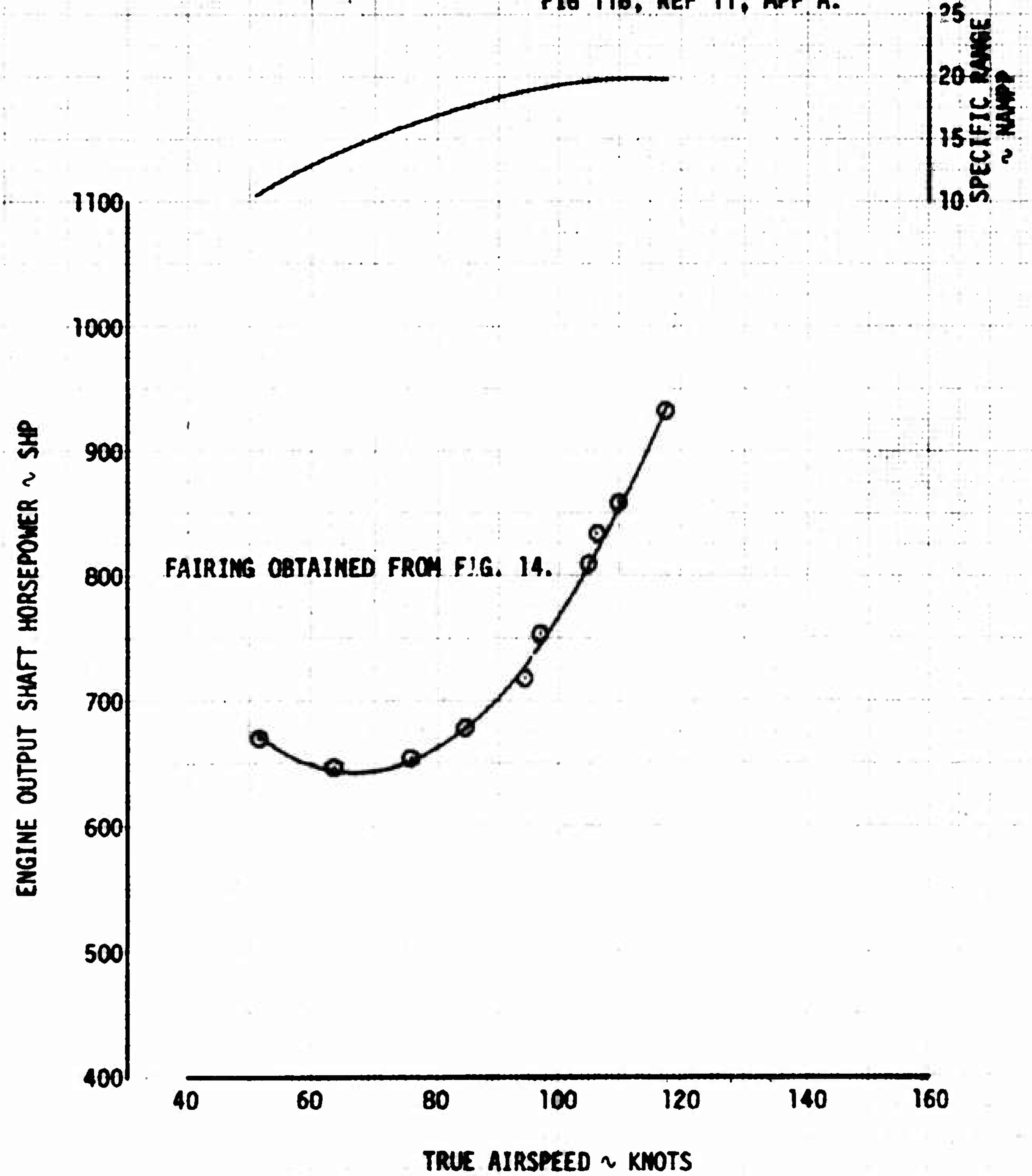


FIGURE 18
LEVEL FLIGHT PERFORMANCE
AH-1S USA S/N 71-20985
IR/OPTICAL PAINT CONFIGURATION
AVG GROSS WEIGHT (LB)
AVG DENSITY ALTITUDE (FT)
AVG OAT (°C)
AVG CG LOCATION (IN.)
AVG ROTOR SPEED (RPM)
AVG C_T
ARMAMENT CONFIGURATION
8930
7800
4.0
199.0(AFT)
324
0.006620
HEAVY HOG
NOTE: FUEL FLOW DATA OBTAINED FROM FIG 116, REF 11, APP A.
SPECIFIC RANGE ~ NAMPP
25
20
15
10
ENGINE OUTPUT SHAFT HORSEPOWER ~ SHP
1100
1000
900
800
700
600
500
400
FAIRING OBTAINED FROM FIG. 14.
40
60
80
100
120
140
160
TRUE AIRSPEED ~ KNOTS

FIGURE 19
LEVEL FLIGHT PERFORMANCE
AH-1G USA S/N 71-20985
IDENTICAL PAINT CONFIGURATION

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	AVG C_T	ARMAMENT CONFIGURATION
9010	9480	6.5	199.4(AFT)	324	0.005958	HEAVY HOG

NOTE: FUEL FLOW DATA OBTAINED FROM FIG 116, REF 11, APP A.



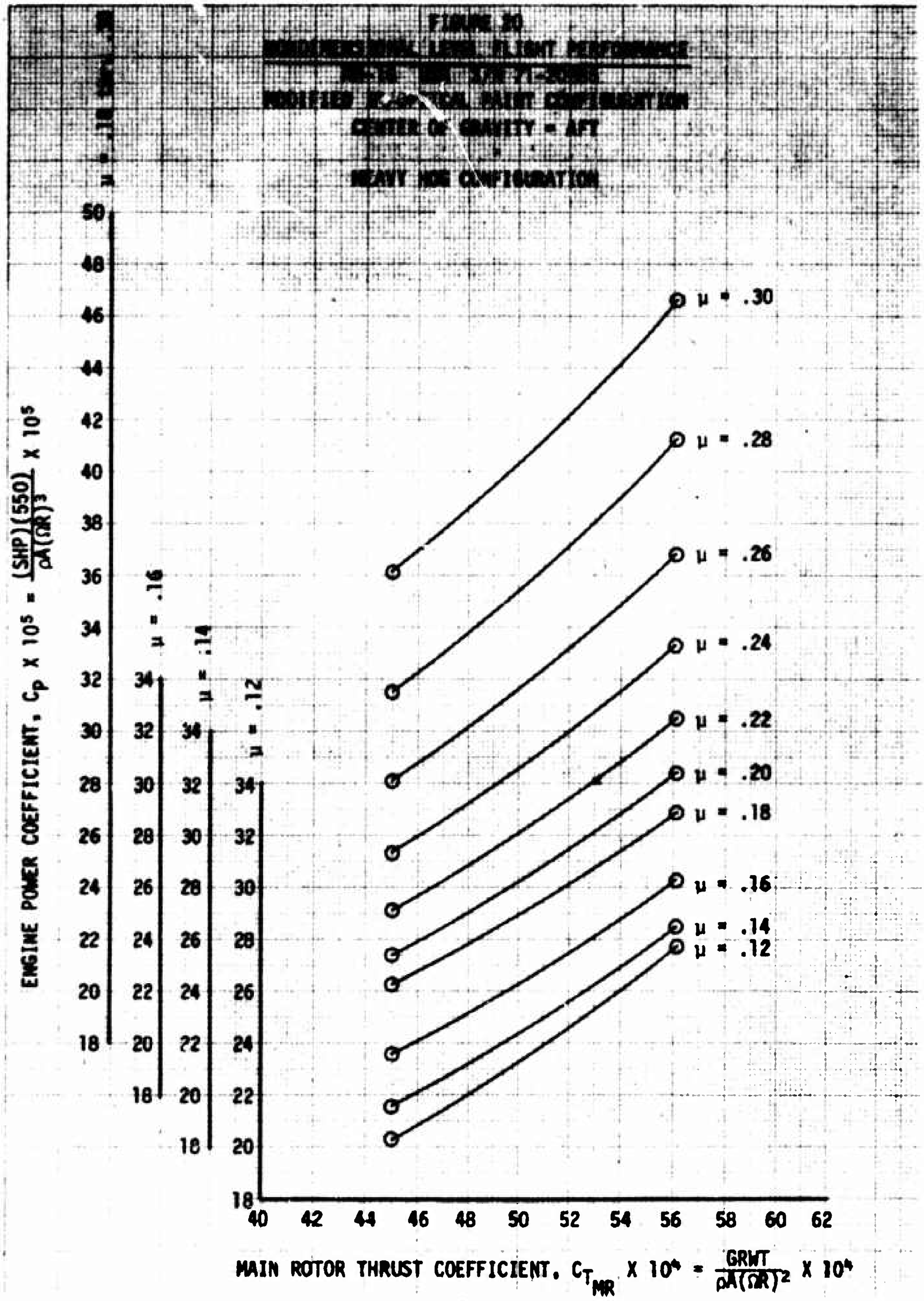
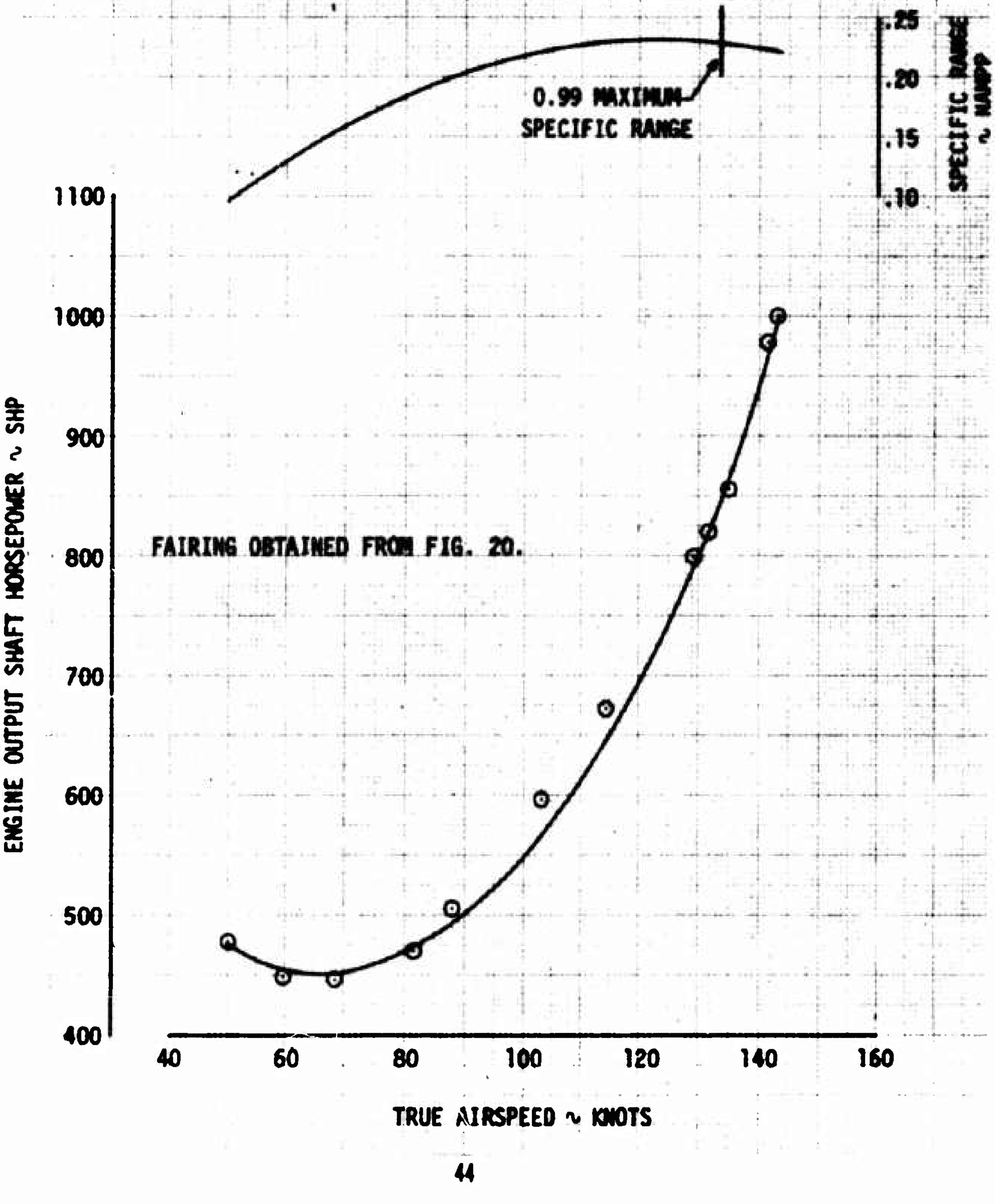


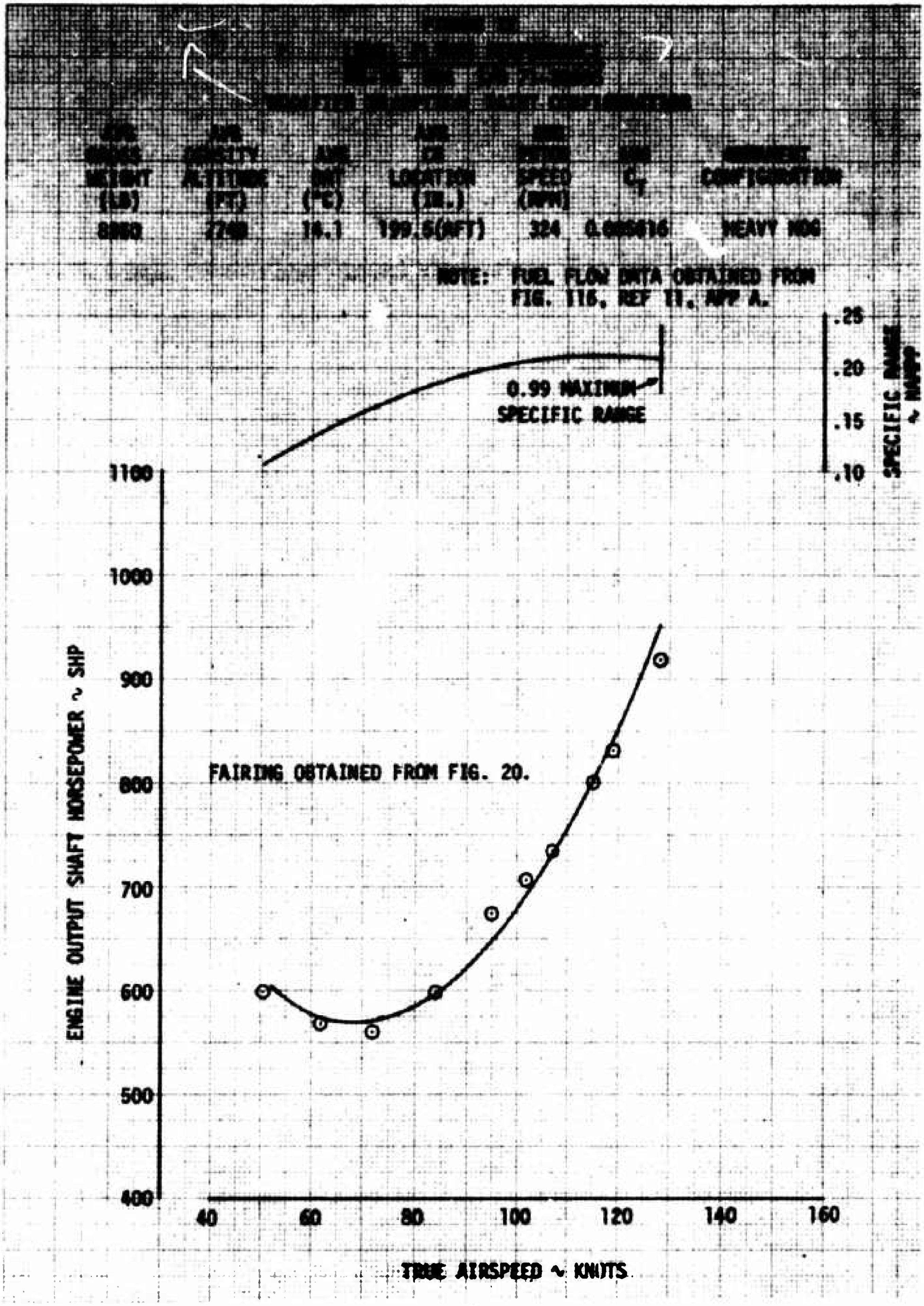
FIGURE 30
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
[illegible]
MODIFIED [illegible] CONFIGURATION
CENTER OF GRAVITY - AFT
HEAVY HUB CONFIGURATION

FIGURE 21
LEVEL FLIGHT PERFORMANCE
AH-1S USA S/N 71-20[illegible]
MODIFIED IR/OPTICAL PAINT CONFIGURATION

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	AVG C_T	ARMAMENT CONFIGURATION
7790	5280	14.0	199.4(AFT)	324	0.004503	HEAVY HOG

NOTE: FUEL FLOW DATA OBTAINED FROM FIG 116, REF 11, APP A.



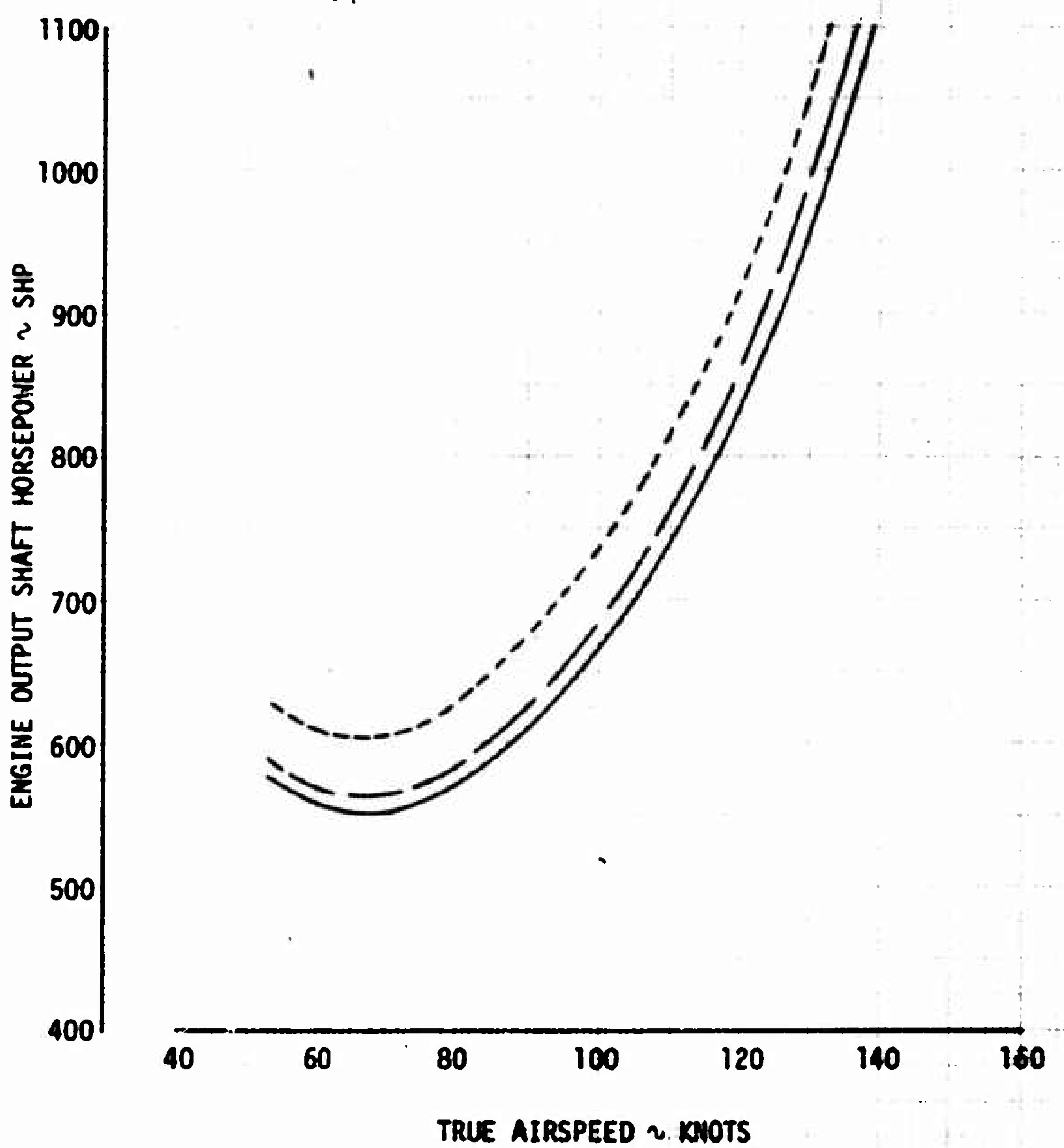


WEIGHT
ALTITUDE
LOCATION
SPEED
CONFIGURATION
(IN.)
(RPM)
199.5(AFT)
324
HEAVY HOG
NOTE: FUEL FLOW DATA OBTAINED FROM FIG. 116, REF 11, APP A.
0.99 MAXIMUM SPECIFIC RANGE
SPECIFIC RANGE ~ NAMPP
.25
.20
.15
.10
FAIRING OBTAINED FROM FIG. 20.
ENGINE OUTPUT SHAFT HORSEPOWER ~ SHP
1100
1000
900
800
700
600
500
400
40
60
80
100
120
140
160
TRUE AIRSPEED ~ KNOTS

FIGURE 23
LEVEL FLIGHT PERFORMANCE COMPARISON
AH-1G USA S/N 71-20985

AVG GROSS WEIGHT (LB)	AVG CG LOCATION (IN.)	AVG DENSITY ALTITUDE (FT)	AVG AMBIENT TEMPERATURE (°C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT	ARMAMENT CONFIGURATION
9500	199.5(AFT)	SEA LEVEL	15.0	324	0.004718	HEAVY HOG

LEGEND	PAINT CONFIGURATION
———	BASIC
- - - - -	IR/OPTICAL
— — —	MODIFIED IR/OPTICAL



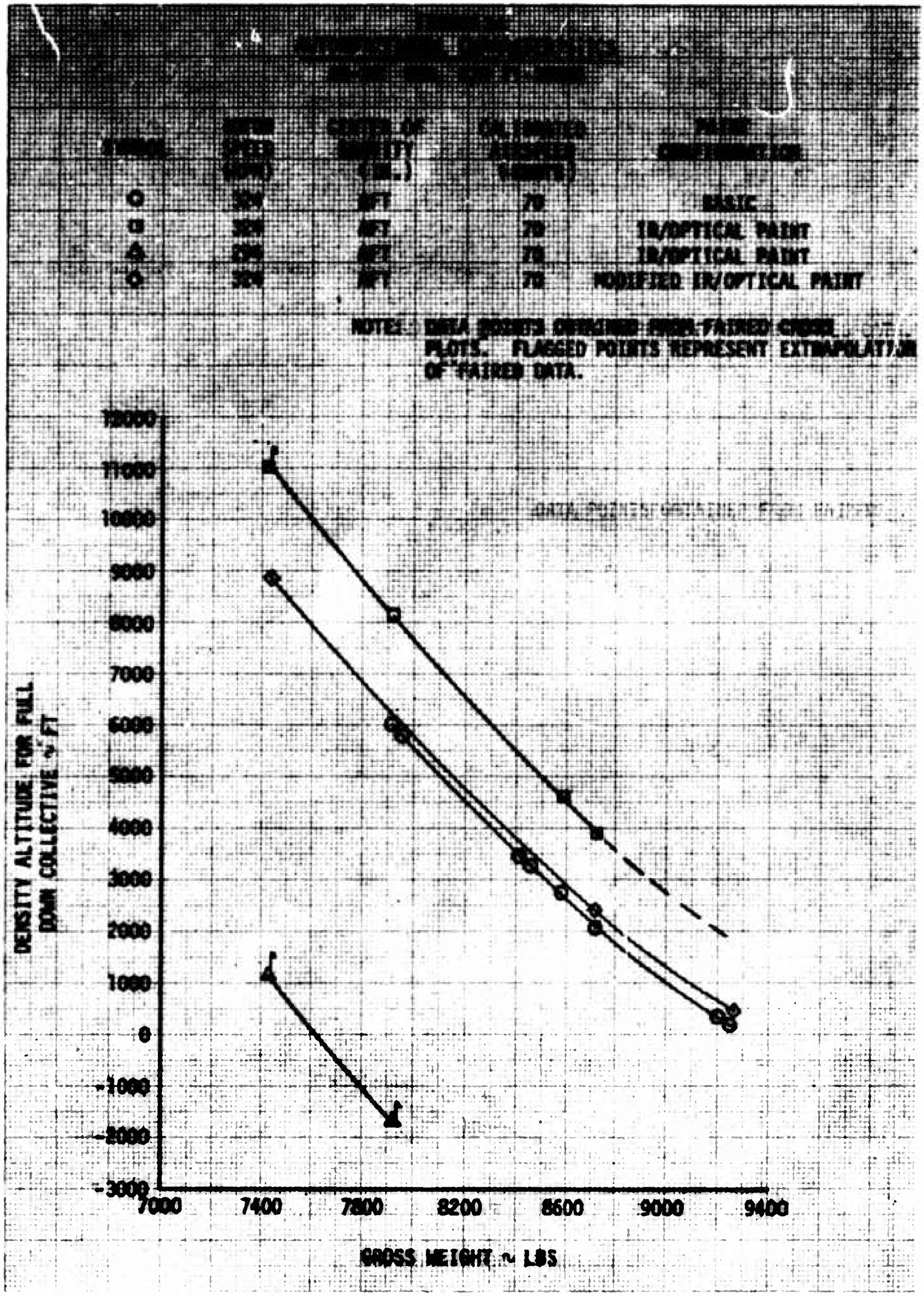

AFT
70
BASIC
IR/OPTICAL PAINT
IR/OPTICAL PAINT
MODIFIED IR/OPTICAL PAINT
NOTES: 1. DATA POINTS OBTAINED FROM FAIRED CROSS PLOTS. FLAGGED POINTS REPRESENT EXTRAPOLATION OF FAIRED DATA.
DENSITY ALTITUDE FOR FULL DOWN COLLECTIVE ~ FT
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
7000
7400
7800
8200
8600
9000
9400
GROSS WEIGHT ~ LBS

FIGURE 28

MANEUVERING STABILITY

AH-1G USA S/N 71-20985

IR/OPTICAL PAINT CONFIGURATION

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	TRIM AIRSPEED	FLIGHT CONDITION
○	7880	19, 8(AFT)	4820	18.0	324	0.004402	112	LEFT TURN
□	7700	19/.8(AFT)	5150	18.5	325	0.004427	110	RIGHT TURN
△	[illegible]	197.8(AFT)	5040	18.5	324	0.004383	111	PULL UP

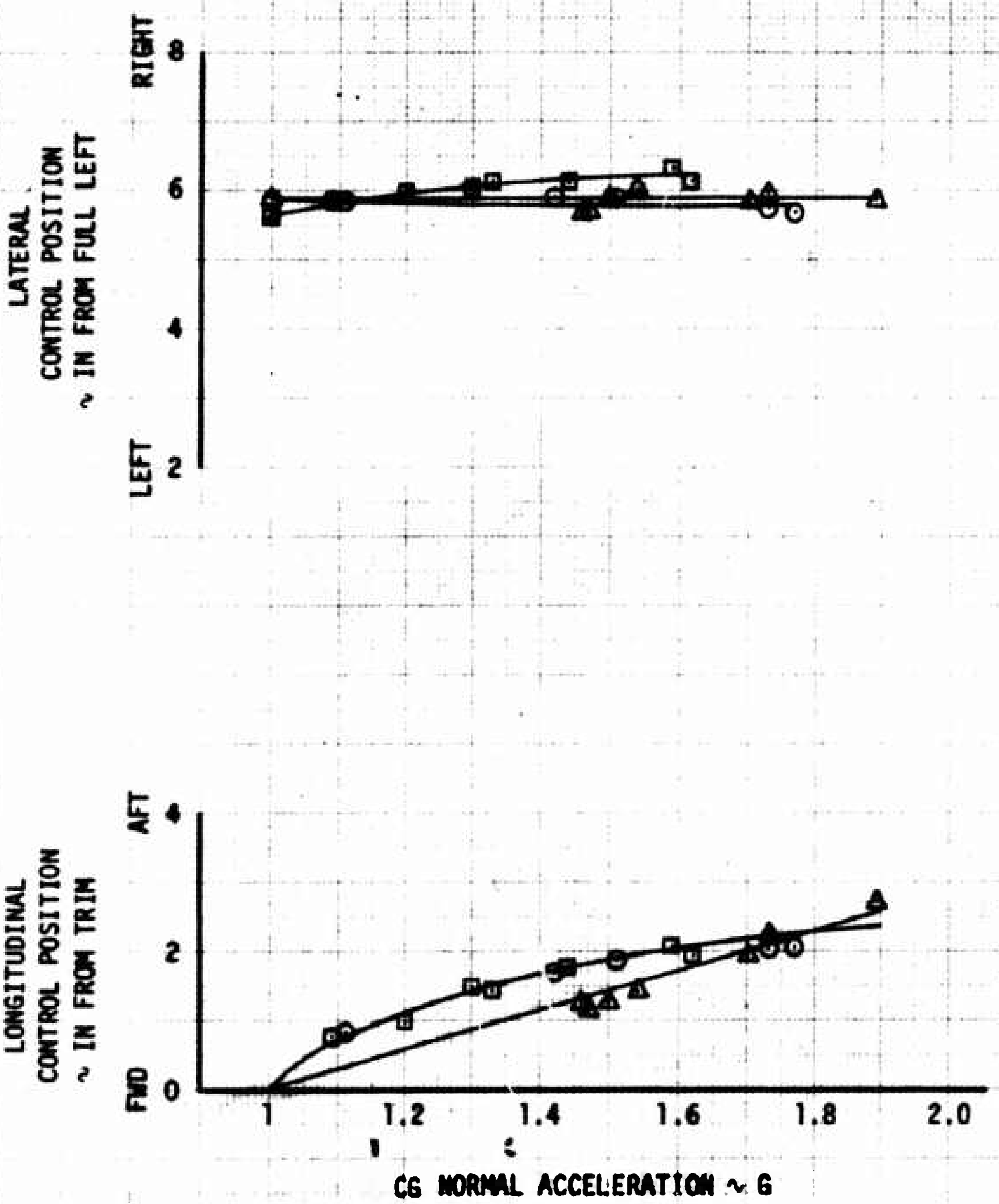


FIGURE 26
MANEUVERING STABILITY
AH-1S USA S/N 71-20985
IR/OPTICAL PAINT CONFIGURATION

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	TRIM AIRSPEED	FLIGHT CONDITION
○	8100	198.0(AFT)	5150	15.5	321	0.004774	139	LEFT TURN
□	8020	198.0(AFT)	5150	16.0	322	0.004702	139	RIGHT TURN
△	7860	198.0(AFT)	4840	17.5	320	0.004619	127	PULL UP