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PERFORMANCE AND HANDLING QUALITIES - AH-1G HELICOPTER EQUIPPED WITH THREE HOT METAL/PLUME INFRARED SUPPRESSORS

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Army Aviation Engineering Flight Activity
Edwards Air Force Base, California

April 1975

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PERFORMANCE AND HANDLING QUALITIES AH–1G HELICOPTER EQUIPPED WITH THREE HOT METAL/PLUME INFRARED SUPPRESSORS

FINAL REPORT

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APRIL 1975

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The performance and handling qualities of the AH-1G helicopter were quantitatively and qualitatively evaluated with a standard exhaust duct and with Garrett, Lycoming, and Bell infrared suppressors installed. Flight tests were conducted at the United States Army Aviation Engineering Flight Activity, Edwards Air Force Base, California, between 2 September and 14 November 1974. Twenty-one flights were flown for a total of 20.7 productive flight hours. The effectiveness of these

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20. Abstract

suppressors in reducing infrared radiation was not a part of this test. All suppressors caused a reduction in the AH-1G hover capability and an increase in power required in level flight. The ranking of each suppressor according to the performance degradation it caused was the same for both hover and level flight. The Bell suppressor caused the least performance degradation; the Garrett suppressor resulted in a slightly greater performance penalty; and the Lycoming suppressor caused the greatest performance degradation. The out-of-ground-effect hover capability of the AH-1G under sea-level, standard-day conditions was reduced by 140 to 200 pounds. The level flight power required at 9500 pounds gross weight at sea-level, standard-day conditions was increased by 17 to 35 horsepower at the minimum power-required airspeed of 70 knots true airspeed. Maximum level flight airspeed (power limited) was decreased by 5 to 11 knots. The specific range with the suppressor installed was degraded in the same manner as the level flight power requirements. There was no detectable difference in handling qualities due to suppressor installation. With the Garrett and Lycoming suppressor kits installed, the master caution light and engine inlet caution light illuminated during dives at airspeeds over 150 knots indicated airspeed, indicating a low pressure at the engine inlet, a shortcoming which should be corrected in future designs. No adverse engine characteristics were encountered during the tests.

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A

INTRODUCTION

BACKGROUND

1. The Aircraft Survivability Equipment Product Manager contracted with the AirResearch Manufacturing Company of the Garrett Corporation and the AVCO Lycoming Division of the AVCO Corporation to build flight test units of a hot metal/plume infrared (IR) suppressor. Because of a critical need for an IR suppressor in Vietnam, the Bell Helicopter Company IR suppressor ("Bell scoop") was fielded prior to obtaining quantitative helicopter performance data. The United States Army Aviation Engineering Flight Activity (USAAEFA) was directed by the United States Army Aviation Systems Command (AVSCOM) (ref 1, app A) to evaluate the effect that the installation of these IR suppressor systems would have on the hover and level flight performance and handling qualities of the AH-1G helicopter.

TEST OBJECTIVES

2. The major objective of this test was to evaluate the effects of the installation of the Garrett, Lycoming, and Bell IR suppressors on the hover and level flight performance characteristics of the AH-1G helicopter and additionally, to qualitatively evaluate the suppressors' effect on helicopter handling qualities.

DESCRIPTION

3. The test helicopter, serial number 71-20985, was a production AH-1G. Modifications to the airframe included a very-high-frequency omnidirectional receiver antenna on the underside of the tail boom (fuselage station (FS) 390); a glide-slope receiver antenna under the nose section (FS 60); a total temperature sensor under the nose section (FS 53); and fittings for a trailing bomb used during airspeed calibration on the left side of the fuselage (FS 90). The AH-1G is a single-rotor high-speed attack helicopter manufactured by the Bell Helicopter Company of Hurst, Texas. 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, and skid-type landing gear. Tandem seating is provided for a crew of two, the copilot/gunner being seated forward of the pilot. The main rotor is a two-bladed, semirigid, teetering-type rotor. The antitorque rotor is a delta-hinge tractor-type tail rotor. The flight control system is a positive mechanical hydraulically boosted irreversible system actuated by conventional helicopter controls. 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 helicopter is contained in the operator's manual (ref 2, app A).

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4. The three IR suppressors tested involved modifications to the AH-1G exhaust stack and to the engine cowling. In general, all three suppressors directed the exhaust gases upward from the longitudinal axis of the aircraft. The Garrett and Lycoming IR suppressors required that two air scoops be mounted on each of the two engine cowling doors. The Bell IR suppressor required one scoop on each door. A more detailed description of the IR suppressors with accompanying photographs is contained in appendix B.

TEST SCOPE

5. A hover and level flight performance evaluation of the basic AH-1G helicopter and the AH-1G with the Garrett, Lycoming, and Bell IR suppressors installed was conducted at the USAAEFA facility at Edwards Air Force Base, California, between 2 September and 14 November 1974. The test program was comprised of 21 flights for a total of 27.6 flight hours, 20.7 of which were productive. All tests were conducted with the helicopter in the clean configuration (no external stores) with guns removed from the chin turret. An instrumented cargo hook was installed for tethered-hover testing and was removed and the fuselage cover plate reinstalled for level flight performance testing. The flight envelope and operating limits prescribed in the operator's manual and the safety-of-flight releases (refs 3 and 4, app A) were observed during this evaluation. Table 1 is a summary of the general test conditions. The order in which tests were conducted was as follows: basic AH-1G, Garrett suppressor, Bell suppressor, Lycoming suppressor, and basic AH-1G. Flight tests on the basic AH-1G were repeated after the suppressor tests in order to verify the validity of the basic data and to determine any discernible degradation to the engine from the suppressor installations.

TEST METHODOLOGY

6. Engineering flight test techniques described in Army Materiel Command Pamphlet AMCP 706-204 (ref 5, app A) were used in conducting tethered hover and level flight performance tests. Data were recorded on magnetic tape using a pulse-code-modulation (PCM) recorder. A detailed listing of the test instrumentation is given in appendix C. Hand-recorded cockpit data were taken from sensitive cockpit indicators to facilitate correlation of the automatically recorded data. Data reduction was accomplished using the USAAEFA computer facilities. The test techniques and data analysis methods employed are described in appendix D.

Table 1. Test Conditions.

Test	Gross Weight (lb)	Center-of-Gravity Location (in.)	Rotor Speed (rpm)	Density Altitude (ft)	Configuration
Hover performance	7700 to 10,800[1]	198.2 (aft)	296 to 324	1350	Standard exhaust duct
				3450	
				2600	Garrett IR suppressor
				2400	Lycoming IR suppressor
				2000	Bell IR suppressor
Level flight performance	7700	198.6 (aft)	324	5000	All
				9500	All
				12,000	Standard exhaust duct

[1]Helicopter gross weight plus tether cable tension.

RESULTS AND DISCUSSION

GENERAL

7. The performance and handling qualities of the AH-1G helicopter were quantitatively and qualitatively evaluated in the basic AH-1G exhaust configuration and with three different IR suppressors installed. The evaluation was conducted as a comparison between the suppressed and basic configurations. All suppressor configurations resulted in level flight and hover performance degradation. In each performance area tested the suppressors were ranked the same: the Bell suppressor causing the least performance penalty, the Garrett suppressor slightly more performance degradation, and the Lycoming suppressor causing the greatest performance loss. No deficiencies were found and one shortcoming was found: illumination of the master caution and engine inlet caution lights during diving attacks on target with the Garrett and Lycoming suppressors installed.

PERFORMANCE

Hover

8. The hover performance characteristics of the AH-1G helicopter in each configuration were determined at the conditions shown in table 1. The tethered-hover technique was used to determine the 5-foot skid height in-ground-effect (IGE) hover and the 100-foot skid height out-of-ground-effect (OGE) hover performance characteristics. A summary of OGE hover performance is shown in figures 1, 2, and 3 of appendix E. Nondimensional hover performance data are presented in figures 4 through 7. In figure 5, the IGE performance of the Garrett suppressor is omitted because of an instrumentation malfunction. The effects of exhaust gas reingestion in a hover were not determined.

9. The hover performance summaries depict the aircraft weight for OGE hover at the power available, as shown in figure 8, appendix E. The power available presented was extracted from figure 114 of USAASTA Final Report No. 66-06 (ref 6, app A). A comparison of the standard-day, sea-level OGE hover capability shows a reduction in hover performance due to the suppressor installations of the following magnitudes: Garrett, 170 pounds; Lycoming, 200 pounds; and Bell, 140 pounds. When considering the increase in the basic weight of the aircraft caused by the suppressor installation, the useful load is reduced by the following magnitudes: Garrett, 214 pounds; Lycoming, 284 pounds; and Bell, 183 pounds. The OGE hover weight differential between the standard and suppressed AH-1G helicopter becomes smaller as altitude or ambient temperature increase.

Level Flight

10. The 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 figures 9 and 10, appendix E. Figures 11 through 13 depict the level flight power required and specific range curves for the basic AH-1G. Figures 14 through 19 are the level flight performance plots for the three suppressor configurations, as indicated on the plots. All tests were conducted in the clean configuration at an aft center of gravity. 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 20. Highlights of this comparison are shown in table 2.

Table 2. Level Flight Power-Required Summary.[1]

Suppressor	Increase in Power Required Due to Suppressor (shp)		Degradation in Maximum Horizontal Velocity at 1100 SHP
	70 KTAS	130 KTAS	KTAS
Garrett	22	64	7
Lycoming	35	130	11
Bell	17	48	5

[1]Based on figure 20, appendix E. Conditions: 9500 pounds gross weight; sea-level, standard-day ambient conditions; 324 rpm main rotor speed.

11. Specific range characteristics are shown on the plots for each level flight test (figs. 11 through 19, app E). Cruise airspeeds were taken to be the high airspeed for 99 percent of maximum specific range. Table 3 is a cruise summary at a mid range thrust coefficient (C_T).

Table 3. Cruise Characteristics.[1]

Exhaust Duct	True Cruise Airspeed (kt)	Specific Range at Cruise Airspeed (NAMPP)[2]	Pressure Altitude (ft)	Ambient Temperature (°C)	Gross Weight (lb)
Standard	140	0.266	8980	16.5	7800
Garrett	135	0.256	9300	11.0	7750
Lycoming	132	0.248	9540	3.5	7680
Bell	136	0.261	9550	9.0	7680

[1]Main rotor speed: 324 rpm.
[2]NAMPP: Nautical air miles per pound of fuel.

Engine Characteristics

12. Engine performance parameters were monitored during all level flight and hover testing. Engine data plots are presented in figures 21 through 28, appendix E. Engine parameters monitored during these tests are shown in appendix C. The aircraft was not instrumented to measure engine inlet pressures and temperatures or exhaust system losses. Engine inlet conditions were computed using the measured test-day conditions and the temperature and pressure recovery factors shown in figure 113 of USAASTA Final Report No. 66-06 (ref 6, app A). Power available and engine fuel flow used for specific range computations were calculated assuming no increase in engine installation losses due to the various suppressor installations as compared to the standard AH-1G. Any differences in engine performance noted during this test were within the limits of measuring engine power and reducing the parameters to the referred values shown in figures 21 through 28, appendix E. Within the scope of this test there was no significant difference in the engine performance characteristics due to suppressor installation. Future flight test programs involving systems which have a potential for degrading installed engine performance should have suitable engine instrumentation installed to determine the magnitude of any engine performance degradation.

13. During dives simulating steep-angle target attacks with the Garrett and Lycoming suppressors mounted, the engine inlet light illuminated, which indicates low engine air inlet pressure. This light came on over an airspeed range from 150 to 175 knots indicated airspeed (KIAS) and was extinguished after the pullout when airspeed had decreased. Illumination of the engine inlet light and the associated illumination of the master caution light will distract the pilot during diving target attacks. This distraction will be minimal when the pilot is familiar with the characteristics; however, since the pilot will probably not reset the master caution

light prior to breaking off the attack, he may be unaware of additional malfunctions and/or battle damage. The illumination of the engine inlet caution light and the master caution light during high-speed dives is a shortcoming which should be corrected in future IR suppressor system designs. No adverse engine characteristics were noted in dives to the limit airspeed (190 KIAS) with 35-psi torque and 324-rpm rotor speed.

HANDLING QUALITIES

14. Handling qualities were qualitatively evaluated throughout the conduct of the test program. Within the scope of this test, the IR suppressor installation had no noticeable effect on aircraft handling qualities.

CONCLUSIONS

GENERAL

15. The following general conclusions were reached upon completion of testing:

a. The installation of all IR suppressors degraded aircraft performance in hover and level flight (paras 9, 10, 11).

b. The IR suppressors tested were ranked in each test in order of least to greatest performance degradation as Bell, Garrett, Lycoming (para 9).

c. Within the scope of this test, the IR suppressor installation had no significant effect on engine performance characteristics (para 12).

d. Within the scope of this test, the IR suppressor installation had no noticeable effect on aircraft handling qualities (para 14).

e. One shortcoming was identified.

SHORTCOMING

16. The following shortcoming was identified: During high-speed dives with the Garrett and Lycoming suppressors installed, the engine inlet caution light and master caution light illuminated at airspeeds in excess of 150 KIAS (para 13).

RECOMMENDATIONS

17. Correct the shortcoming in future IR suppressor system designs.

18. Future flight test programs involving systems which have a potential for degrading installed engine performance should have suitable engine instrumentation installed to determine the magnitude of any engine performance degradation (para 12).

APPENDIX A. REFERENCES

1. Letter, AVSCOM, AMSAV-EFT, 29 July 1974, subject: AVSCOM Test Directive No. 75-01, AH-1G Hot Metal/Plume Suppressor Evaluation.

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

3. Message, AVSCOM, AMSAV-EFT, 271400Z September 1974, subject: Safety-of-Flight Release for Infrared Countermeasures (IRCM) AH-1G 71-20985.

4. Message, AVSCOM, AMSAV-EFS, 312015Z October 1974, subject: Safety-of-Flight Release (SOFR) for Lycoming IR Suppressor Installed in AH-1G.

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

6. Final Report, USAASTA, No. 66-06, *Engineering Flight Test, AH-1G Helicopter (HueyCobra), Phase D, Part 2, Performance*, April 1970.

APPENDIX B. DESCRIPTION

GARRETT INFRARED SUPPRESSOR

1. The 20-inch mitered duct suppressor (kit no. 190982) manufactured by the AirResearch Manufacturing Division of the Garrett Corporation (photos 1 through 5) is an advanced development test prototype of an IR radiation suppressor system. The equipment was designed to reduce the IR radiation emitted by the aircraft engine, exhaust components, and exhaust plume. The system consists primarily of an exhaust nozzle, an insulated upturned (mitered) duct, air inlet ram scoops, and related adapting, supporting, and attaching hardware. When installed on the aircraft the system deflects the engine exhaust upward through the mitered duct at approximately 45 degrees relative to the aircraft longitudinal axis. The ejector action, created by the engine exhaust as it is accelerated through the replacement nozzle, draws ambient air through the four air inlet ducts mounted on the engine cowl. This airflow, which is increased by ram action in forward flight, passes through the engine compartment and is mixed with the engine exhaust by an arrangement of vanes internal to the duct. The exhaust plume is thus cooled, reducing the IR radiation emitted by the exhaust plume. The insulated mitered duct reduces the temperature of exhaust and engine components visible from below the aircraft. The airflow induced by the ejector is approximately 60 percent of engine mass flow. Net weight added to the aircraft by the installation is 44 pounds.

LYCOMING INFRARED SUPPRESSOR

2. The "dog leg" elbow suppressor system (kit no. PDS10705) manufactured by the AVCO Lycoming Division of AVCO Corporation (photos 6 through 11) is an advanced development test prototype IR suppressor system. The device was designed to reduce total aircraft IR signature by cooling, insulating, or blocking the view of hot engine and exhaust system components and by diluting the hot exhaust plume. The basic components consist of an exhaust nozzle, a dog-leg shaped elbow, air inlet ram scoops, and related adapting, supporting, and attaching hardware. The Lycoming nozzle, termed the "ejector vane cascade," draws in ejected air both radially and circumferentially (photos 10 and 11). The dog-leg shaped elbow blocks the view of the hot engine turbine and nozzle area when viewed from above or below the aircraft. The exhaust angle of the Lycoming duct is 55 degrees upward relative to the aircraft longitudinal axis. The airflow induced by the ejector is approximately 80 percent of engine mass flow. Net weight added to the aircraft by the installation is 84 pounds.

BELL SCOOP INFRARED SUPPRESSOR

3. The Bell scoop suppressor system (kit no. 209-706-020) manufactured by Bell Helicopter Company is a suppressor system that was fielded during the Vietnam conflict to counter IR-seeking missiles employed during that conflict (photos 12 and 13). This device was designed to reduce IR radiation produced by hot engine and exhaust system components, but not the exhaust plume, and to provide protection against attack from the ground only. The kit consists of an insulated upturned elbow, two air inlet ducts, and attaching hardware. The ejector nozzle and insulated elbow provide enough airflow to cool the engine compartment only of the AH-1G helicopter and not enough air to dilute the exhaust plume. The airflow induced by this ejector is approximately 10 percent of engine mass flow. It is estimated that the exhaust gas exits the elbow at approximately 30 degrees relative to the aircraft longitudinal axis. Net increase to the aircraft weight is 43 pounds.

Garrett IR Suppressor

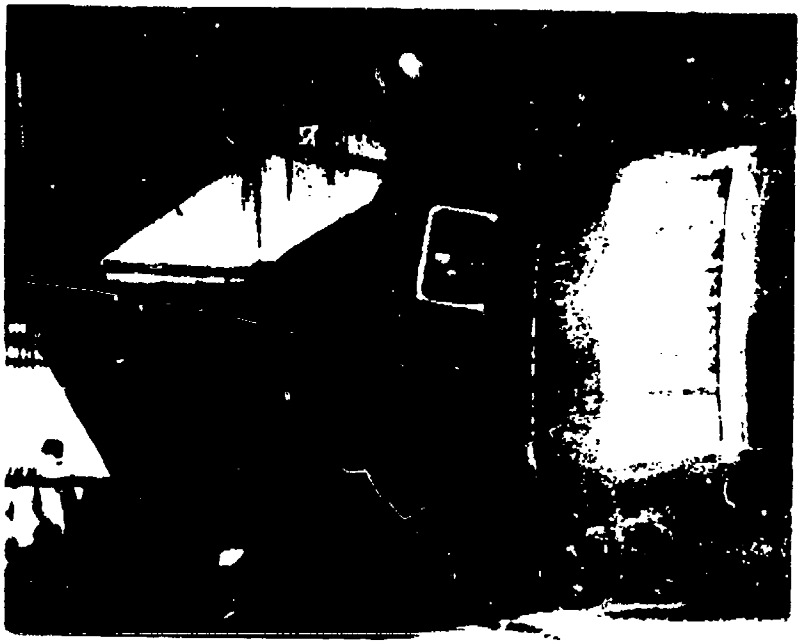


Photo 1.

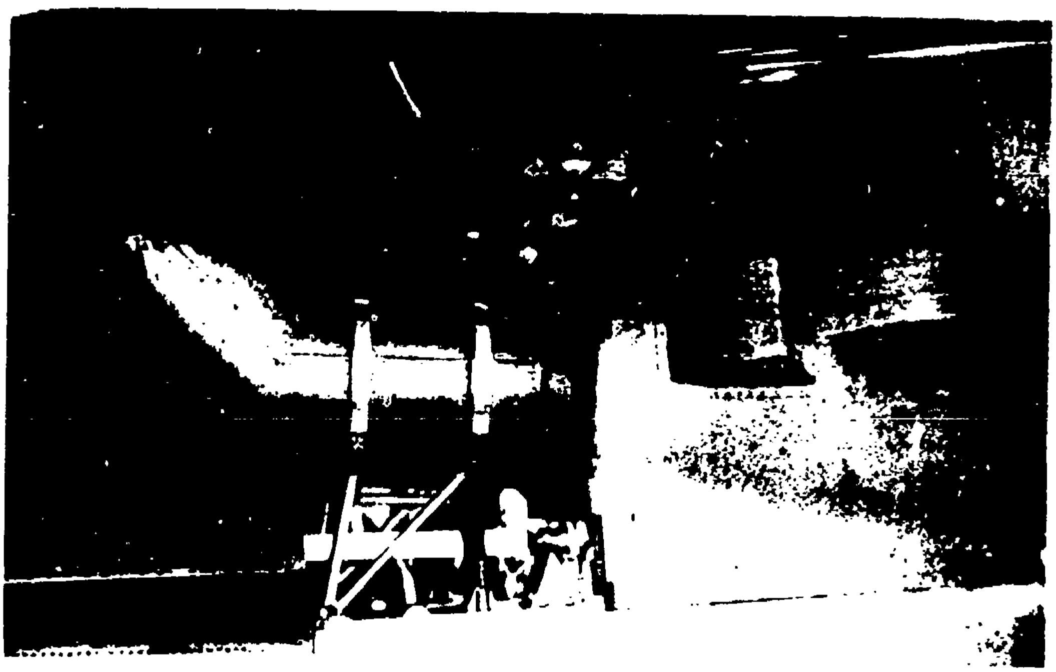


Photo 2.

Photo 3.

Photo 4.

Photo 5.

Lycoming IR Suppressor

Photo 6.

Photo 7.

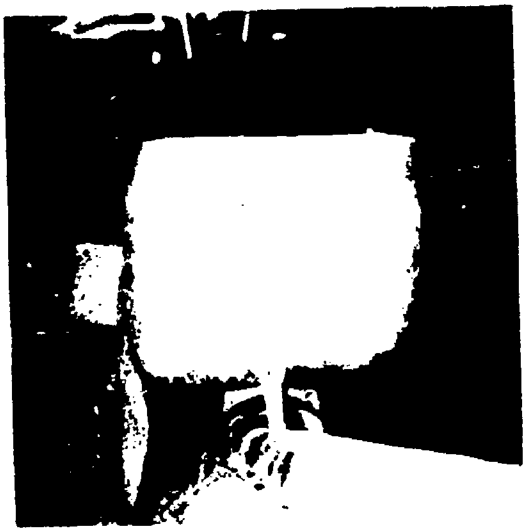


Photo 8.

Photo 9.

Lycoming IR Suppressor Ejector Vane Cascade

Photo 10.

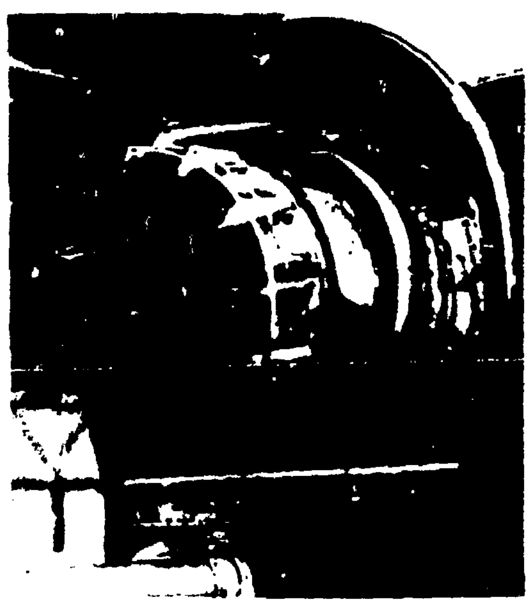


Photo 11.

Bell Scoop IR Suppressor

Photo 12.

Photo 13.

APPENDIX C. INSTRUMENTATION

1. 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, sideslip vane, and angle-of-attack vane. A total-temperature sensor was mounted aft of the test boom on the underside of the aircraft nose section (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 listing shows the instrumentation used during this evaluation.

Pilot Panel

Airspeed (boom)
Altitude (boom)
Main rotor speed
Sideslip
Vertical speed (ship's system)
Torque
Gas producer speed (ship's system)
Exhaust gas temperature (ship's system)

Engineer Panel

Airspeed (boom)
Altitude (boom)
Main rotor speed
Total outside air temperature
Cable tension
Fuel flow
Fuel consumed
Torque (ship's system)
Gas producer speed (ship's system)
Exhaust gas temperature (ship's system)
Time code display

Magnetic Tape

Airspeed (boom)
Altitude (boom)
Torque
Main rotor speed
Gas producer speed
Exhaust gas temperature (ship's system)
Fuel temperature

- Fuel flow
- Fuel consumed
- Total outside air temperature
- Sideslip
- Pitch attitude
- Roll attitude
- Load cell
- Control position:
    - Longitudinal cyclic
    - Lateral cyclic
    - Pedal
    - Collective
- Time code
- Pilot event
- Engineer event

APPENDIX D.
TEST TECHNIQUES AND DATA ANALYSIS

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 was weighed after installation of the Garrett and Lycoming IR suppressors. Weighing was not required after installation of the Bell IR suppressor since the modification work order for the Bell IR suppressor contained sufficient weight and balance data. All weighings were performed 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 center of gravity were controlled by installing ballast in 25-pound increments at the tail skid (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-hover technique as described in AMCP 706-204. Two hover heights were tested: skid heights of 5 feet (IGE) and 100 feet (OGE). With the aircraft tethered to the ground by steel cables, engine torque was varied from that required to maintain a minimum of 200-pound cable tension to the maximum defined either by a torque limit (50 psi) or by reaching topping power. (For this test, topping power was determined by an inability to further increase collective and still maintain the desired rotor speed.) This torque range was repeated for main rotor speeds of 294, 314, and 324 rpm at each skid height. 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 testing was conducted in winds less than 3 knots. All hover test data were recorded on magnetic tape 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 described in AMCP 706-204. This method allows the entire flight to be flown at a constant value of the nondimensional parameter, C_T, defined in paragraph 5. In flight the aircraft was stabilized at airspeeds between

40 KIAS and the maximum airspeed for level flight (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 a main rotor speed of 324 rpm. The helicopter was flown for a minimum of 2 minutes at each stabilized test condition.

Handling Qualities

4. Handling qualities were qualitatively assessed during other tests.

DATA ANALYSIS

Hover Performance

5. 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 of power coefficient (C_P) and C_T through application of the following equation:

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

Where:

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

A = Main rotor disc geometric area (ft^2) (1520.5 ft^2 for the AH-1G)

Ω = Main rotor speed (radians/sec)

R = Main rotor radius (ft) (44.0 ft for the AH-1G)

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

SHP = Total engine power - Determined from main rotor speed and engine torque

s = Standard-day condition

t = Test-day condition

6. 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; however, it does not, in general, reveal the degradation of maximum power available due to the presence of the IR suppressor, since it was not possible to reach topping power in all hover tests.

Level Flight Performance

7. Test-day level flight power required was corrected to standard-day conditions by the following relationship:

$$SHP_s = SHP_t \times \frac{\rho_s}{\rho_t}$$

The data were then generalized through the use of C_P, C_T, and the following additional nondimensional coefficients:

$$V_T = \frac{V_C}{\sqrt{\sigma}} \quad ; \quad \mu = \frac{1.689 V_T}{\Omega R}$$

Where:

V_T = True airspeed (kt)

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

σ = Density ratio determined by $\sigma = \frac{\rho_t}{.0023769}$

μ = Advance ratio - A nondimensional ratio between true airspeed and rotor tip speed

ρ_t = Test-day ambient density

ρ_s = Standard-day average density for the flight

Curves defined by the power required as a function of airspeed were plotted as C_P versus μ for a constant value of C_T. These curves were then joined by lines of constant μ value to form a carpet plot. The reduction of this carpet plot into a family of curves, C_T versus C_P, for constant μ value allows determination of the power required as a function of airspeed for any value of C_T. Power polars for each suppressor configuration were used to compute an apparent change in helicopter drag due to the suppressor, as a function of airspeed. The drag relationship was then used to obtain the fairing for the suppressor configurations based on the basic aircraft data.

8. The specific NAMPP range data were derived from the test level flight power required and specification engine fuel flow data obtained from figure 116 of USAASTA Final Report No. 66-06.

Engine Performance

9. Data concerning engine performance were taken during hover and level flight tests and were converted to referred values for presentation. The data as plotted in this report represent actual installed engine performance. Inlet temperature and pressure were computed using ambient conditions and applying the inlet correction derived from figure 113 of USAASTA Final Report No. 66-06. Referred engine parameters are defined below:

$$SHP_{ref} = \frac{SHP}{\delta_i \sqrt{\theta_i}} \quad ; \quad N_{1_{ref}} = \frac{N_1}{\sqrt{\theta_i}}$$

$$EGT_{ref} = \frac{EGT + 273.15}{\theta_i} - 273.15 \quad ; \quad W_{F_{ref}} = \frac{W_F}{\delta_i \sqrt{\theta_i}}$$

Where:

δ_i = Ratio of engine inlet air pressure to standard-day sea-level pressure

θ_i = Ratio of engine inlet air temperature (°K) to standard-day sea-level ambient temperature

SHP = Engine shaft horsepower

N_1 = Gas producer speed (percent)

EGT = Exhaust gas temperature (°C)

W_F = Fuel flow rate (lb/hr)

"ref" (subscript) indicates referred values

APPENDIX E. TEST DATA

INDEX

NOTES: 1. SHP OBTAINED FROM FIGURE 8.
2. CURVES DERIVED FROM FIGURES 4 AND 5.
3. WIND LESS THAN 3 KNOTS.
4. ROTOR SPEED = 324 RPM.
5. BROKEN LINE DENOTES STANDARD EXHAUST DUCT.

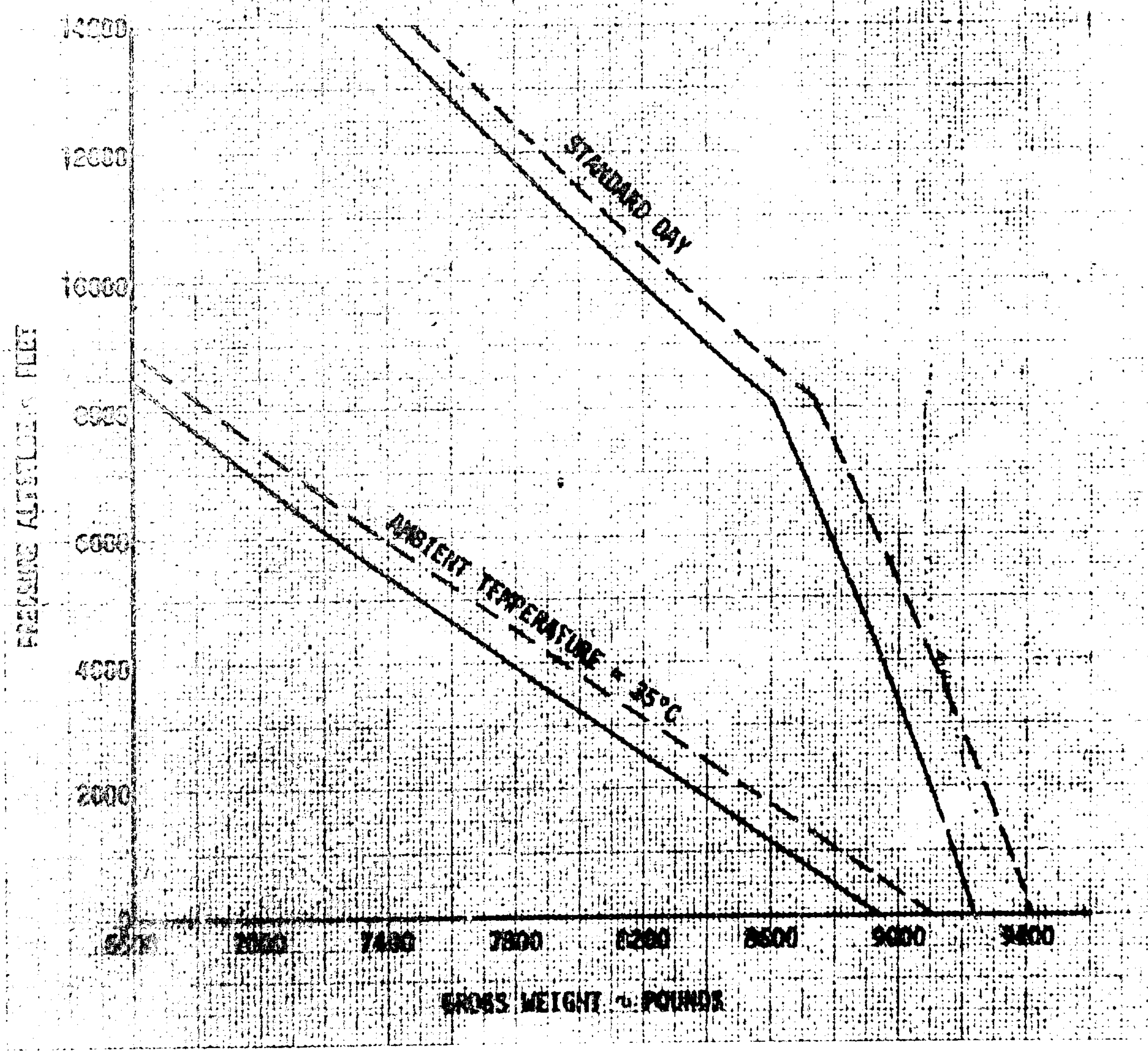


FIGURE 2
[illegible] HOVERING PERFORMANCE
[illegible]
MILITARY RATED POWER AVAILABLE
LYCOMING INFRARED SUPPRESSOR

NOTES: 1. SHP OBTAINED FROM FIGURE 8.
2. CURVES DERIVED FROM FIGURES 4 AND 6.
3. WIND LESS THAN 3 KNOTS.
4. ROTOR SPEED = 324 RPM.
5. BROKEN LINE DENOTES STANDARD EXHAUST DUCT.

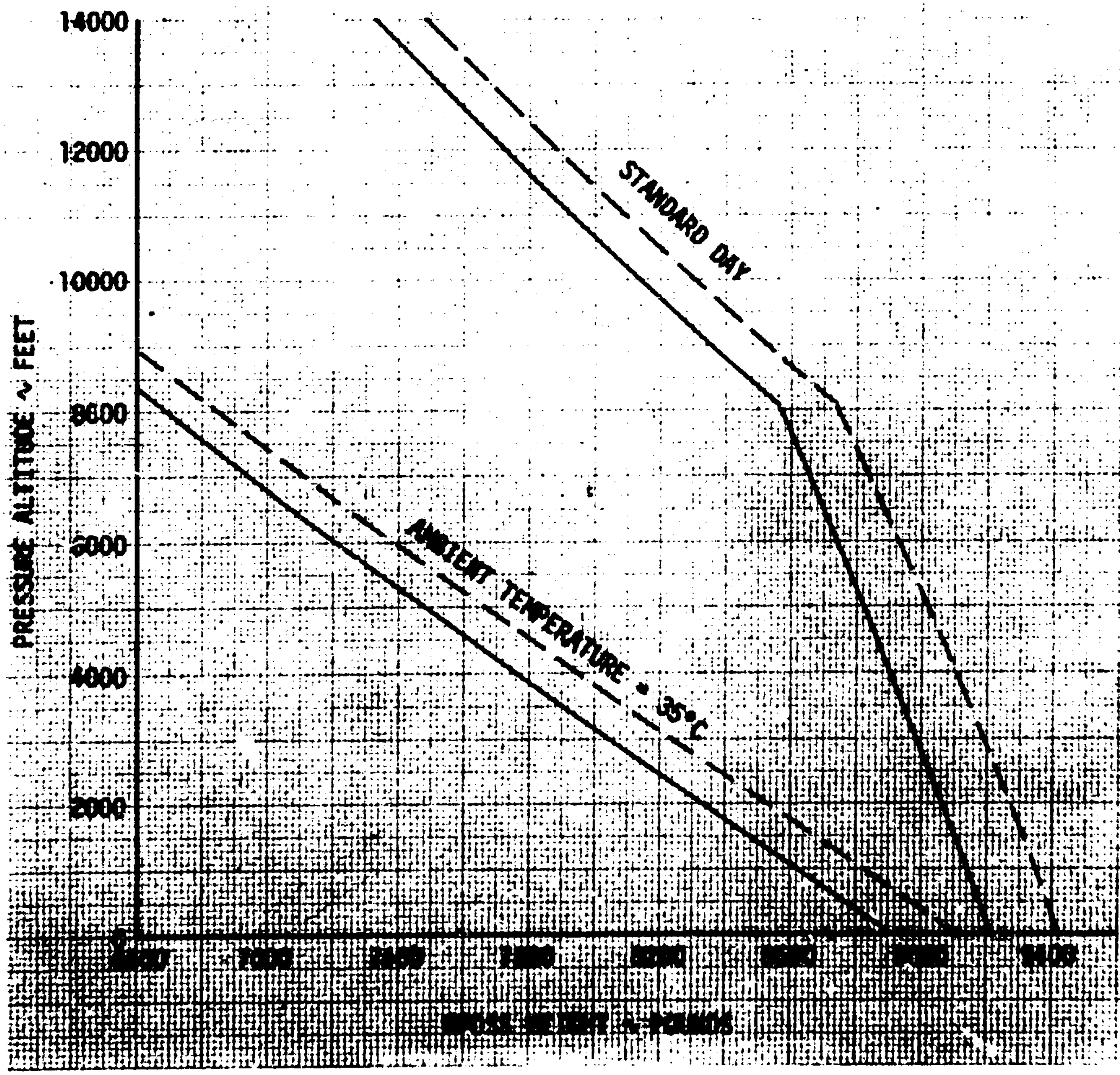


FIGURE 9

[illegible] USA S/N [illegible]

MILITARY RATED POWER AVAILABLE

BELL SCOOP INFRARED SUPPRESSOR

NOTES:
1. SHP OBTAINED FROM FIGURE 8.
2. CURVES DERIVED FROM FIGURES 4 AND 7.
3. WIND LESS THAN 3 KNOTS.
4. ROTOR SPEED = 324 RPM.
5. BROKEN LINE DENOTES STANDARD EXHAUST DUCT.

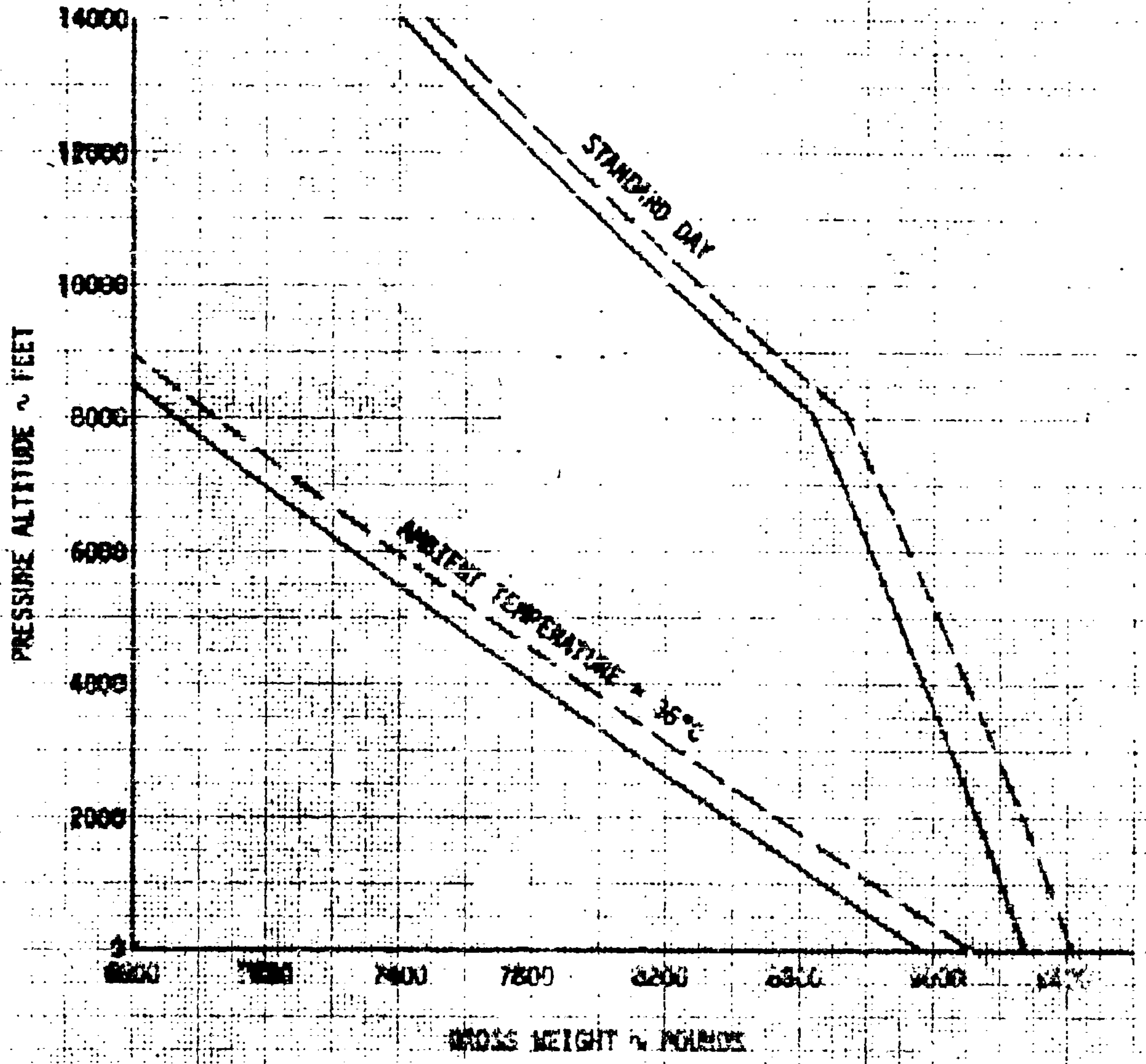


FIGURE [illegible]

NON-DIMENSIONAL HOVERING PERFORMANCE

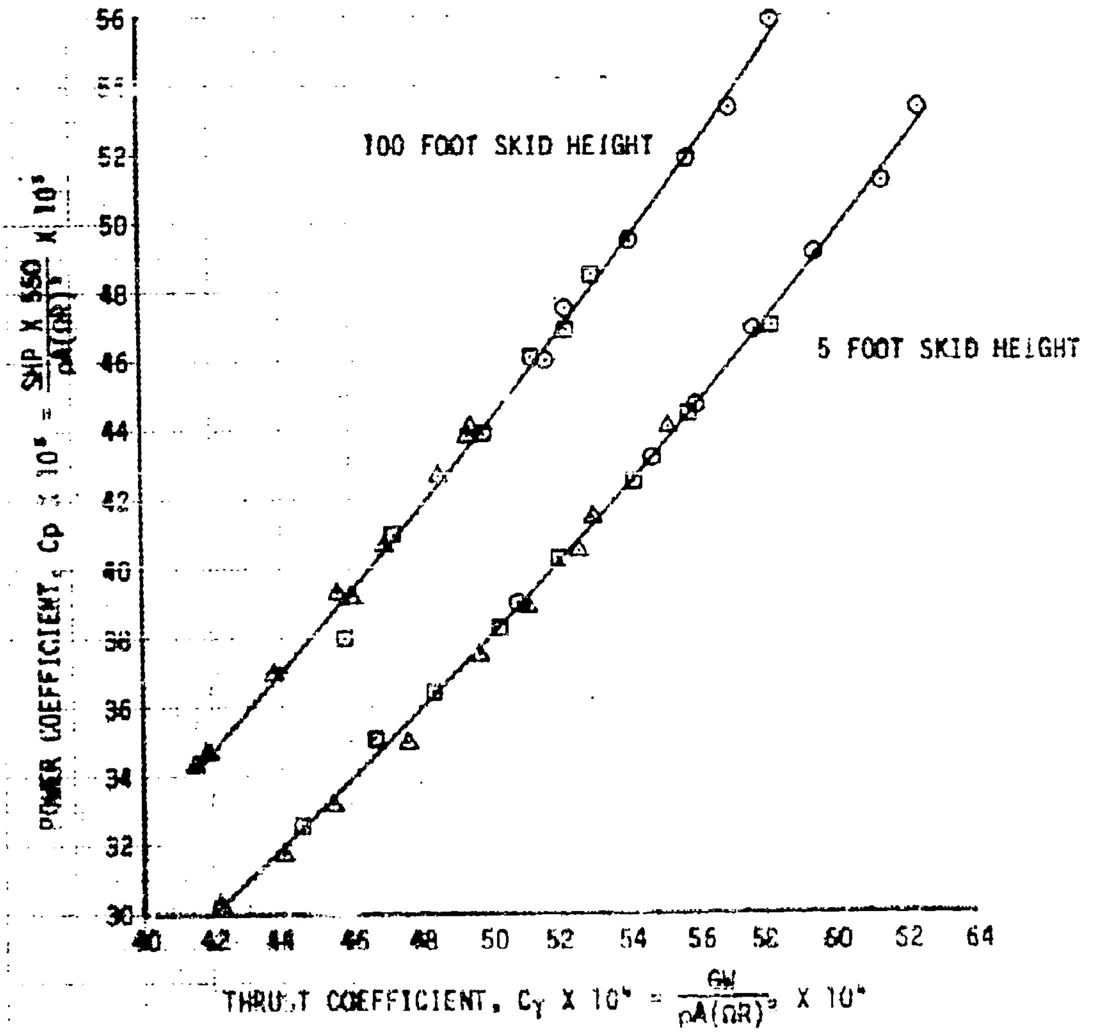
AH-1Q USA S/N 71-20965

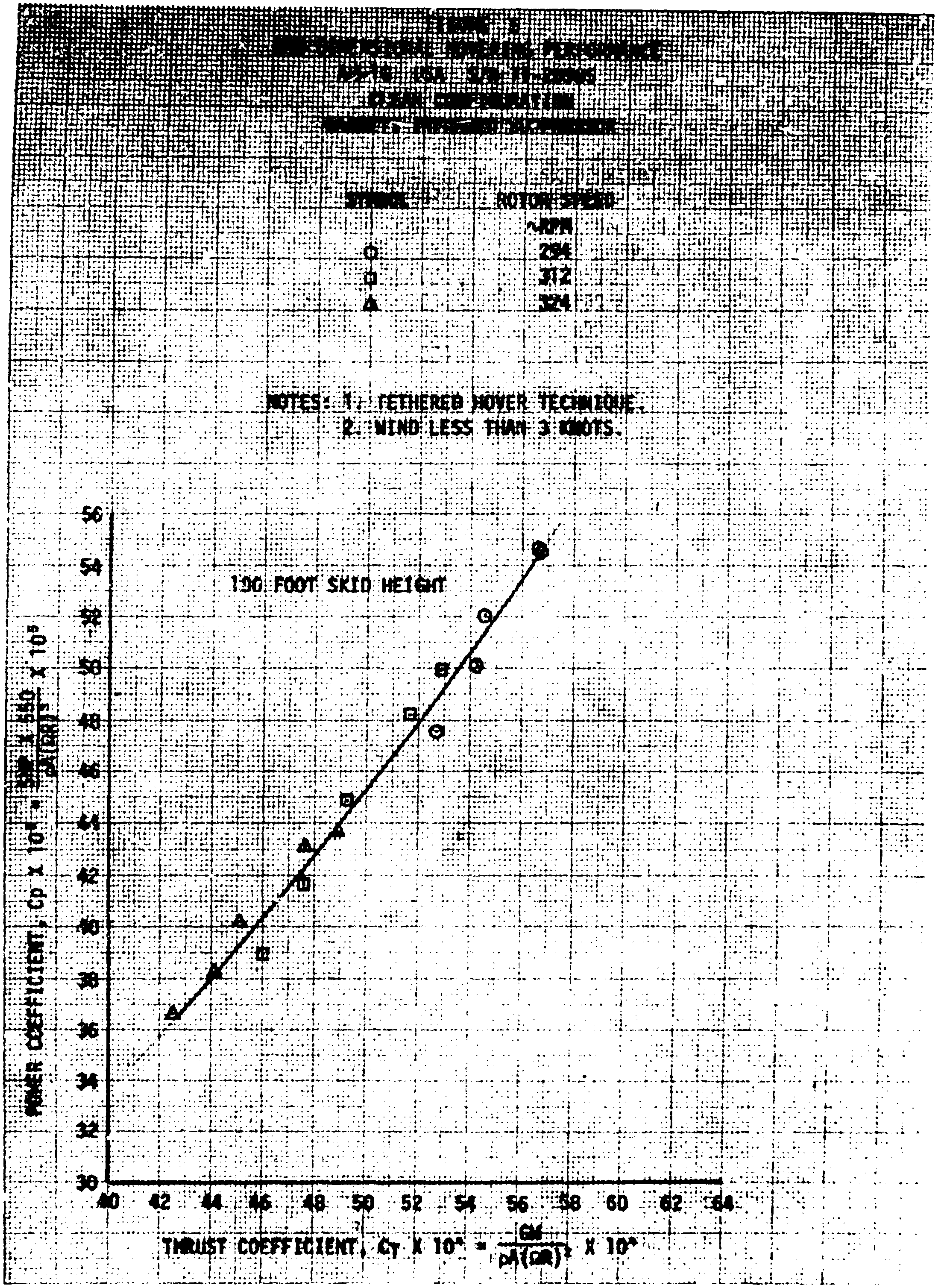
CLEAN CONFIGURATION

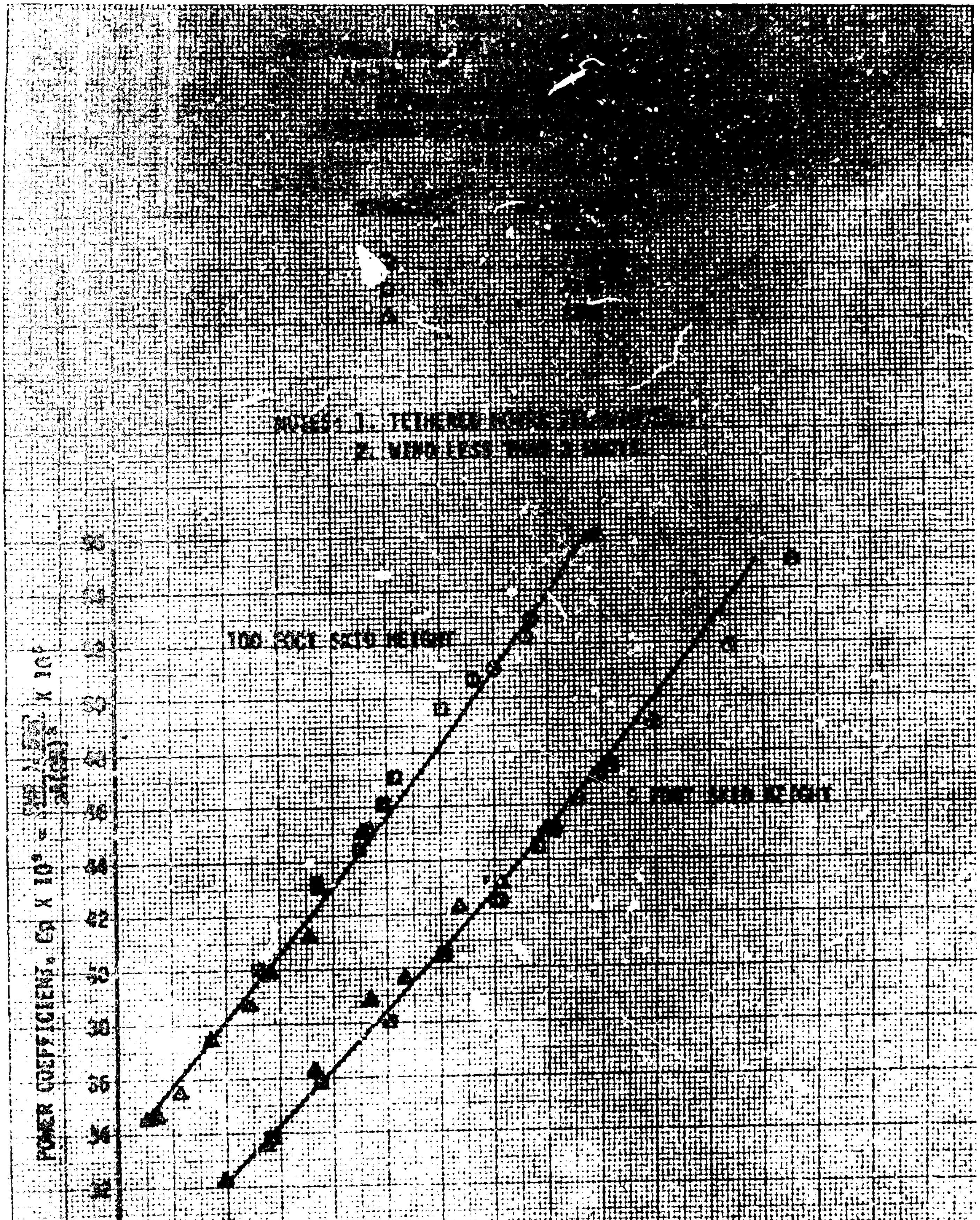
STANDARD EXHAUST DUCT

SYMBOL	ROTOR SPEED ~RPM
○	295
□	315
△	325

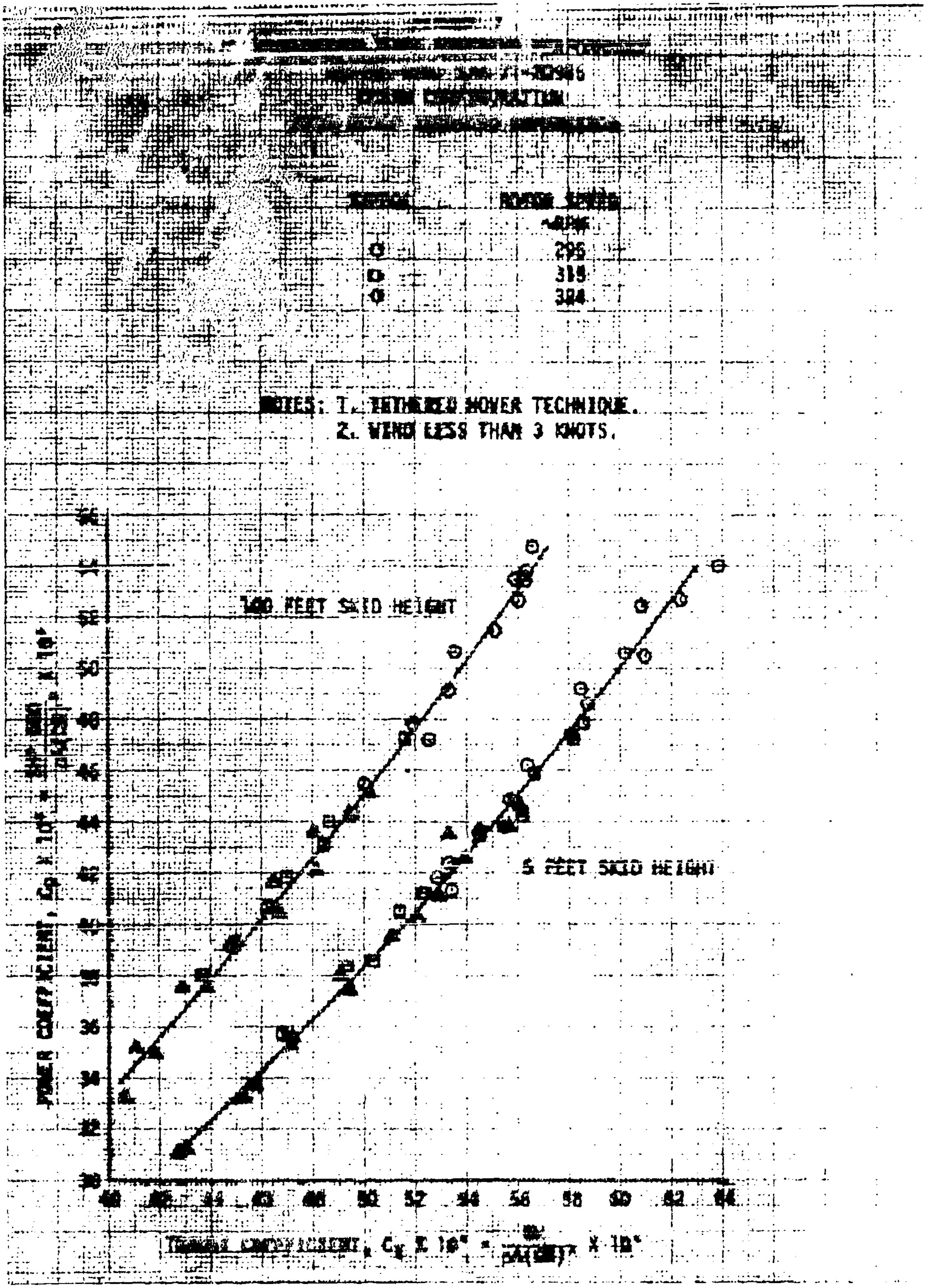
NOTES: 1. TETHERED HOVER TECHNIQUE.
2. WIND LESS THAN 3 KNOTS.

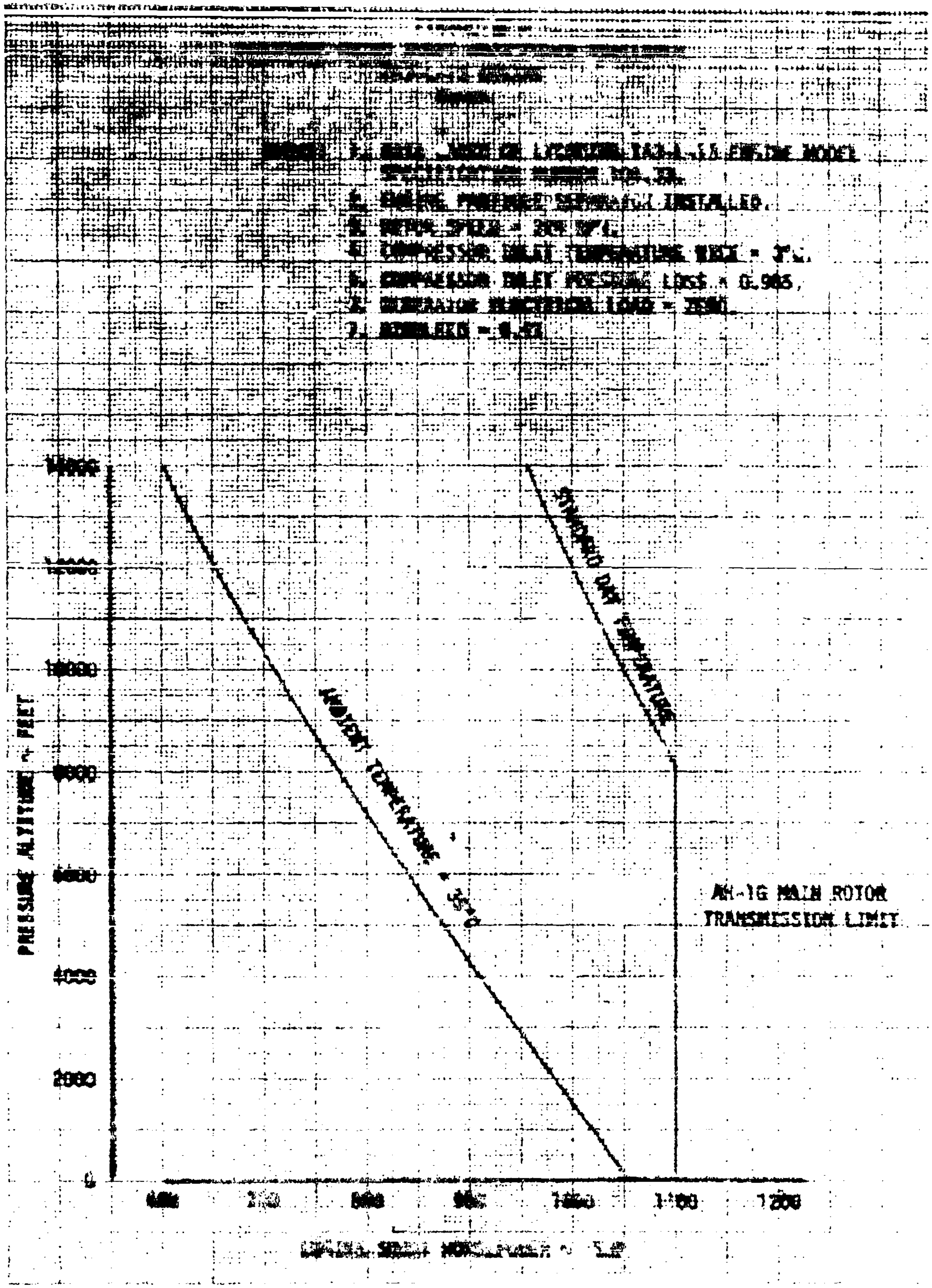



SYMBOL
ROTOR SPEED
~RPM
294
312
324
NOTES: 1. TETHERED HOVER TECHNIQUE.
2. WIND LESS THAN 3 KNOTS.
100 FOOT SKID HEIGHT
56
54
52
50
48
46
44
42
40
38
36
34
32
30
40
42
44
46
48
50
52
54
56
58
60
62
64
THRUST COEFFICIENT, CT X 10^4 = GW / ρA(ΩR)² X 10^4

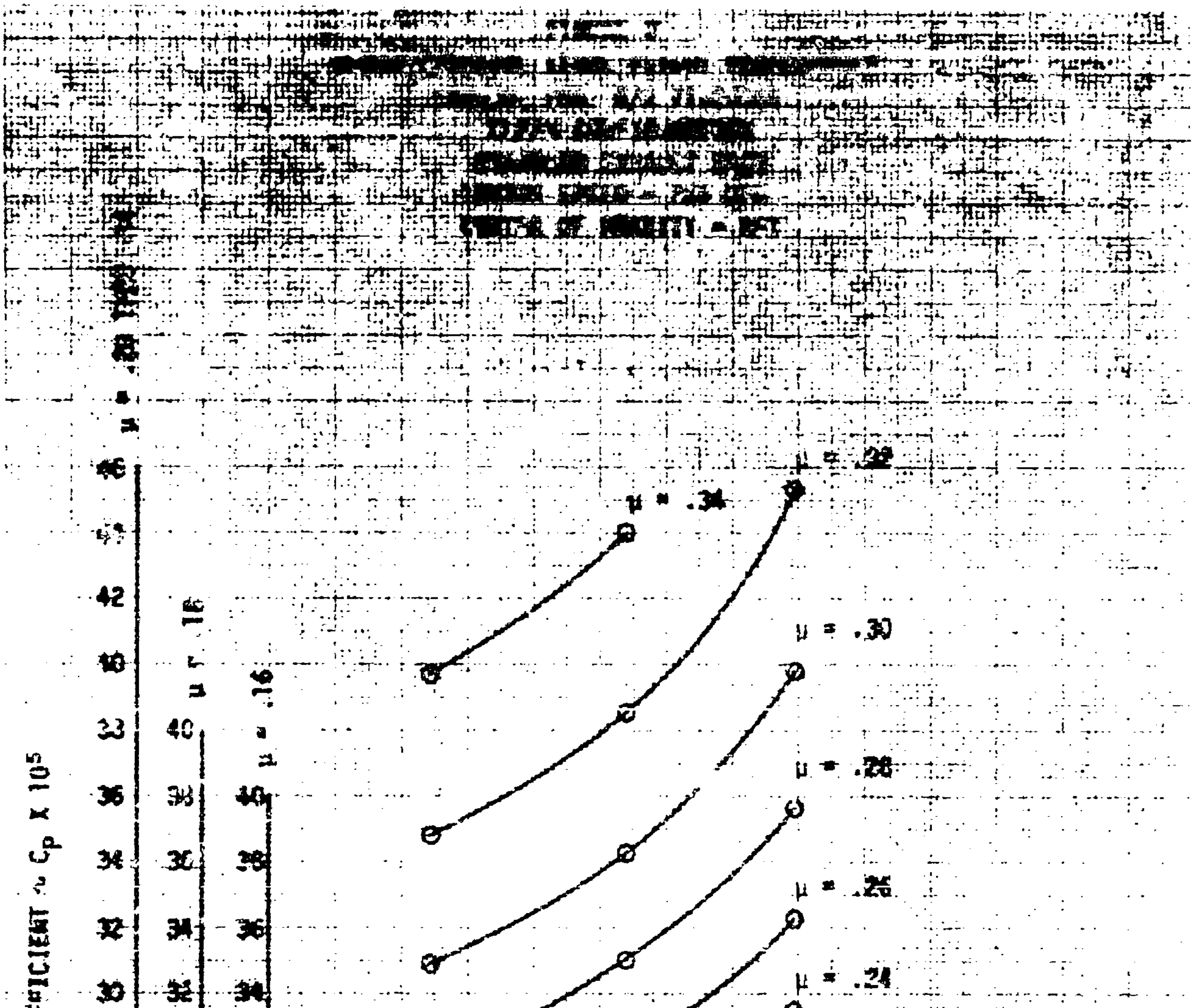


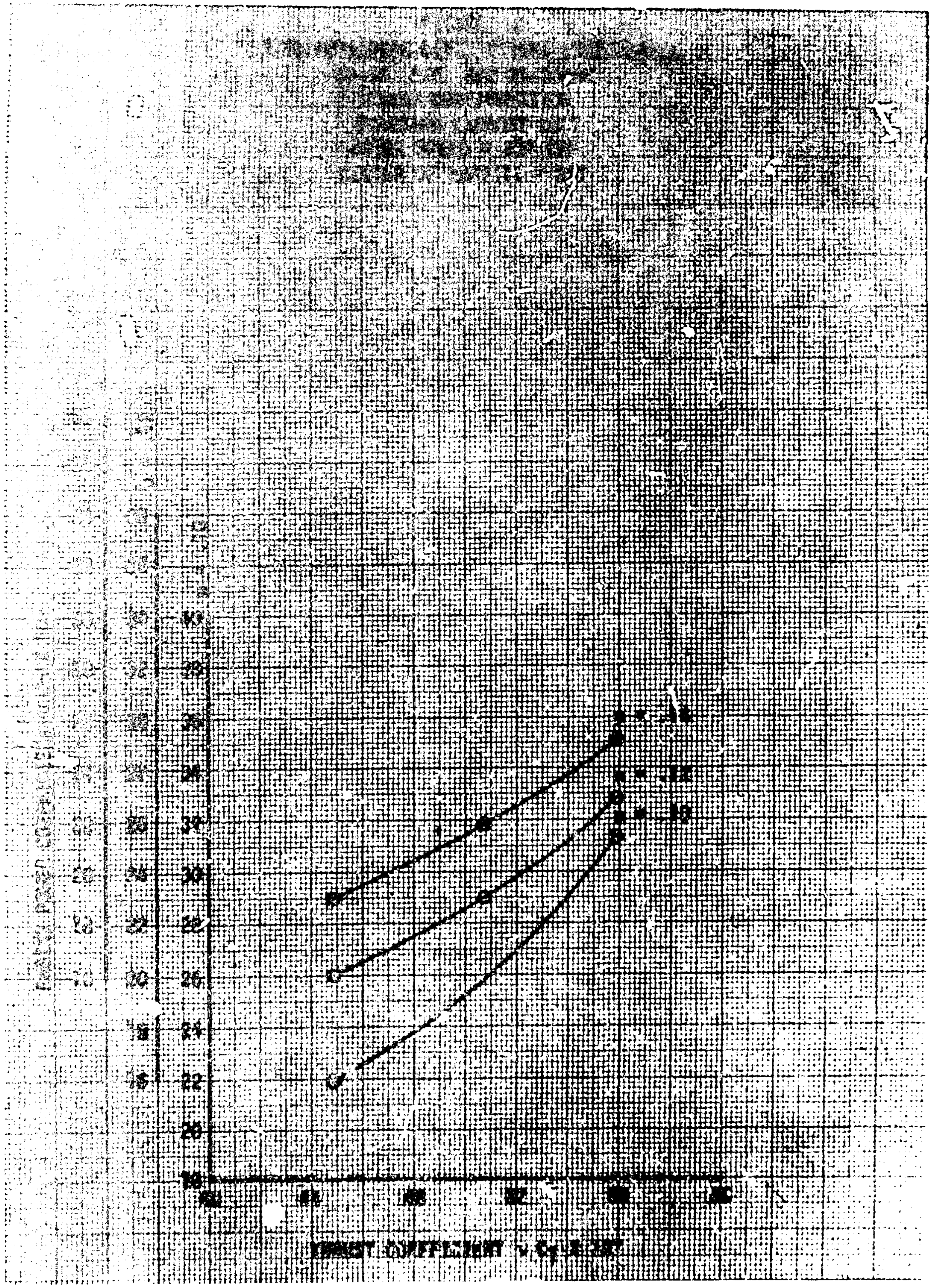
POWER COEFFICIENT, CP X 10
THRUST COEFFICIENT, CT X 10

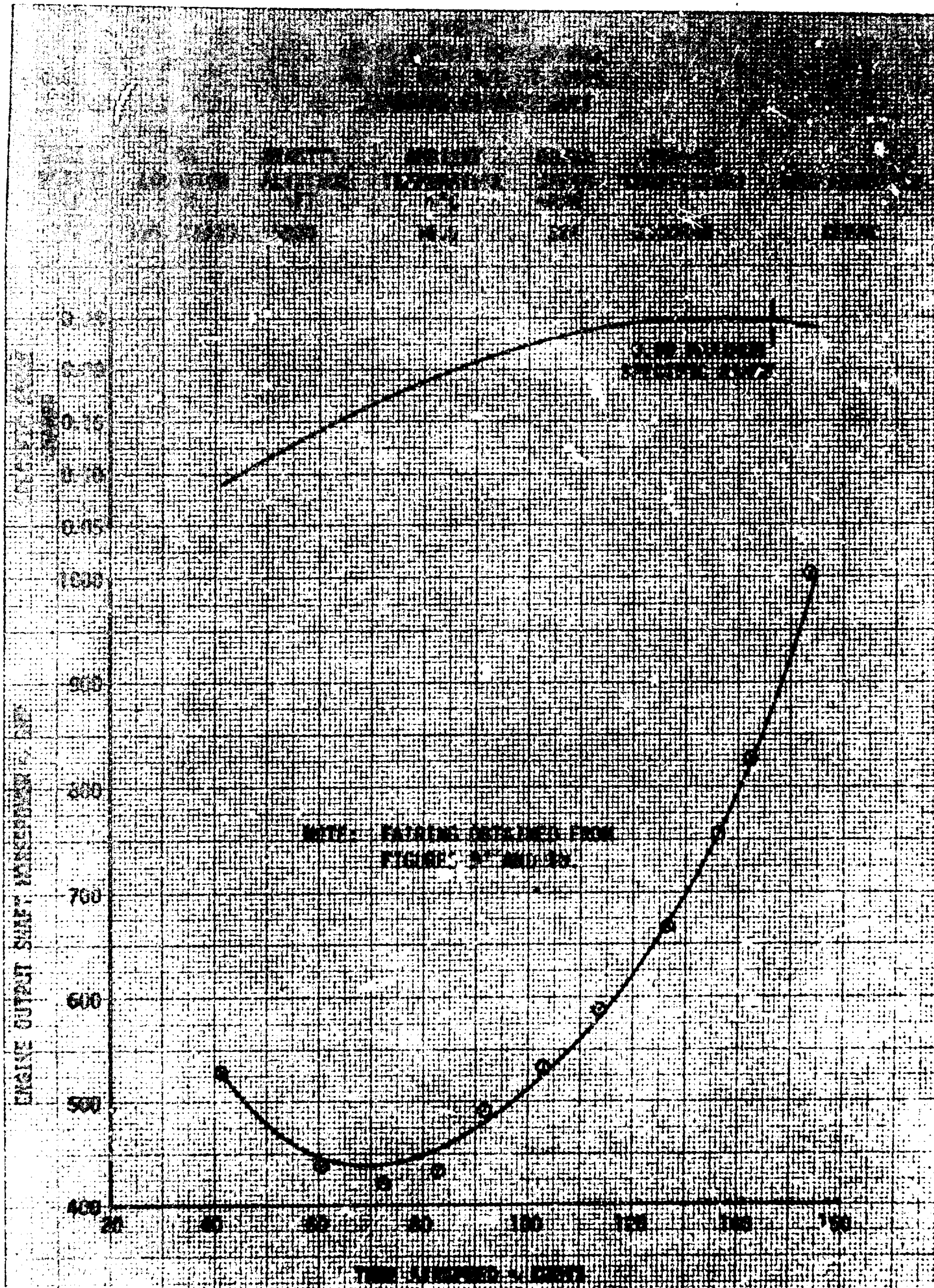

NOTES: 1. TETHERED HOVER TECHNIQUE.
2. WIND LESS THAN 3 KNOTS.
100 FEET SKID HEIGHT
5 FEET SKID HEIGHT
POWER COEFFICIENT, C_P X 10^4
THRUST COEFFICIENT, C_T X 10^4



INSTALLED.
LOSS = 0.985
STANDARD DAY TEMPERATURE
AMBIENT TEMPERATURE
AH-1G MAIN ROTOR
TRANSMISSION LIMIT
PRESSURE ALTITUDE ~ FEET
10000
8000
6000
4000
2000
0
600
1000
1200


ENGINE POWER COEFFICIENT ~ C_p X 10^5
μ = .32
μ = .34
μ = .30
μ = .28
μ = .26
μ = .24
μ = .22
μ = .20
μ = .18
μ = .16





0.05
1000
900
800
700
600
500
400
20
40
60
80
100
120
140
160
ENGINE OUTPUT SHAFT HORSEPOWER

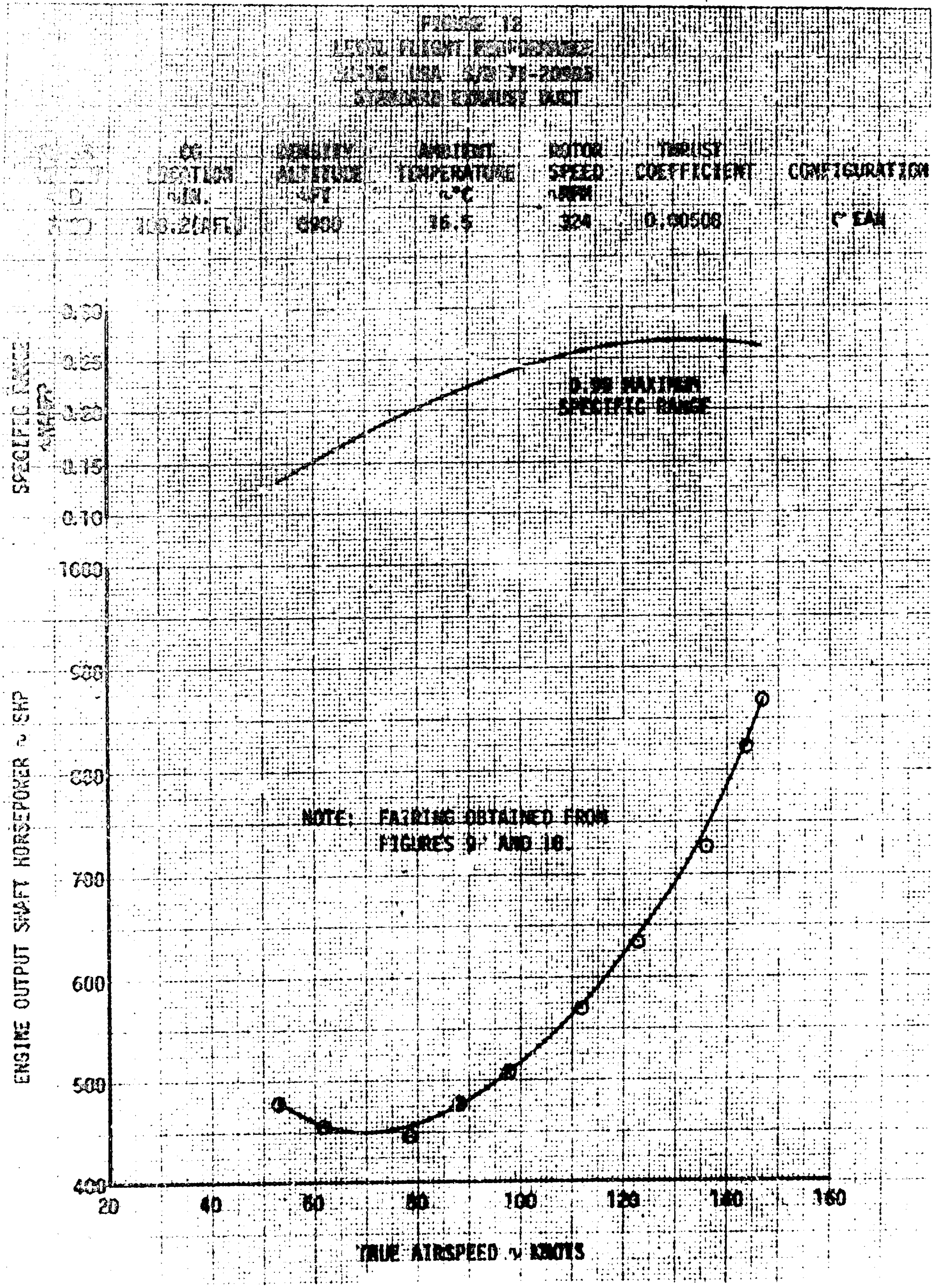
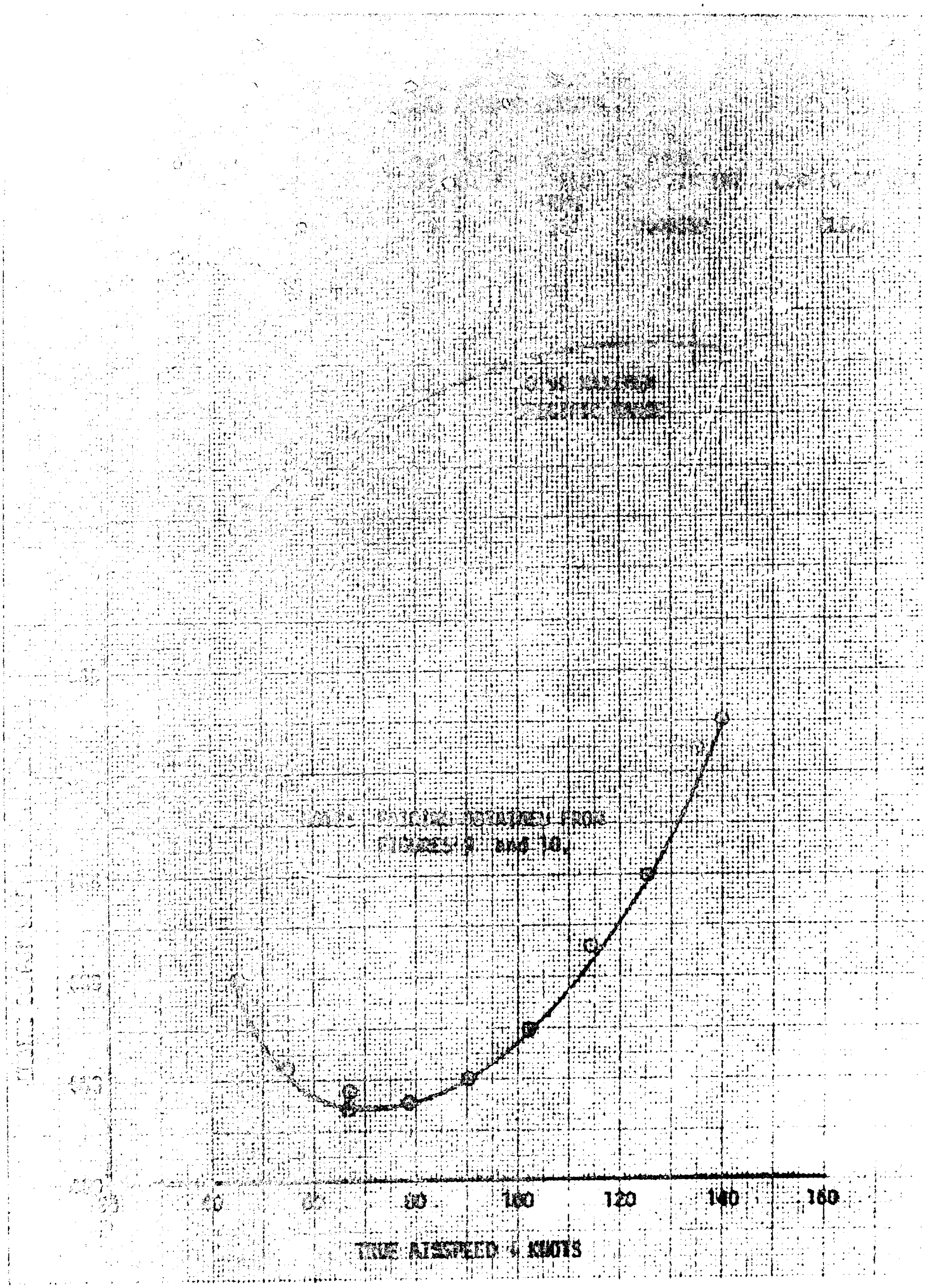
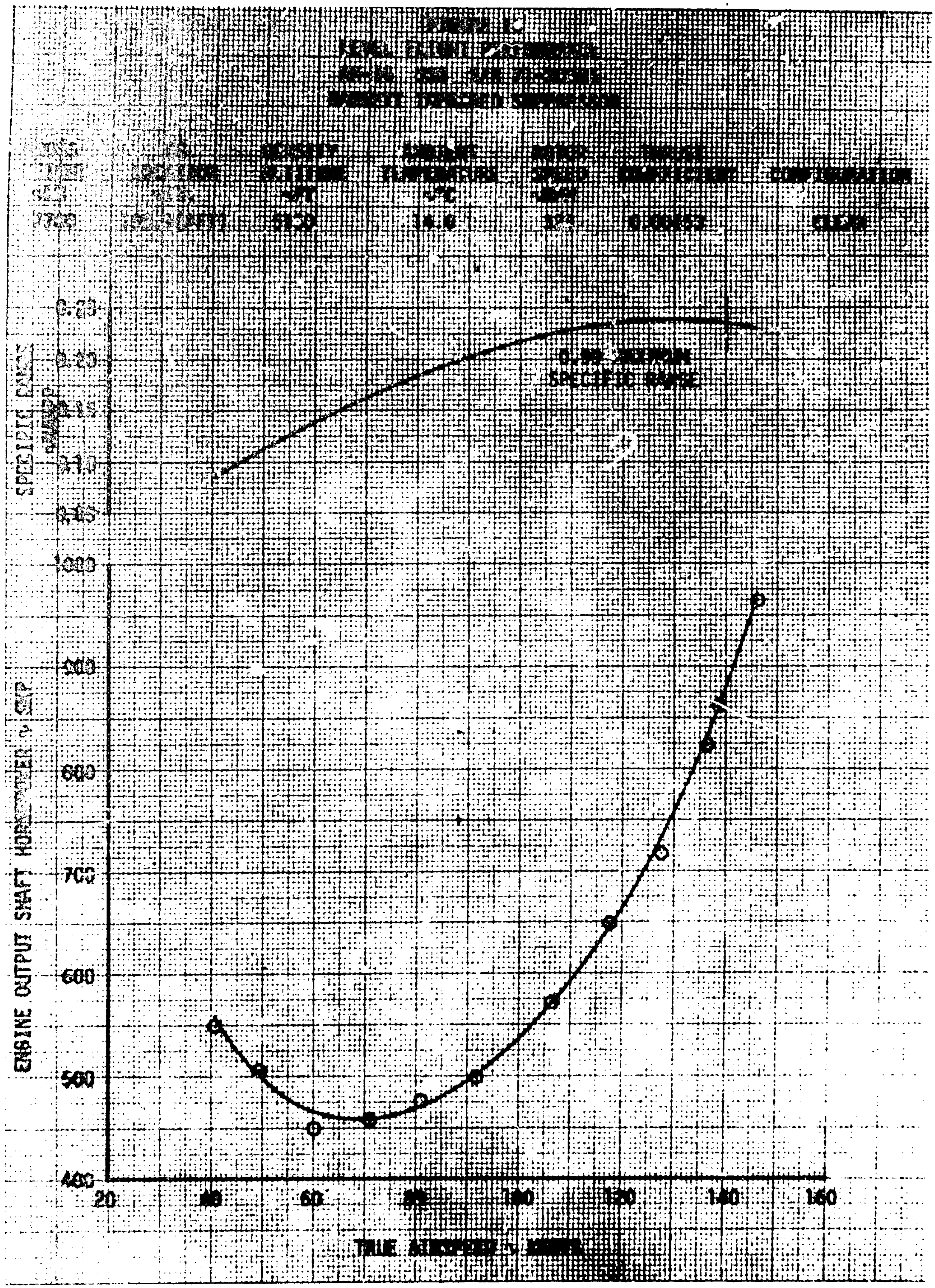
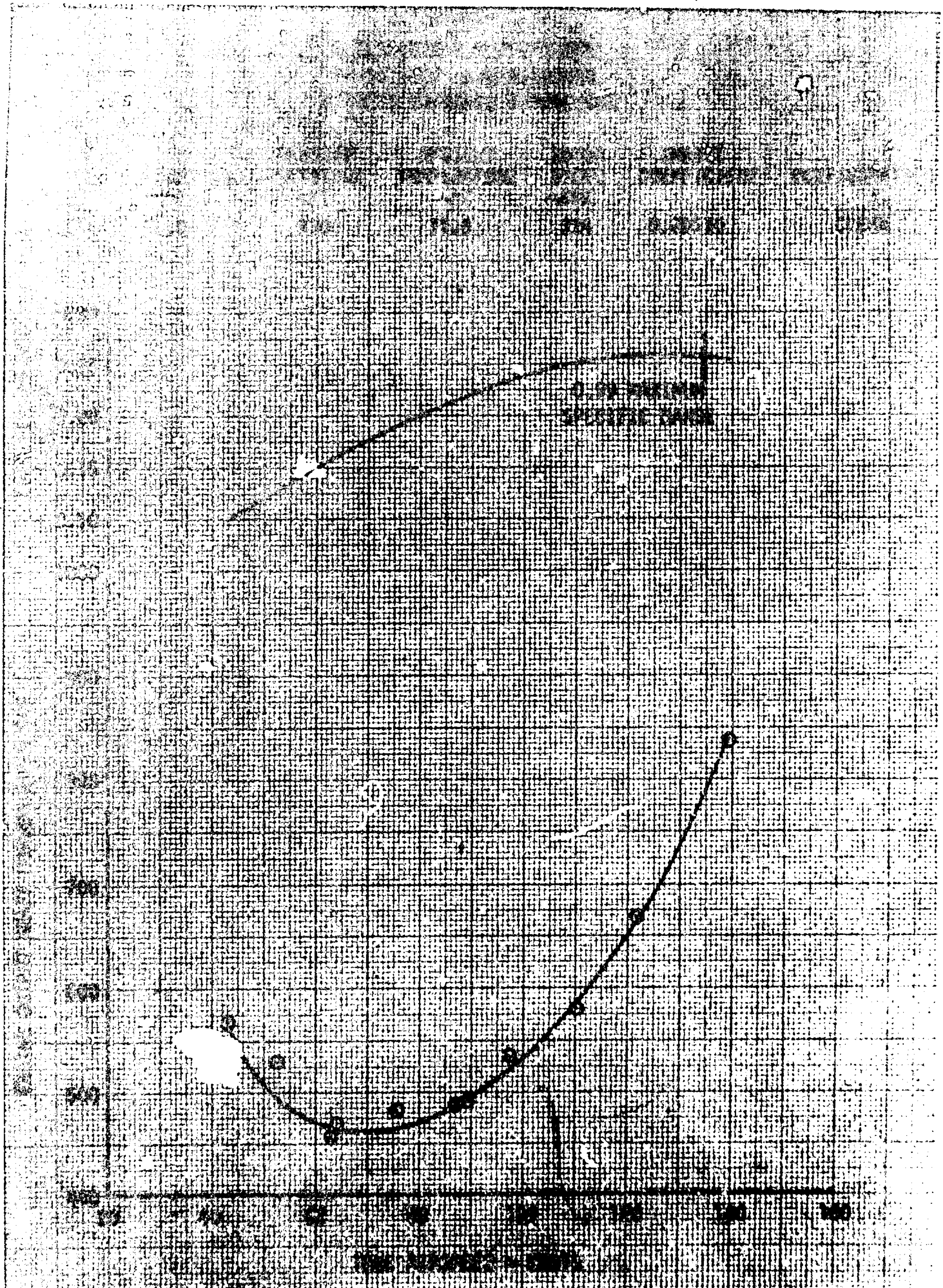
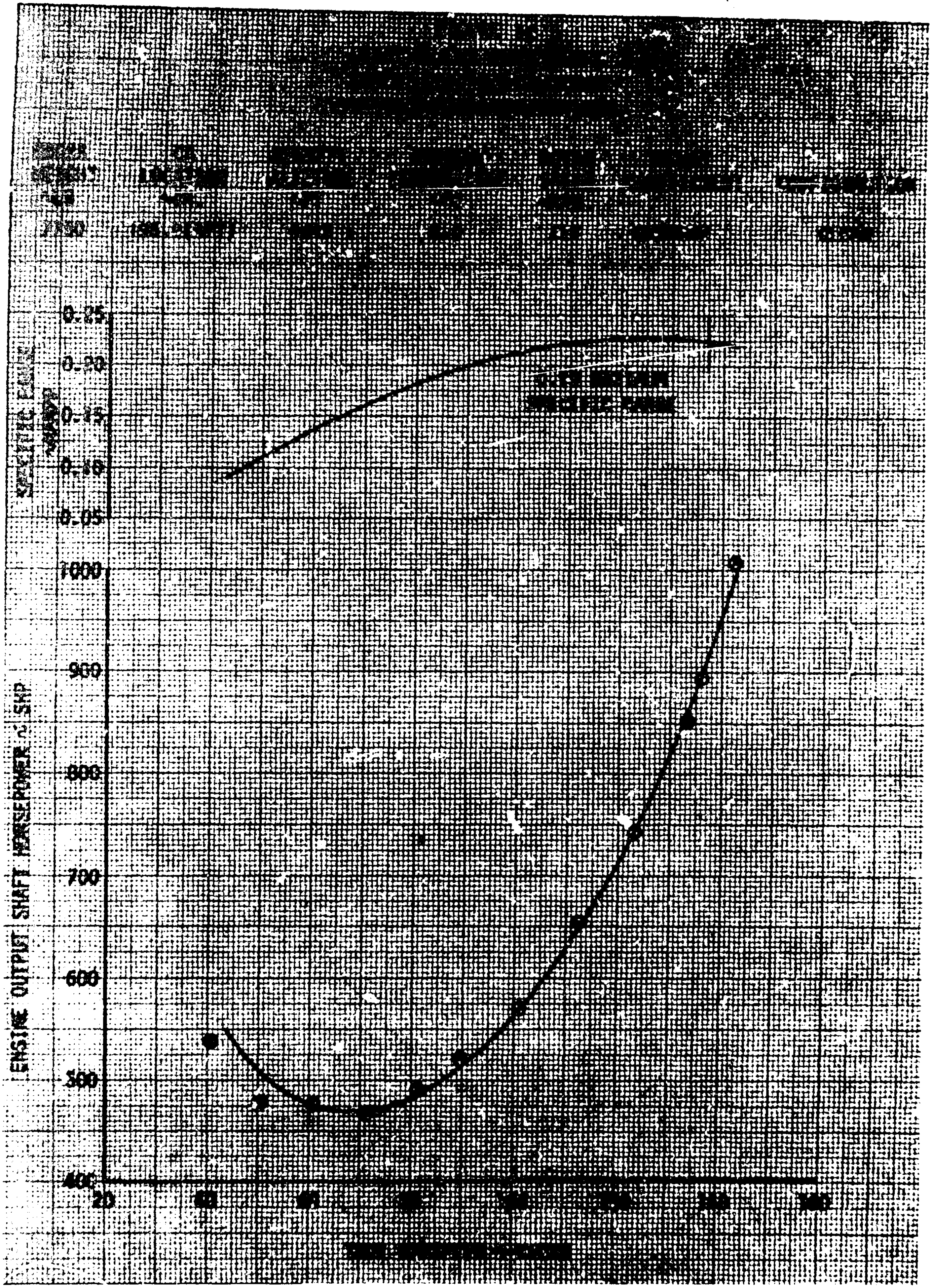


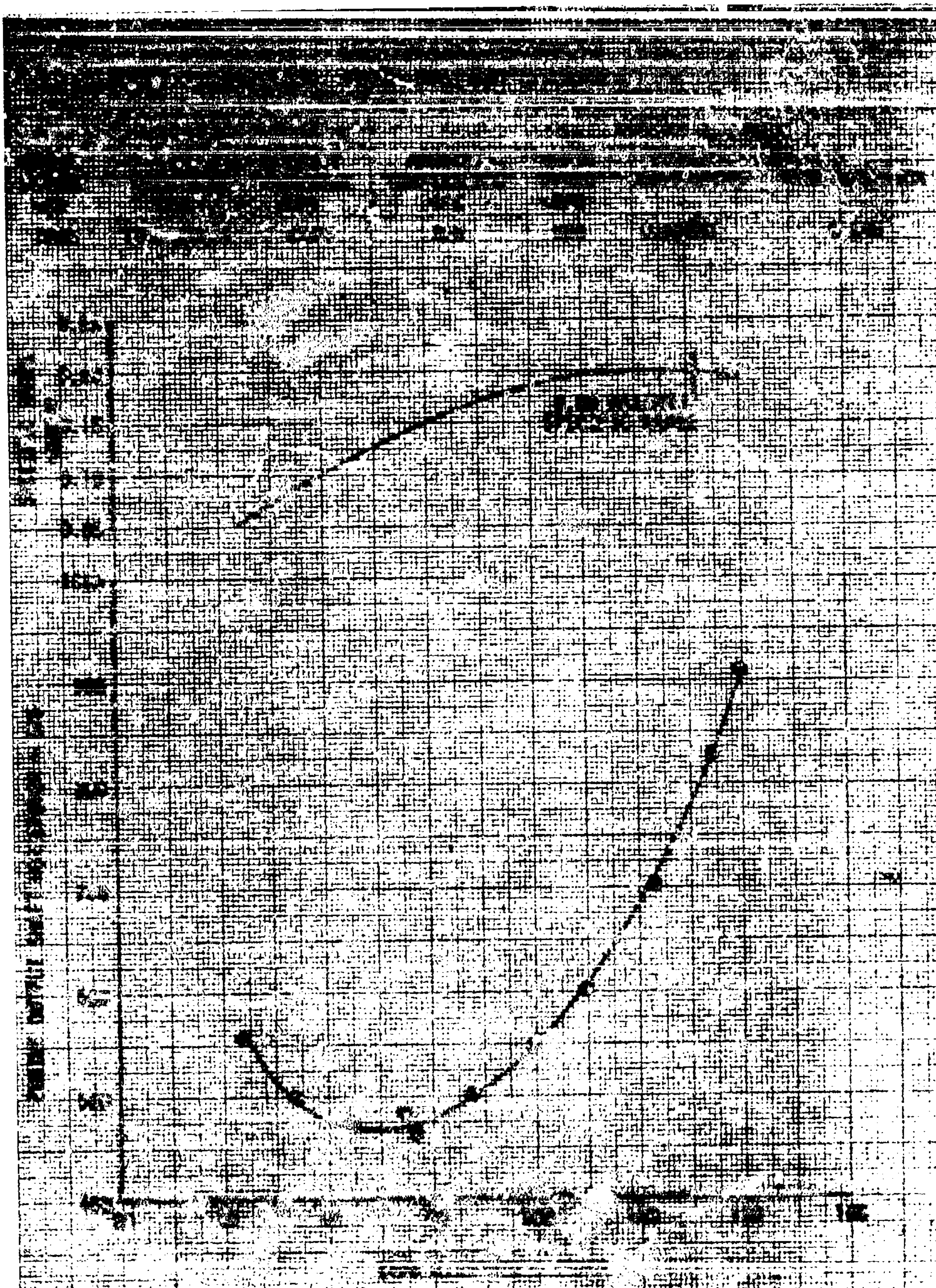
FIGURE 12
LEVEL FLIGHT PERFORMANCE
STANDARD EXHAUST DUCT
CG LOCATION ~IN.
DENSITY ALTITUDE ~FT
AMBIENT TEMPERATURE ~°C
ROTOR SPEED ~RPM
THRUST COEFFICIENT
CONFIGURATION
16.5
324
0.00508
0.99 MAXIMUM SPECIFIC RANGE
NOTE: FAIRING OBTAINED FROM FIGURES 9 AND 10.
SPECIFIC RANGE
ENGINE OUTPUT SHAFT HORSEPOWER ~ SHP
TRUE AIRSPEED ~ KNOTS
0.10
0.15
0.20
0.25
0.30
400
500
600
700
800
900
1000
20
40
60
80
100
120
140
160

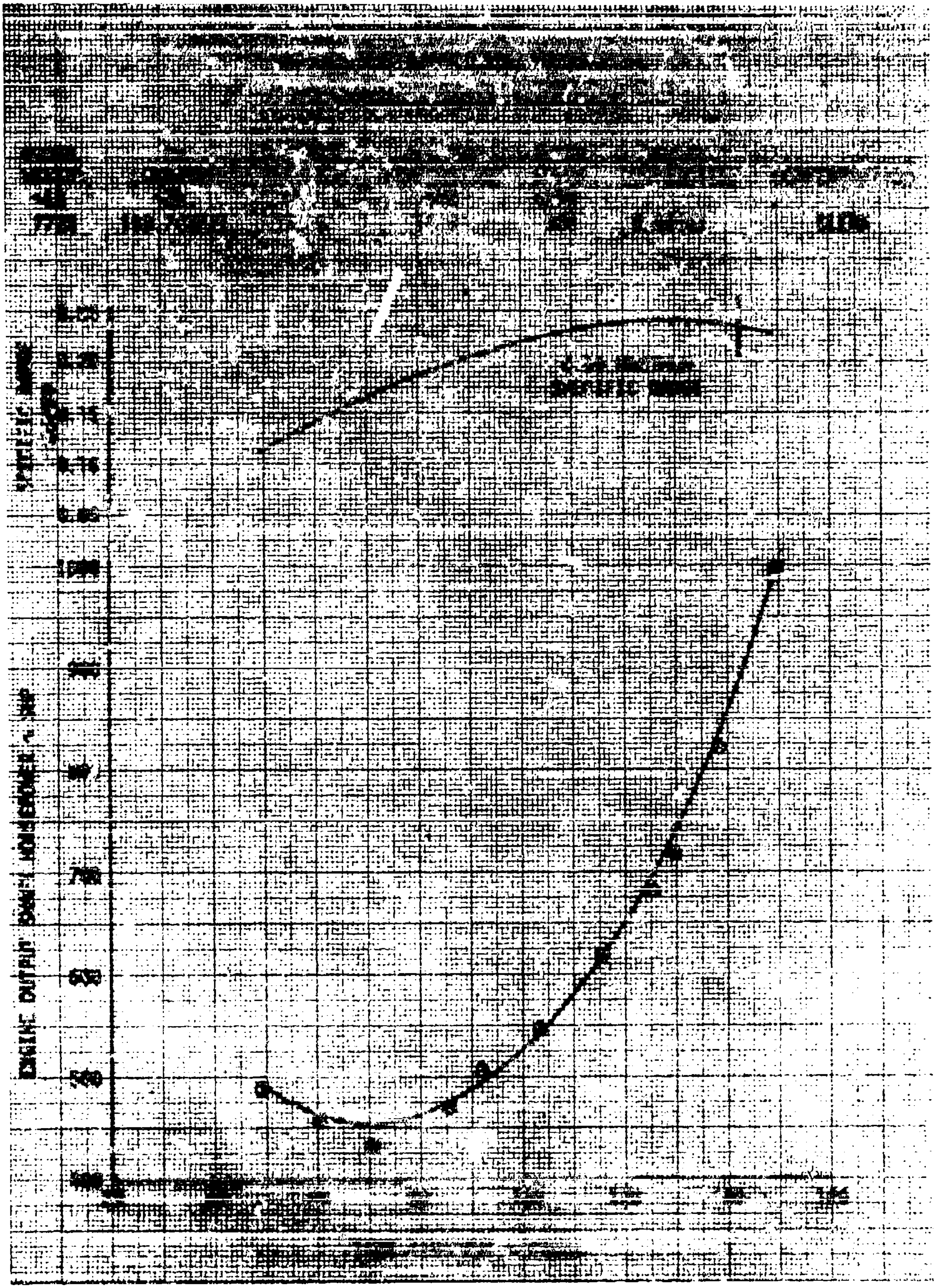

40
100
120
140
160
TRUE AIRSPEED ~ KNOTS


CONFIGURATION
CLEAN
SPECIFIC RANGE
0.10
0.05
ENGINE OUTPUT SHAFT HORSEPOWER ~ SHP
1000
700
600
500
400
20
40
60
80
100
120
140
160
TRUE AIRSPEED ~ KNOTS


0.99 MAXIMUM
SPECIFIC GRAVITY


ENGINE OUTPUT SHAFT HORSEPOWER ~ SHP
0.25
0.20
0.15
0.10
0.05
1000
900
800
700
600
500
400
20
40




ENGINE OUTPUT SHAFT HORSEPOWER

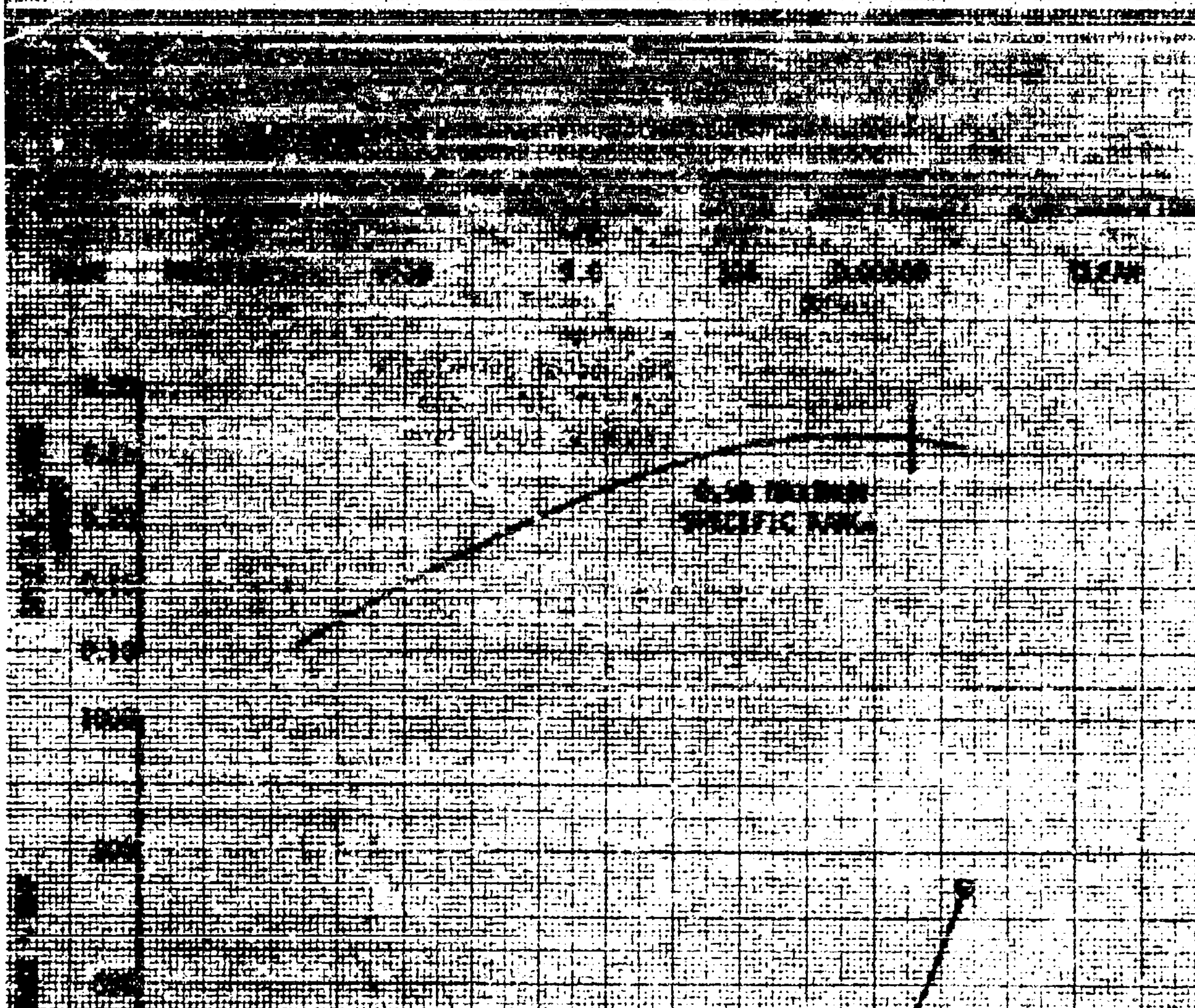


FIGURE 20
LEVEL FLIGHT PERFORMANCE COMPARISON
AH-1G USA S/N 71-20985

GROSS WEIGHT ~LB	CG LOCATION ~IN.	DENSITY ALTITUDE ~FT	AMBIENT TEMPERATURE ~°C	ROTOR SPEED ~RPM	THRUST COEFFICIENT	CONFIGURATION
9500	190.6(AFT)	SEA LEVEL	15.0	324	0.00478	CLEAN

LEGEND — EXHAUST DUCT

- STANDARD
- BELL SCOOP SUPPRESSOR
- GARRETT SUPPRESSOR
- LYCOMING SUPPRESSOR

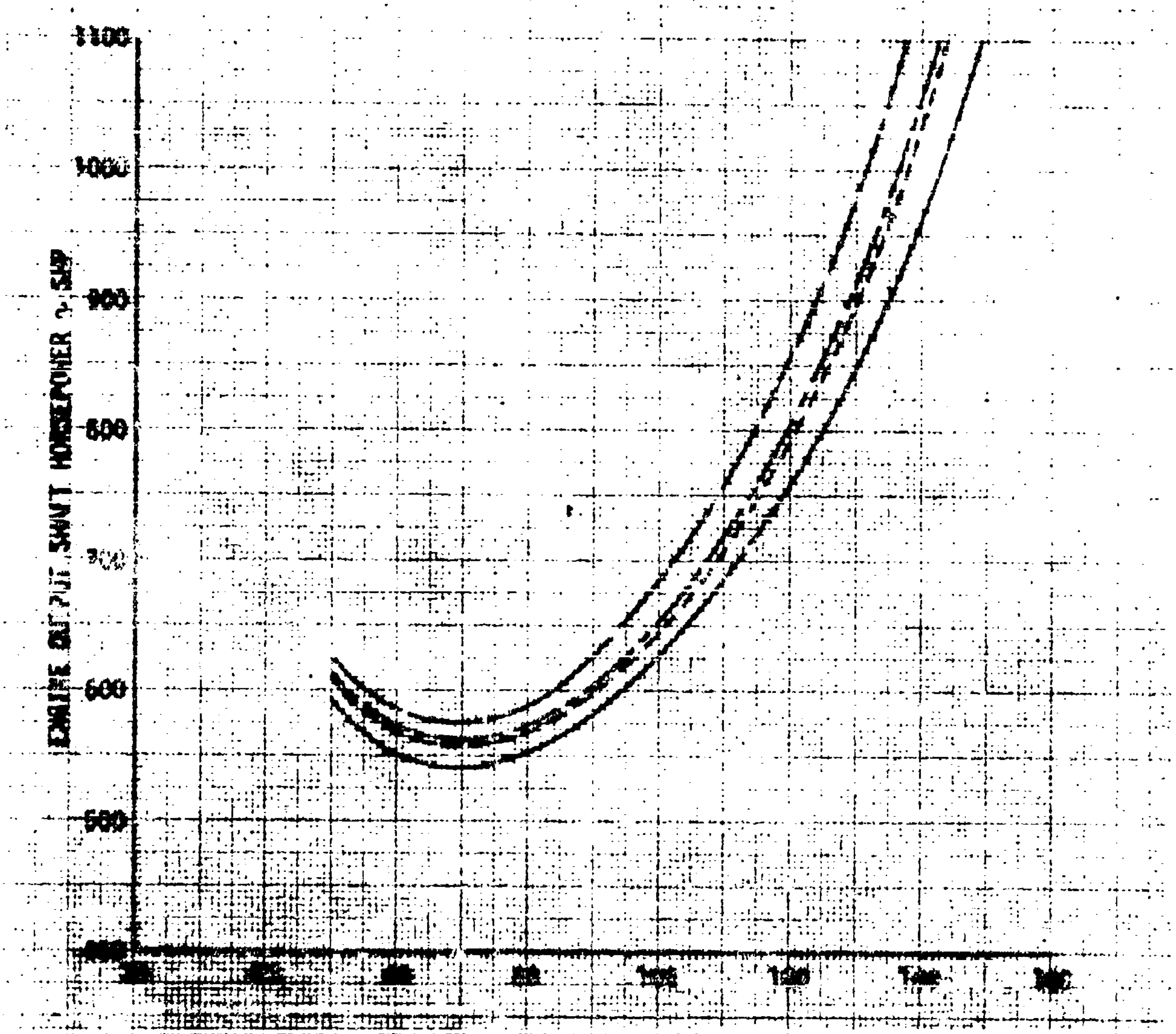


FIGURE [illegible]

[illegible] ENGINE CHARACTERISTICS

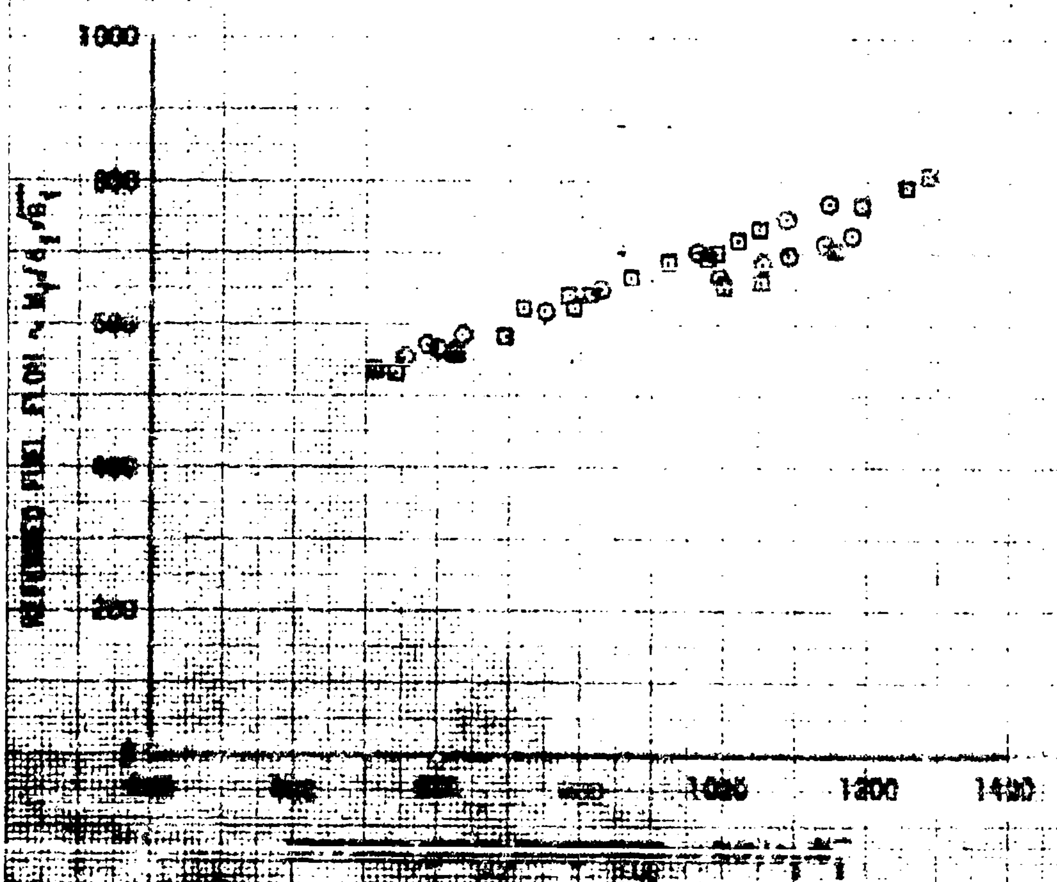
[illegible] S/N 71-[illegible]

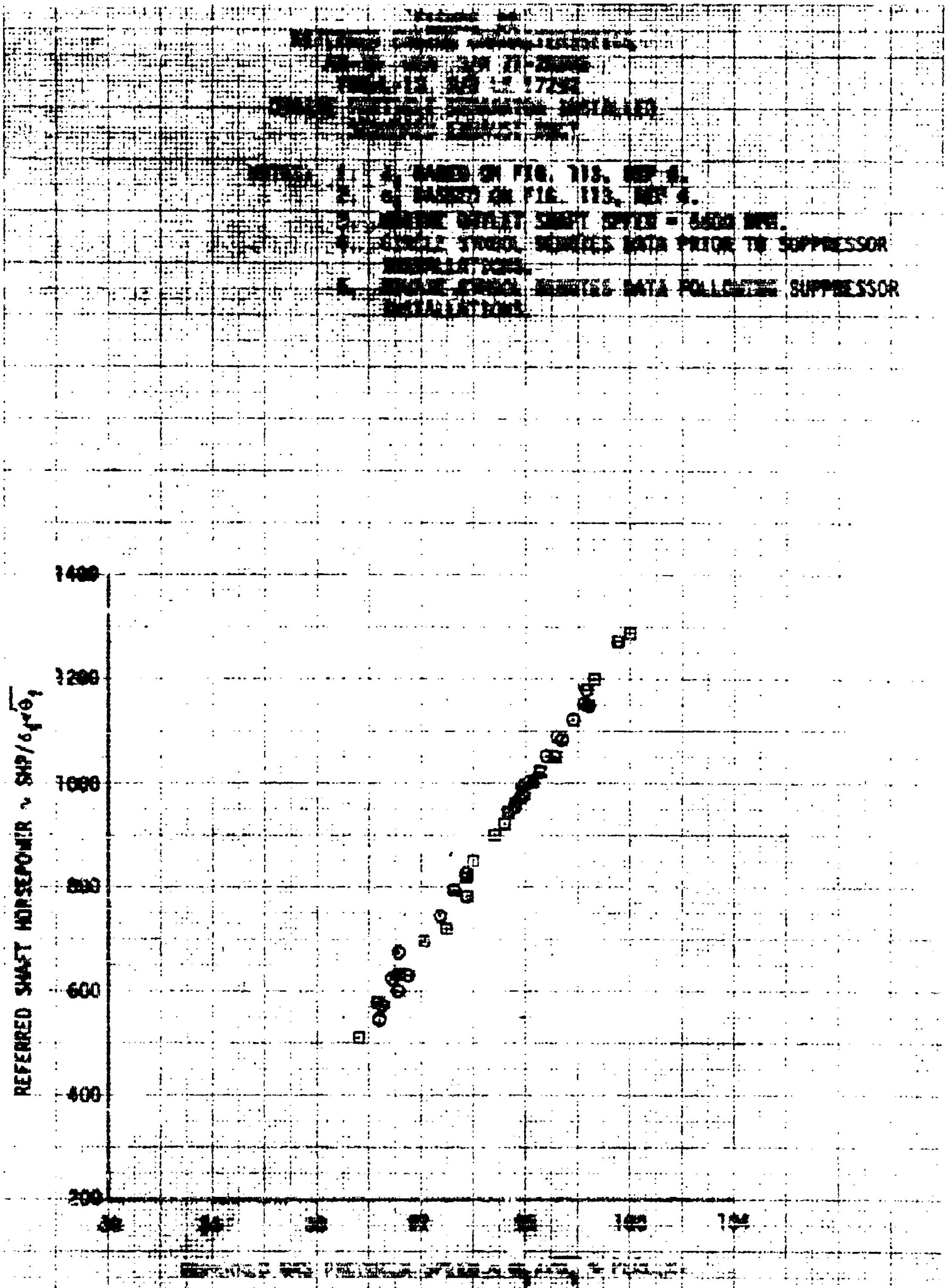
T63-[illegible] S/N LE [illegible]

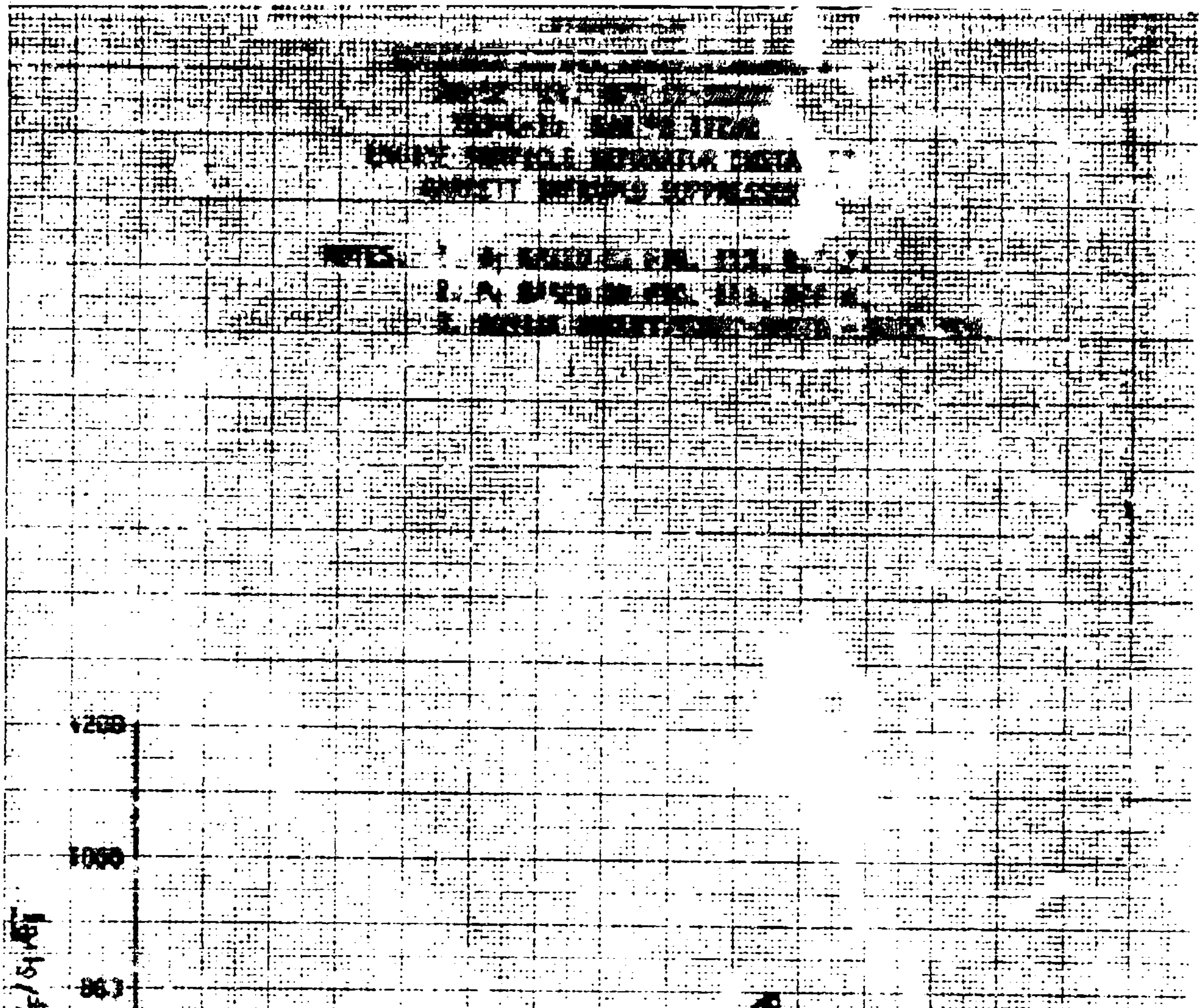
[illegible] PARTICLE SEPARATOR INSTALLED

STANDARD EXHAUST DUCT

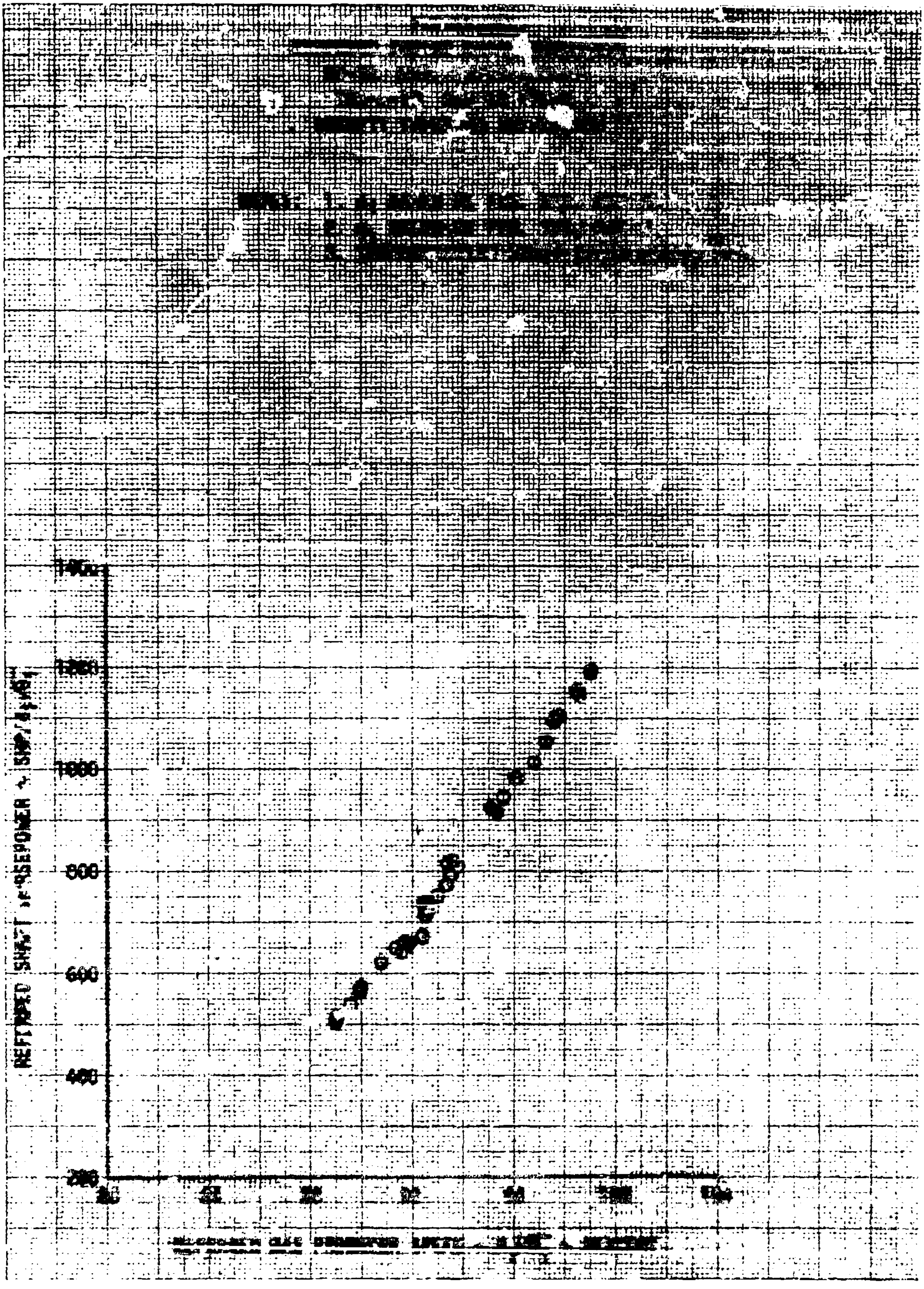
NOTES:
1. δ_1 BASED ON FIG. 113, REF [illegible].
2. θ_1 BASED ON FIG. 113, REF [illegible].
3. ENGINE OUTPUT SHAFT SPEED = [illegible] RPM.
4. CIRCLE SYMBOL DENOTES DATA PRIOR TO SUPPRESSOR TESTS.
5. SQUARE SYMBOL DENOTES DATA FOLLOWING SUPPRESSOR TESTS.

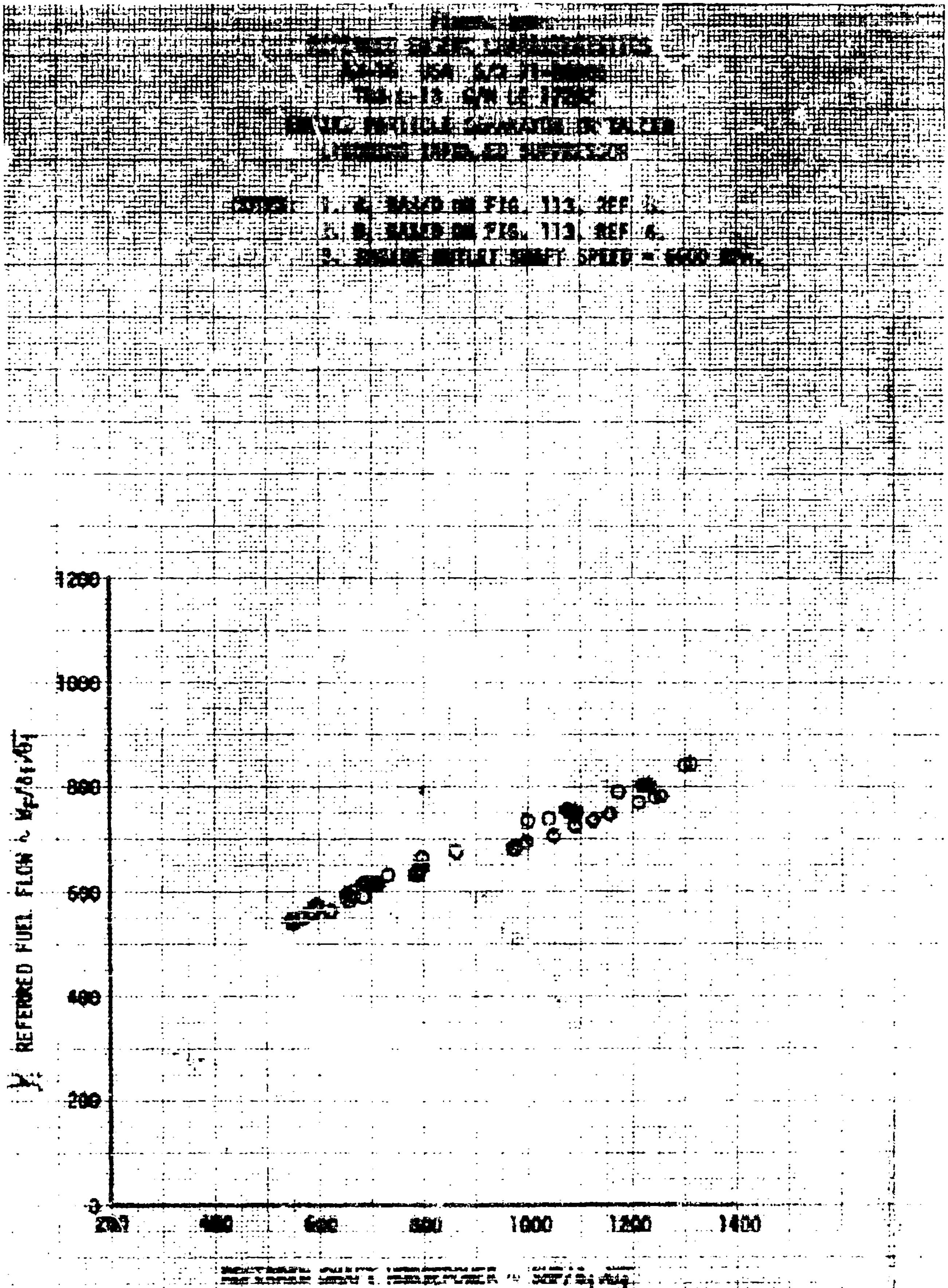



SUPPRESSOR
INSTALLATIONS.
SUPPRESSOR
REFERRED SHAFT HORSEPOWER ~ SHP/$\delta_1\sqrt{\theta_1}$
1400
1200
1000
800
600
400
200
100

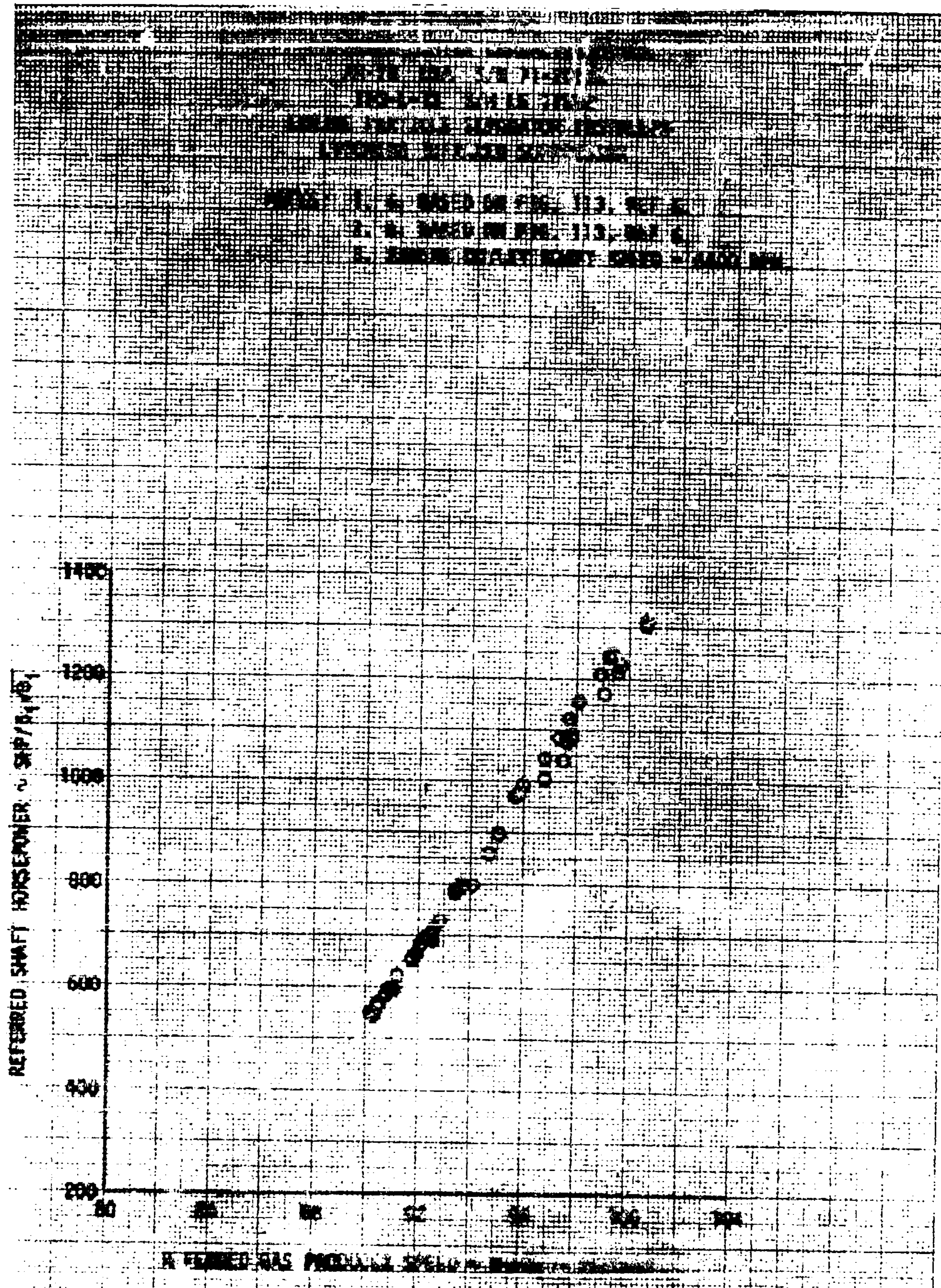


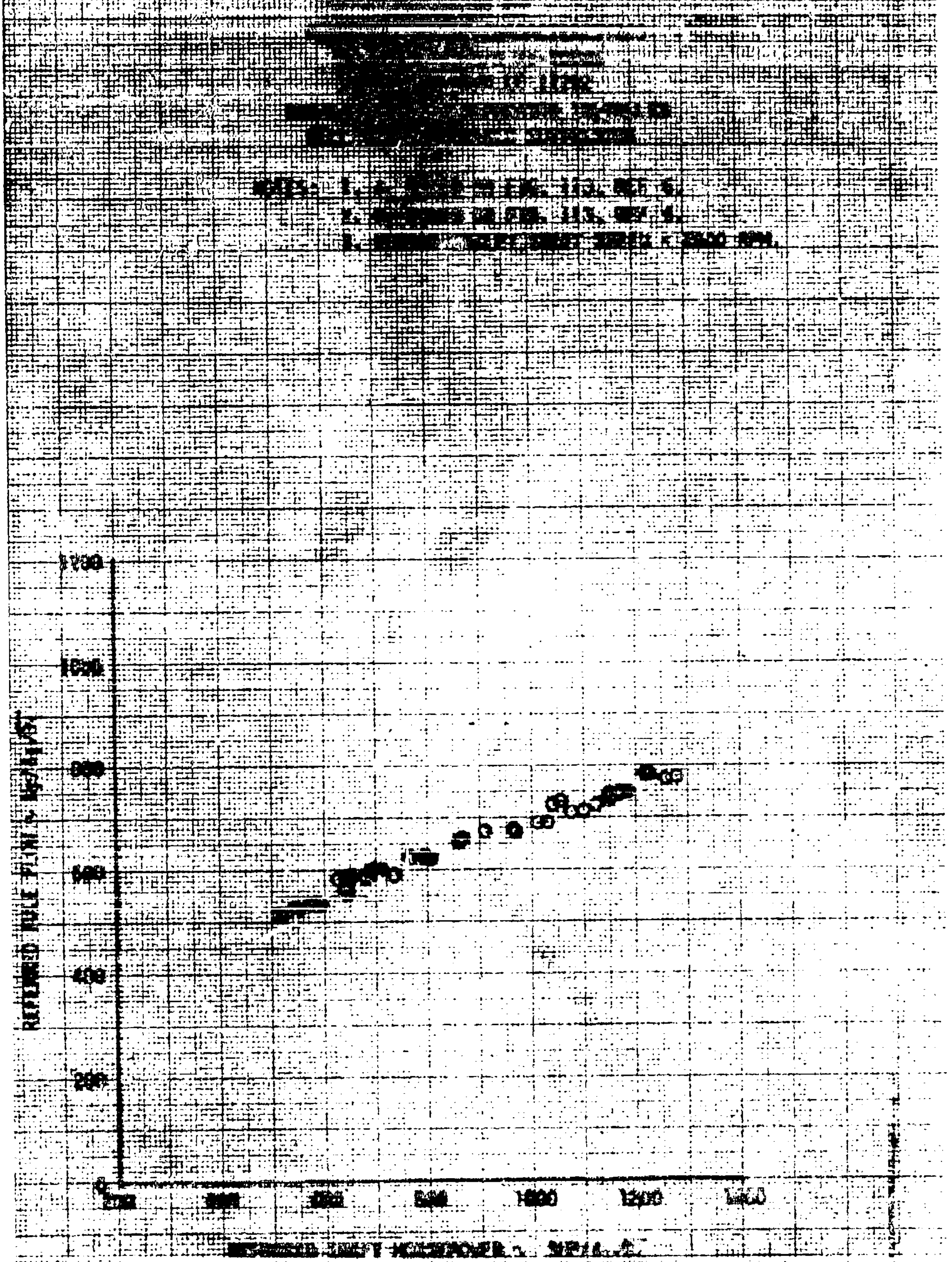
REFERRED FUEL FLOW
0
1000
1200


1400
1200
1000
800
600
400
200



REFERRED FUEL FLOW
0
200
400
600
800
1000
1200
1400


1400
1200
1000
800
600
400
200
80
REFERRED SHAFT HORSEPOWER ~ SHP/$\delta_1\sqrt{\theta_1}$


400
200
1000
1200