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USAAEFA PROJECT NO. 82-14

PRELIMINARY AIRWORTHINESS EVALUATION OF THE UH-60A CONFIGURED WITH THE EXTERNAL STORES SUPPORT SYSTEM (ESSS)

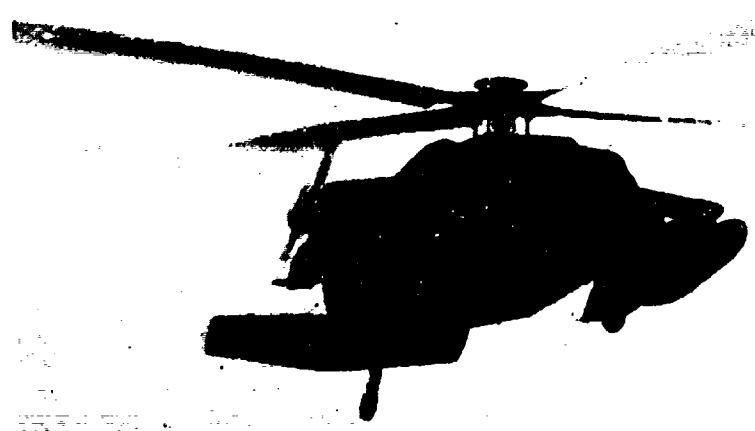
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MARCH 1983
FINAL REPORT



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UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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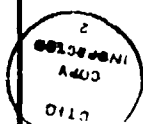
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drag of the UH-60A helicopter caused by three External Stores Support System configurations with various stores installed. An unexplained increase in power required was found between the Preliminary Airworthiness Evaluation test aircraft and the aircraft used during a previous Airworthiness and Flight Characteristics evaluation. The maximum range for the self deployment ferry mission was determined by US Army Aviation Research and Development Command using the power required obtained from this report to be 1176 nautical miles in the original External Stores Support System with four tanks configuration. This exceeded the 1150 nautical mile requirement for the self deployment ferry mission described in the Material Need Document.

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DRDAV-D

DEPARTMENT OF THE ARMY
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SUBJECT: Directorate for Development and Qualification Position on the Final Report of USAAEFA Project No. 82-14, Preliminary Airworthiness Evaluation of the UH-60A Configured with the External Stores Support System (ESSS)

SEE DISTRIBUTION

1. The purpose of this letter is to establish the Directorate for Development and Qualification position on the subject report. In addition to documenting the test results of the subject evaluation, this report also identifies a significantly higher and unexplained increase in power required for the test aircraft as compared to the results of the Airworthiness and Flight Characteristics (A&FC) evaluation, USAAEFA Project No. 77-17.
2. The self deployment range for the UH-60A equipped with the ESSS, 4 fuel tank configuration has been calculated by this Directorate. The calculations are based on the test data of this report (used to increment the A&FC baseline) and show that the UH-60A range is 1176 nautical miles with the standard ESSS 4 tank configuration and 1207 nautical miles with the ESSS 4 tank configuration with the modified vertical pylon fairings. The unexplained power required increase found for the subject test aircraft over the power required measured for the aircraft used during the A&FC test has not been used to increment the baseline during the range calculations. The ground rules for the range calculations are 10 knots headwind and 10% mission fuel reserve as quoted in the BLACK HAWK Material Need Document (Reference 1 in report). Based on the fact that the calculations indicate the South Atlantic route can be flown with the standard ESSS, this Directorate has recommended to the Project Manager that the modified fairings for the vertical pylons not be procured.
3. This Directorate agrees with the conclusions stated in this report. There were no reported shortcomings or deficiencies associated with this evaluation. An evaluation has been tentatively planned for performance testing of a UH-60A, with production ESSS fixed provisions, to be done at USAAEFA.

FOR THE COMMANDER:

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as



CHARLES C. CRAWFORD, JR.
Director of Development
and Qualification

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INTRODUCTION

BACKGROUND

1. The United States Army has stated a requirement for a self deployment capability for the UH-60A helicopter. Sikorsky Aircraft (SA) Division of United Technologies has designed the External Stores Support System (ESSS) to satisfy this requirement. Specific self deployment mission requirements are contained in the Material Need Document (ref 1, app A).

2. In November 1982 the United States Army Aviation Engineering Flight Activity was tasked by the United States Aviation Research and Development Command (AVRADCOM) (ref 2, app A) to plan, conduct, and report on the Preliminary Airworthiness Evaluation (PAE) of the UH-60A configured with the ESSS.

TEST OBJECTIVE

3. The objective of the PAE was to obtain limited level flight performance data for use by the AVRADCOM Directorate for Development and Qualification to determine if the UH-60A with the ESSS installed meets the self deployment capability requirement.

DESCRIPTION

4. The test helicopter, UH-60A Black Hawk US Army S/N 77-22714, was configured with the ESSS (photo 1). The ESSS for the Black Hawk consists of the airframe fixed provisions and the external stores subsystem. The external stores subsystem is comprised of a horizontal stores support, two support struts, and two vertical stores pylons for each side of the aircraft. The pylons are designed to accommodate 450 gallon fuel tanks at the inboard stations and 230 gallon fuel tanks at the outboard stations. All stores stations are designed to permit jettison of loads. A fuel transfer system was not installed in the test aircraft. A description of the standard UH-60A Black Hawk can be found in the operator's manual (ref 3, app A) and a more detailed description of the ESSS is included in appendix B.

TEST SCOPE

5. The PAE was conducted at the Sikorsky Flight Test Facility at West Palm Beach, Florida (elevation 28 feet) and consisted of level flight performance testing. A total of 26 flights were conducted between 4 December 1982 and 26 January 1983 for a total of 20.2 productive flight hours. SA calibrated and maintained

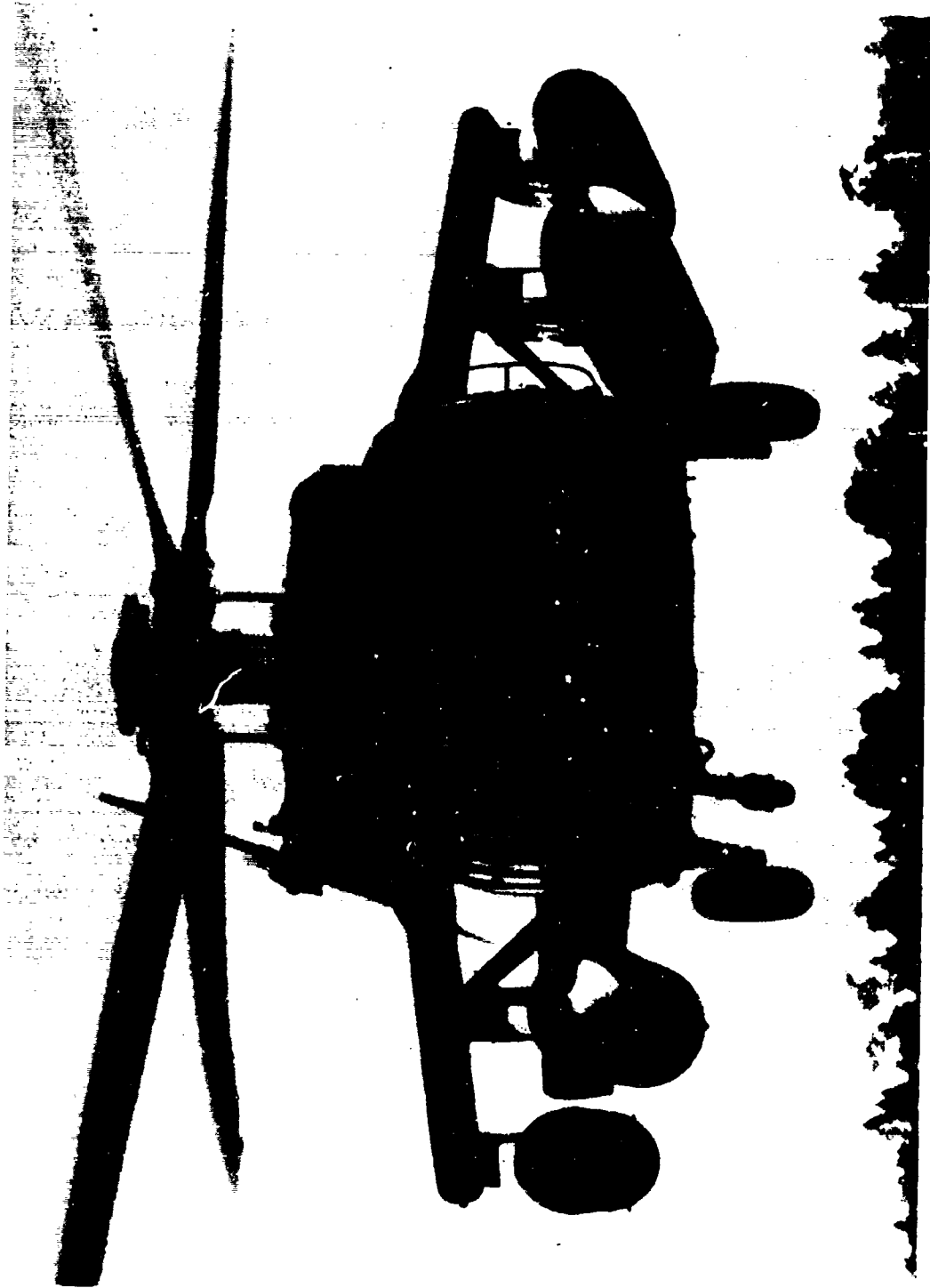


Photo 1. UH-60A in the Modified ESSS with Four Tanks Configuration

all test instrumentation and performed all required maintenance on the test helicopter. Flight restrictions and operating limitations observed during the PAE are contained in the operator's manual (ref 3, app A) and the airworthiness release (ref 4, app A). Testing was conducted in accordance with the test plan (ref 5, app A) at the conditions shown in table 1. These conditions were based on the requirements of the Material Need Document (ref 1, app A).

TEST METHODOLOGY

6. Flight test data were obtained from test instrumentation displayed on the instrument panel and recorded on magnetic tape installed in the aircraft. A detailed list of test instrumentation is contained in appendix C. Established flight test techniques and data analysis procedures used are described in appendix D.

Table 1. Level Flight Performance Test Conditions¹

| Configuration | Gross Weight Range (lb) | Average Longitudinal Center of Gravity (FS) | Density Altitude Range (ft) | Calibrated Airspeed Range (KT) | Thrust Coefficient Range ($\times 10^4$) |
|--|-------------------------|---|-----------------------------|--------------------------------|--|
| Fixed Provisions ² | 16,040 to 18,000 | 347.0 | 6580 to 7680 | 30 to 147 | 70.20 to 80.14 |
| Original ESSS with No Stores ³ | 16,080 and 17,960 | 347.0 | 6740 and 7300 | 38 to 137 | 70.20 and 80.32 |
| Original ESSS with Two Tanks ³ | 17,900 to 21,880 | 347.0 | 7660 to 5120 | 36 to 140 | 70.14 to 90.18 |
| Original ESSS with Four Tanks ³ | 17,960 and 24,560 | 343.0 | 1380 and 10,740 | 31 to 121 | 90.15 and 90.61 |
| | 16,000 to 17,960 | 350.0 | 6540 to 10,740 | 29 to 131 | 69.92 to 90.18 |
| Modified ESSS with Four Tanks ⁴ | 24,540 | 343.3 | 820 | 38 to 122 | 90.33 |
| | 16,080 to 24,460 | 350.0 | 5920 to 9640 | 41 to 136 | 70.07 to 100.16 |

NOTES:

¹Test conducted in ball centered flight, all windows closed, a mid lateral center of gravity, and at a referred rotor speed of 258 RPM.

²Fixed provisions - normal utility configuration with ESSS mounting provisions enclosed by fairings.

³Original ESSS - normal utility configuration with the horizontal and vertical stores support system and ejector assemblies with the various stores installed.

⁴Modified ESSS - same as original ESSS but with extended pylon fairings added.

RESULTS AND DISCUSSION

GENERAL

7. Limited level flight performance and flight control position data were obtained for the UH-60A Black Hawk helicopter in three configurations (fixed provisions, original ESSS and modified ESSS) with various external stores installed. The flight tests were conducted at the Sikorsky Aircraft Division of United Technologies Flight Test Center in West Palm Beach Florida. Test site elevation was 28 feet. The aircraft was flown in ball-centered flight at a referred rotor speed of 258 RPM. The maximum range in the self deployment ferry mission configuration (original ESSS with four tanks) was calculated by AVRADCOM using the power required data contained in this evaluation. This range was determined to be 1176 nautical miles using a cruise climb flight profile and the criteria in the Material Need Document (ref 1, app A).

LEVEL FLIGHT PERFORMANCE

General

8. Initially, level flight performance tests were conducted in the fixed provisions configuration to provide a baseline to compare with the Airworthiness and Flight Characteristics (A&FC) Evaluation test results. Additional tests were conducted to determine the change in drag of the UH-60 helicopter configured with the original ESSS and with various stores installed. A modified ESSS with four tanks was also tested. These tests were conducted at the conditions of table 1. The data obtained were concentrated at thrust coefficients (C_T 's) of approximately 0.007, 0.008, and 0.009. Test techniques and data analysis methods are described in appendix D. Installed engine power and fuel flow for the Black Hawk were derived by AVRADCOM from General Electric (GE) engine deck number 80024, dated 26 February 1981 using installed losses determined by AVRADCOM. All power required data were corrected by an estimate for drag of external test instrumentation and nonstandard aircraft equipment and for instrumentation electrical power consumption. All estimates for drag of these external items were provided by SA. The test results from the A&FC Evaluation of the UH-60A in the normal utility configuration (ref 6, app A) were normalized to the PAE test aircraft. These results were used as the basis for evaluating the effects of drag for the various configurations tested since the A&FC Final Report constitutes the broadest range of available performance data verified by flight test. An unexplained increase in power required was found between the PAE test aircraft and the aircraft used for the A&FC. A maximum range of 1176 nautical miles was determined by AVRADCOM, using the data from

this report, the latest self deployment ferry mission configuration, the criteria of the Material Need Document (ref 1, app A), and power required for a cruise climb and level flight cruise at the maximum range cruise airspeeds. This exceeds the 1150 nautical mile range required for the self deployment ferry mission.

Fixed Provisions Configuration

9. The fixed provisions configuration consisted of the Black Hawk in the normal utility configuration with the addition of the fixed ESSS mounting provisions enclosed by the fixed provisions fairings (fig. 1, and photos 2 and 3, app B). Level flight performance data was obtained on four flights, two of which ($C_T = 0.007286$ and 0.008014) were conducted with the Black Hawk standard stabilator schedule but with the ship system pilot's airspeed input to the stabilator amplifier replaced by the boom (test) system airspeed. These flights were repeated and all subsequent tests conducted with a modified stabilator schedule (fig. 2, app B) and an increased electrical time delay in the stabilator amplifier incorporated. In addition, the airspeed inputs to the stabilator amplifiers were returned to the standard Black Hawk configuration and the ship system airspeed probes rotated inboard 15 degrees about an axis normal to their mounting pad. The power required for level flight was the same for both stabilator schedules.

10. The power required for the fixed provisions configuration was expected to be equal to the A&FC test results with the addition of the fixed provisions drag estimate of 0.78 ft^2 change in equivalent flat plate area (ΔF_e). Initially, a significant amount of additional drag was found, approximately 7.5 ft^2 ΔF_e at high speeds. This amount was considered too large for this small configuration change and led to additional flight tests to verify the boom airspeed system position error provided by SA. The calibration was found to be incorrect and the error accounted for about 3 ft^2 of the drag increase. Other corrections described in paragraph 6, appendix D were applied to the A&FC data used as the baseline for this comparison and resulted in further reducing the difference to approximately 3 ft^2 at an advance ratio of 0.28 (approximately 120 knots true airspeed (KTAS)). The ΔF_e determined for the fixed provisions configuration varied with airspeed. A summary of ΔF_e at this advance ratio of all the configurations tested is presented in figure 1, appendix E. The fairing presented in figure 2, appendix E was derived from all the fixed provisions data, figures 3 through 6, and includes the still unexplained increase in power required between the PAE test aircraft and that of the A&FC aircraft in the same configuration. A performance

evaluation should be conducted on a late production UH-60A helicopter to determine if this power required increase is unique to the PAE test aircraft.

Original ESSS with Four Tanks Configuration

11. The original ESSS with four tanks configuration consists of the horizontal and vertical stores support systems (wing and pylons) and ejector rack assemblies with two 450 gallon fuel tanks mounted on the inboard store positions and two 230 gallon fuel tanks mounted on the outboard store positions (fig. 1, and photos 6 and 7, app B). Five flights were conducted in this configuration. Three were flown to determine C_T effects at a longitudinal center of gravity (CG) of fuselage station (FS) 350. The other two were flown at the forward CG limit, FS 343. This was to provide data over the range of C_T s expected for the ferry mission as well as longitudinal CG effects. The flights at the limit forward CG were conducted near the same C_T but at different test conditions that were representative of the actual ferry mission.

12. Figure 7, appendix E presents a summary of the change in drag from the normal utility to the original ESSS with four tanks configuration. The ΔF_e varied with airspeed and C_T . Figures 8, 9, and 10 present the nondimensional data derived from the dimensional test data presented in figures 11 through 15. The drag increase for the ESSS with four tanks configuration was found to be higher than the amount predicted by SA, especially at the high C_T (approximately 0.0090), where much of the ferry mission flight profile is flown.

13. Test data was obtained to determine the effect on power required of changing the aircraft CG from FS 350.0 to the forward limit CG FS 343.0. The data used to evaluate these effects were obtained on two flights: one at a heavy gross weight (24,580 lb) and a low density altitude (1380 ft); and the other at a lighter gross weight (17,960 lb) and a higher altitude (10,740 ft). The results of these limited tests were inconclusive (figs. 14 and 15, app E). Sufficient testing should be accomplished in the ESSS configuration to define the change in power required by changes in aircraft CG.

Modified ESSS with Four Tanks Configuration

14. Since the aircraft in the original ESSS with four tanks configuration was not expected to meet the required ferry mission range, modification to reduce the drag of the ESSS was incorporated by SA. The modified ESSS with four tanks configuration

was the same as the original ESSS configuration described in paragraph 11 except for fairings added to the vertical stores support system (pylons) to cover the ejector racks and extend from the original fairing to the top of the fuel tanks (photos 8 and 9, app B). Four flights at C_T s near those obtained for the original ESSS data were conducted to determine if the drag was reduced and to evaluate the overall drag change from the normal utility configuration. Figure 16, appendix E presents a summary of the change in drag from the normal utility to the modified ESSS configuration. Figures 17 through 19 present the nondimensional data derived from the dimensional test data presented in figures 20 through 23. The ΔF_e was again found to vary with airspeed and C_T , similar to the data for the original ESSS configuration. The drag was substantially reduced at the low C_T s but only slightly reduced (approximately $0.7 \text{ ft}^2 \Delta F_e$) at $C_T = 0.009$ and 120 KTAS. A comparison at this air speed of the original and modified ESSS ΔF_e data over the range of C_T s tested is presented in figure 1, appendix E.

Original ESSS with no Stores and with Two Tank Configurations

15. Data were also obtained for the original ESSS with no stores (horizontal and vertical stores support systems with no stores) (photo 4, app B) and the original ESSS with two 230 gallon fuel tanks installed at the outboard store positions (photo 5, app B). Figure 24, appendix E presents a summary of ΔF_e from the normal utility configuration for these two configurations. The nondimensional data for the two tank configurations are presented in figures 25, 26 and 27 and the dimensional data for both configurations are presented in figures 28 through 32. The ΔF_e determined for both of these configurations were found to vary with airspeed and not with C_T as with the four tank data (fig. 1, app E). The ΔF_e for the original ESSS with no stores and with two tanks at approximately 120 KTAS was 11.8 ft^2 and 14.2 ft^2 , respectively.

Self-Deployment Ferry Mission Range Estimate

16. The self deployment ferry mission ranges were calculated by AVRADCOM for the original and modified ESSS with four tanks configurations. These ranges were based on the requirements of the Material Need Document (ref 1, app A) and the data from the A&FC final report plus the ΔF_e determined for each configuration. Estimates for the drag of a "hover infrared suppressor" and main rotor deice equipment were also included. These items were not installed on the PAE test aircraft. Five nautical miles were added to the range estimate for the descent from 10,000 ft at the end of the mission. The unexplained increase in the power

required between the PAE and A&FC test aircraft was ignored for this calculation. The maximum range for the original ESSS with four tanks using these criteria was 1176 nautical miles. This exceeds the 1150 nautical mile range required for the self deployment ferry mission. The maximum range for the modified ESSS with four tanks was determined to be 1207 nautical miles for these same criteria.

INHERENT SIDESLIP

17. The inherent sideslip angles were measured during all test flights. No consistent difference was found between configurations but the inherent sideslip did vary with C_T . The data from all the test flights were grouped according to C_T and plots for inherent sideslip, (figures 33 and 34) were developed. The inherent sideslip characteristics for the PAE test aircraft were 1 to 3 degrees closer to zero sideslip than the A&FC test aircraft at high speeds. This unexplained difference was taken into account when normalizing the A&FC data for use in this report (para 7, app D).

HANDLING QUALITIES

Control Positions in Level Flight

18. Control positions in ball centered level flight were obtained in conjunction with the level flight performance data. The data from selected flights at each aircraft configuration tested are presented in figures 35 through 39. The trends of control positions with airspeed were similar to those of the standard UH-60A.

CONCLUSIONS

19. Based on the PAE of the UH-60A helicopter in the configurations tested, the following conclusions were reached:

a. Based on an AVRADCOM analysis using the power required data obtained from this report, the UH-60A in the original ESSS with four tanks configuration exceeds the 1150 nautical mile range required for the self deployment ferry mission (para 15).

b. There is an unexplained increase in the power required for level flight between the PAE test aircraft and the test results from the A&FC Evaluation of the UH-60A helicopter (para 10).

c. The modification to the ESSS reduced the drag of the UH-60A in the ESSS configuration, especially at thrust coefficients less than 0.009 (para 14).

d. The inherent sideslip of the PAE test aircraft was 1 to 3 degrees less left sideslip than the test aircraft used during the A&FC (para 17).

RECOMMENDATIONS

20. Sufficient testing should be accomplished in the ESSS with four tank configuration to determine the change in power required by changes in aircraft CG (para 13).

21. A performance evaluation should be conducted on a late production UH-60A helicopter (para 10).

APPENDIX A. REFERENCES

1. Document, TRADOC, ATCD-B, UH-60A Blackhawk Material Need, Production, updated (MN)(P) (U), Action Control Number 10705, August 1979, with change dated 13 December 1980.
2. Letter, AVRADCOM, DRDAV-D, 5 November 82, subject: Preliminary Airworthiness Evaluation of the UH-60A Configured with the External Stores Support System (ESSS), with revision 1 dated 23 November 82. (Test Request)
3. Technical Manual, TM55-1520-237-10, *Operator's Manual, UH-60A Helicopter, Headquarters Department of the Army*, 21 May 1979, with change 19, dated 3 February 1983.
4. Letter, AVRADCOM, DRDAV-D, 12 January 1983, subject: Airworthiness Release for the Conduct of a Preliminary Airworthiness Evaluation of a UH-60A Configured with the External Stores Support System (ESSS), Project No. 82-14, with revision 2 dated 12 January 1983.
5. Test Plan, USAAEFA Project No. 82-14, *Preliminary Airworthiness Evaluation of the UH-60A Configured with the External Stores Support System*, 26 November 82.
6. Final Report, USAAEFA Project No. 77-17, *Airworthiness and Flight Characteristics Evaluation; UH-60A (Black Hawk) Helicopter*, September 1981, unpublished.

APPENDIX B. DESCRIPTION

1. The UH-60A is a twin engine, single main rotor configured helicopter with nonretractable wheel-type landing gear. A movable horizontal stabilator is located on the lower portion of the tail rotor pylon. The main and tail rotor are both four-bladed with a capability of manual main rotor blade and tail pylon folding. The cross-beam tail rotor with composite blades is attached to the right side of the pylon. The tail rotor shaft is canted 20 degrees upward from the horizontal. Primary mission gross weight is 16,260 pounds and maximum alternate gross weight is 20,250 pounds. The UH-60A is powered by two General Electric T700-GE-700 turboshaft engines having an installed thermodynamic rating (30 minute) of 1553 SHP (power turbine speed of 20,900 RPM) each at sea level, standard-day static conditions. Installed dual-engine power is transmission limited to 2828 SHP. The aircraft also has an automatic flight control and a command instrument system. The test helicopter, UH-60A US Army S/N 77-22714 was manufactured by SA, and is the first production Black Hawk. The main differences between the test aircraft and a standard UH-60A consist of special test instrumentation (app C), modified door jettison system (photo 1), nonstandard gunners windows (photo 2), and airframe fixed provisions for the ESSS. A fuel transfer system was not installed in the test aircraft.

2. The ESSS consists of the airframe fixed provisions and the removable external stores subsystem. The ESSS was designed to enable the UH-60A to carry external stores such as auxiliary fuel tanks or various weapons systems.

3. The airframe fixed provisions (fig. 1, and photos 2 and 3) are the fuselage attachment structure required for the installation of the removable external stores subsystem. The removable external stores subsystem (fig. 1 and photo 4) consists of the horizontal store support which is a composite boxed I-beam structure, the support struts (two on each wing) and the vertical stores pylons (two on each wing) all of which are enclosed with thin aluminum fairings. Ejector racks were mounted on the vertical stores pylons at a 4° nose up angle with reference to the aircraft water line. Model MAU-40 ejector racks were installed at the inboard and outboard stores stations.

4. The test aircraft was configured with various portions of the external range fuel system, which included two 230 gallon external fuel tanks on the outboard pylons (photo 5) and a combination of the two 230 gallon tanks with two 450 gallon fuel tanks on the inboard pylons (photos 6 and 7). Aluminum fairings were added between the vertical stores pylon fairings and the auxiliary tanks (photos 8 and 9) for certain flights.



Photo 1. Modified Door Jettison System

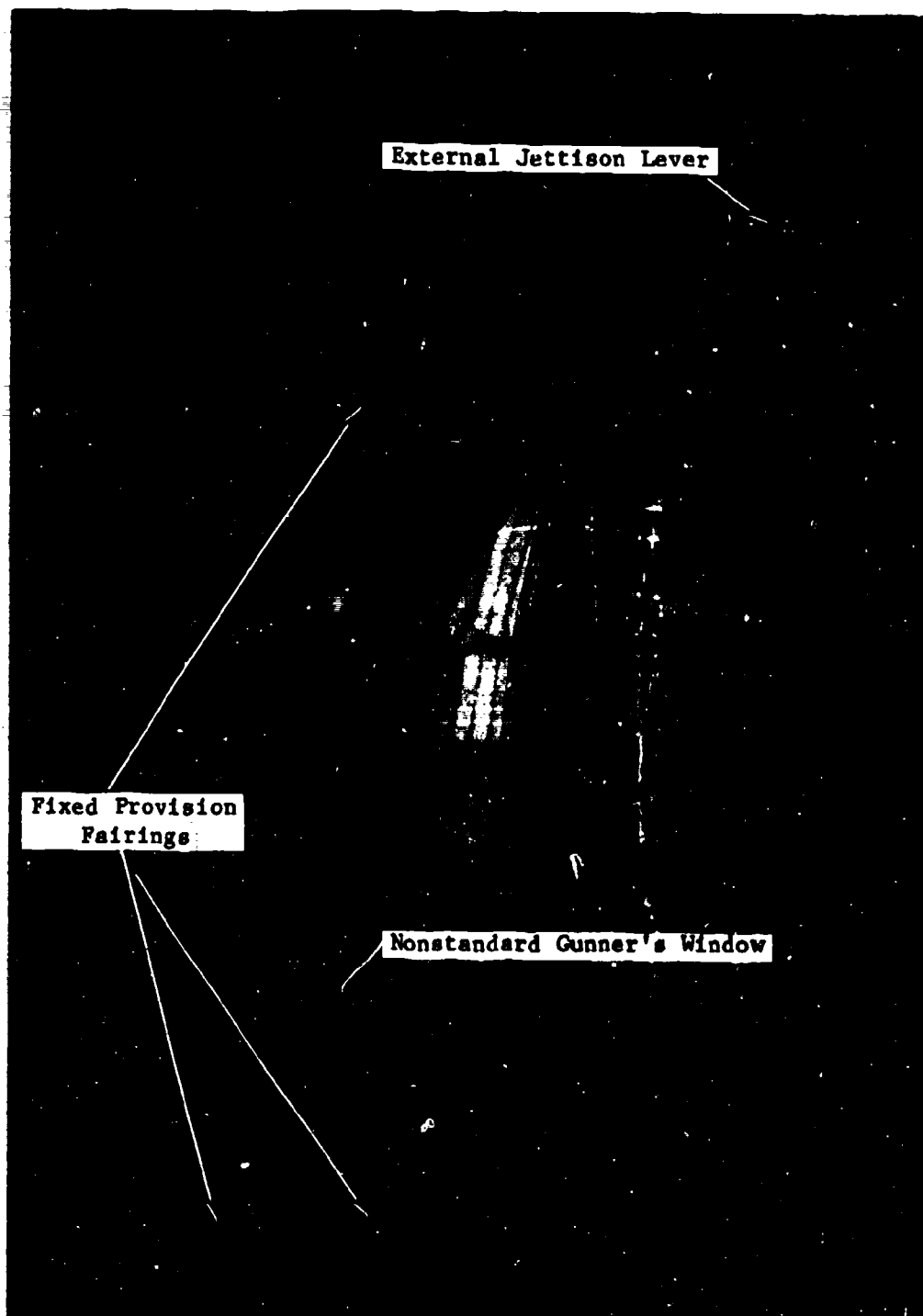


Photo 2. UH-60A ESSS Fixed Provisions Configuration
(Fairings Installed)

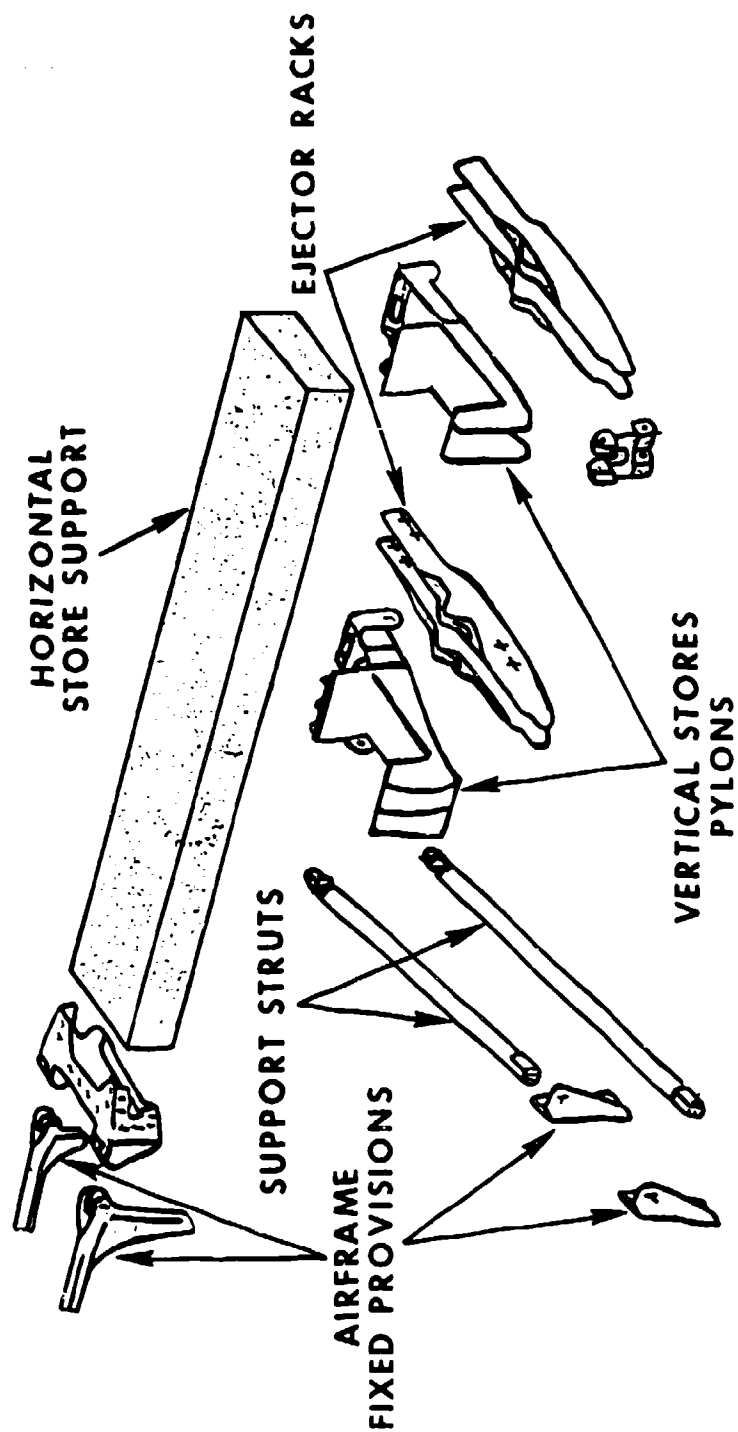


Figure 1. ESSS Structural Components

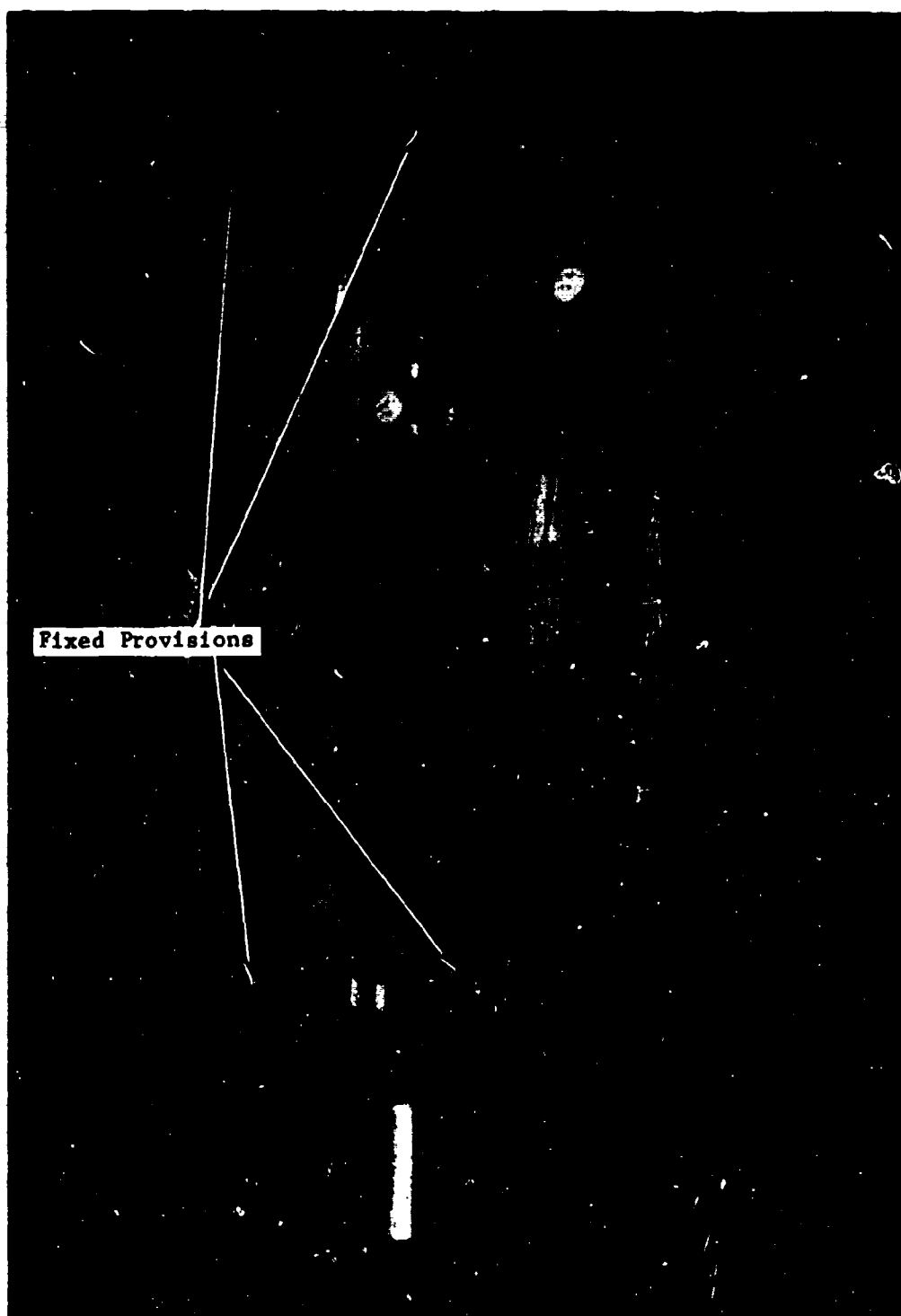


Photo 3. UH-60A ESSS Fixed Provisions Configuration
(Fairings Removed)



Photo 4. UH-60A in the Original ESSS with No Stores Configuration

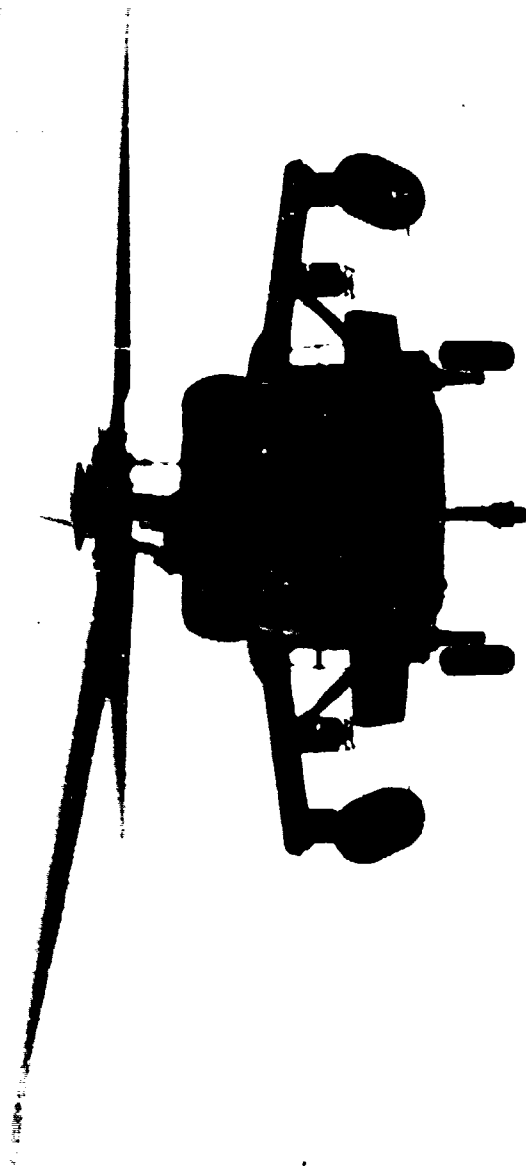


Photo 5. UH-60A in the Original ESSS with Two Tanks Configuration



Photo 6. UH-60A in the Original ESSS with Four Tanks Configuration

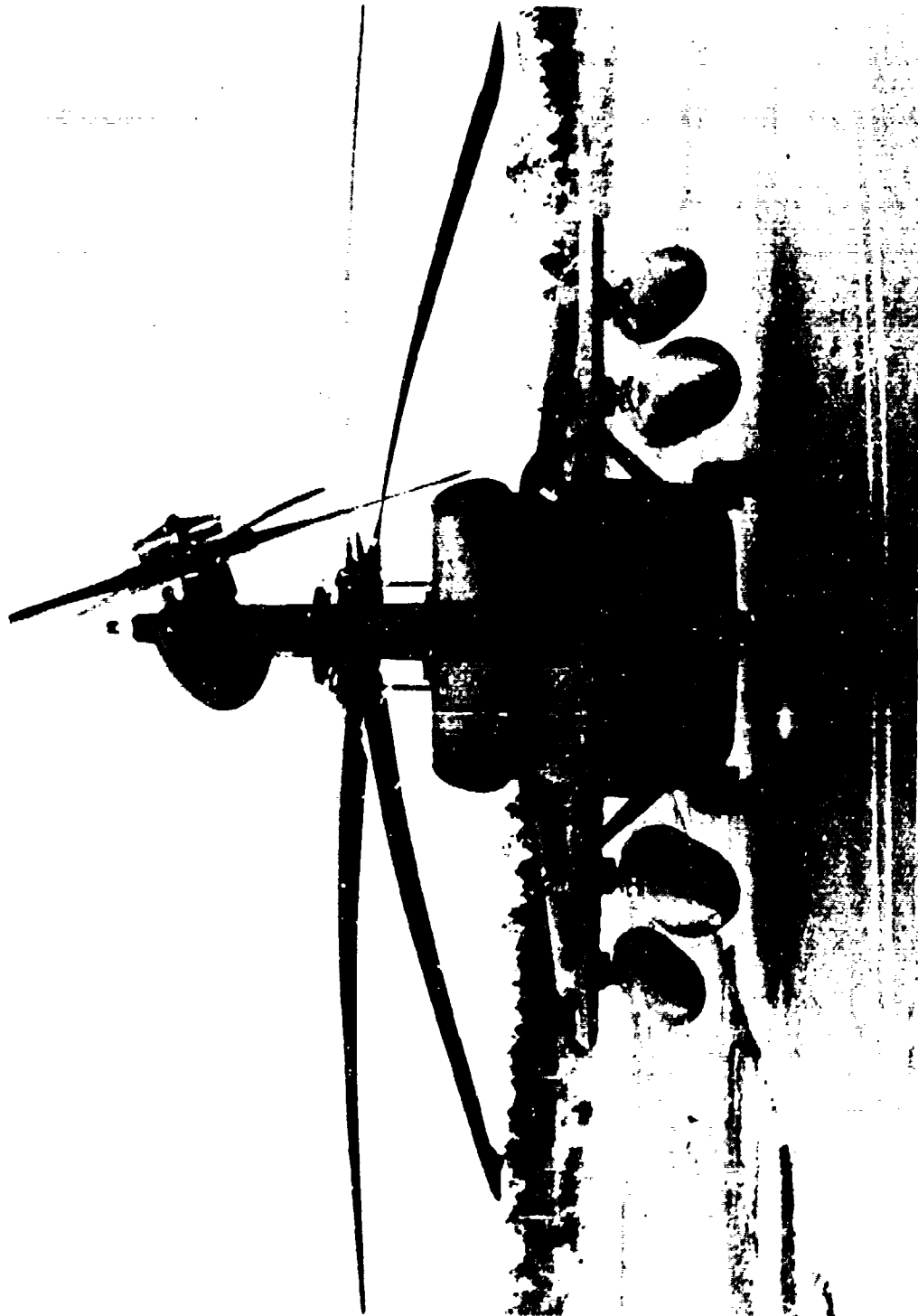


Photo 7. UH-60A in the Original ESSS with Four Tanks Configuration - Rear View

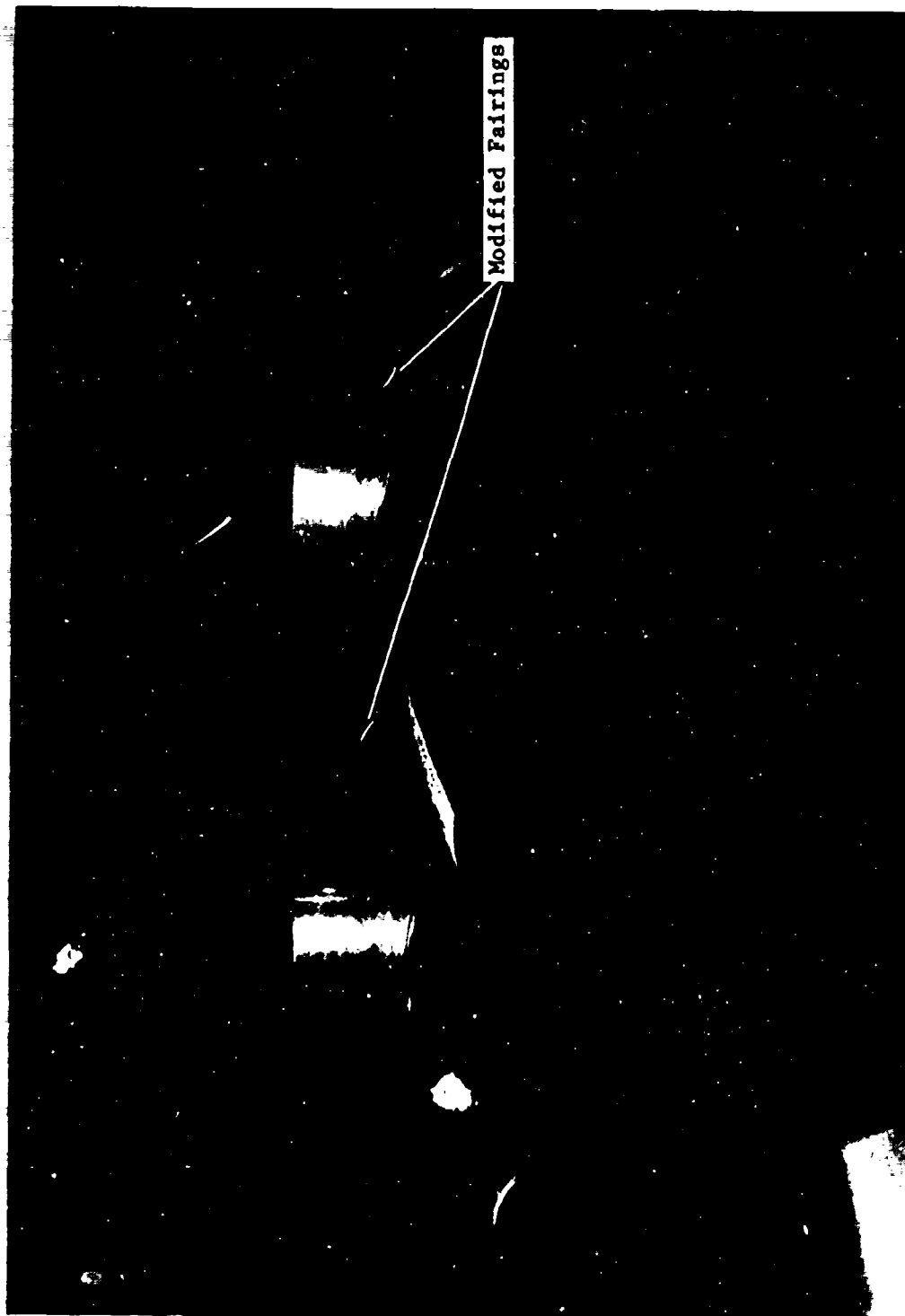


Photo 8. UH-60A in the Modified ESSS with Four Tanks Configuration

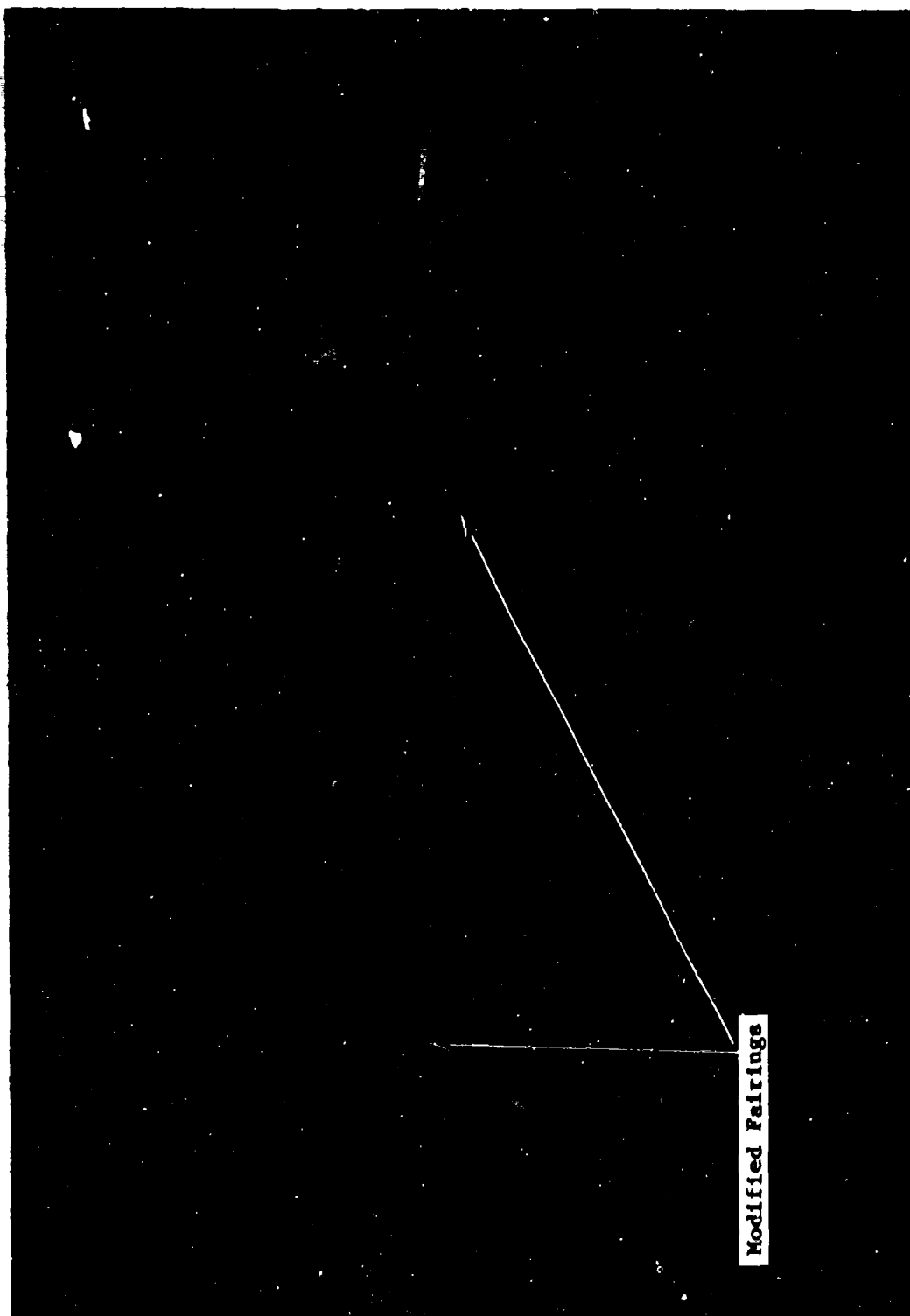


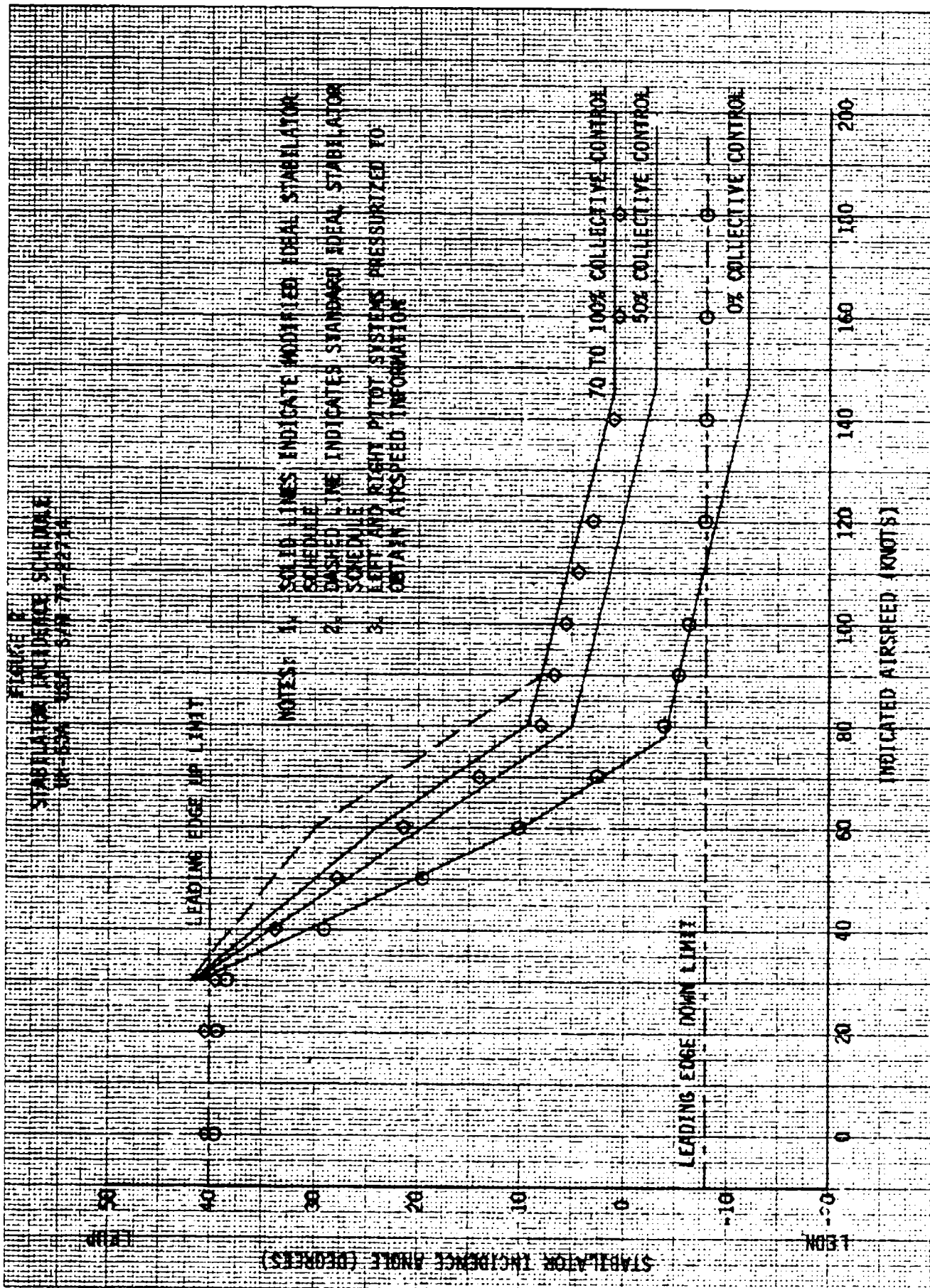
Photo 9. UH-60A in the Modified ESSS with Four Tanks Configuration - Rear View

5. The first two flights of the PAE were flown with the standard Black Hawk stabilator schedule and ship system airspeed probe orientation but with the ship system pilot's input to the stabilator replaced by the boom system airspeed. These flights were conducted in the fixed provisions configuration. After these two flights were completed, the gain control module of the stabilator amplifiers were modified to increase the electrical time delay to 3 seconds and change the stabilator schedule (stabilator incidence angle bias with collective control position) in the test aircraft. The modified stabilator schedule is presented in figure 2. The airspeed inputs to the stabilator were returned to the standard Black Hawk configuration; the copilot's ship system airspeed providing the input to the No. 1 stabilator amplifier and the pilot's ship system airspeed providing the input to the No. 2 stabilator amplifier. Along with the stabilator control modifications, the orientation of both ship system airspeed probes was changed by rotating both probes inboard 15 degrees about an axis normal to their mounting pad.

6. Several external modifications were made to the test aircraft for instrumentation or safety. These modifications were not part of the ESSS modifications or a standard UH-60A. Drag estimates for these items totalled 3.68 ft² of equivalent flat plate area. Each item is listed below:

ITEM

Tail rotor slip ring assembly
Main rotor slip ring assembly
Airspeed boom
Instrumented main rotor blade (1)
Ambient air temperature sensor
Telemetry antenna
Tail rotor junction plate
External instrumentation wiring
Emergency crew door handles
Non-standard gunner's window



APPENDIX C. INSTRUMENTATION

GENERAL

1. The test instrumentation was installed, calibrated and maintained by the SA personnel. A specially constructed boom, with a swiveling pitot-static tube and angle of attack and sideslip vanes, was installed at the nose of the aircraft. The boom design (photo 1) allowed takeoffs and ground handling ease at heavy gross weights without damaging the pitot-static tube. Figure 1 presents the position error correction for the boom airspeed system. Major external instrumentation items such as the airspeed boom and main and tail rotor slipring assemblies are shown in photo 1. Data was obtained from calibrated instrumentation and displayed or recorded as indicated below.

Pilot Panel

Airspeed (boom)
Altitude (ship's)
Altitude (radar)
Rate of climb*
Rotor speed (sensitive)
Engine torque * **
Turbine gas temperature * **
Power turbine speed (N_p) * **
Gas producer speed (N_g) * **
Control positions
 Longitudinal
 Lateral
 Directional
 Collective
Horizontal stabilator position
Turn and slip indicator*

Copilot Panel

Event switch
Airspeed*
Altitude*
Rotor speed*
Engine torque* **

Engineer Panel

Fuel remaining
Instrumentation controls

*Ship's system/not calibrated

**Both engines

Free air temperature
Time code display
Run number
Event switch

2. Data parameters recorded on board the aircraft include the following:

Digital (PCM) Data Parameters

Airspeed (boom)
Altitude (boom)
Total air temperature
Rotor speed
Gas generator speed **
Power turbine speed**
Engine mass fuel flow**
Engine fuel used**
Engine output shaft torque**
Turbine gas temperature**
Main rotor shaft torque
Main rotor shaft temperature
Tail rotor shaft torque
Lateral acceleration at CG (sensitive)
Stabilator position
Control positions
 Longitudinal cyclic
 Lateral cyclic
 Directional pedal
 Collective
Attitude
 Pitch
 Roll
 Heading
Linear acceleration
 Center of gravity normal
 Center of gravity lateral
 Center of gravity longitudinal
Angle of sideslip
Angle of attack
Time of day
Run number
Pilot event
Engineer event

**Both engines

3. Calibrations of the engine torque sensor systems in an engine test cell were not accomplished. The typical engine run sheets provided by the manufacturer for the engine were substituted for these calibrations. Figures 2 and 3 present the "calibrations" used to determine engine torque.

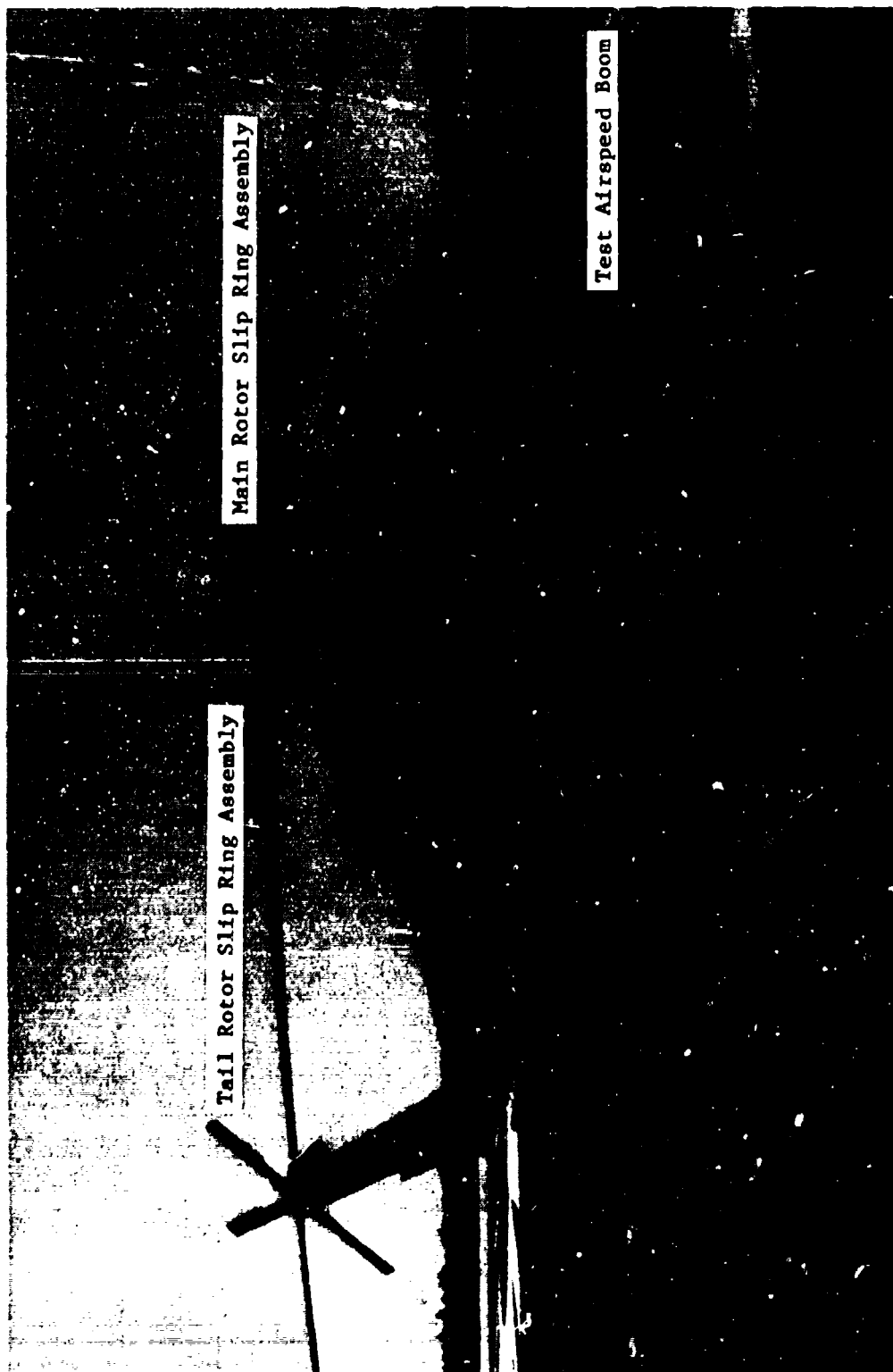


Photo 1. UH-60A ESSS External Instrumentation

FIGURE 1
BOOM SYSTEM AIRSPEED CALIBRATION IN LEVEL FLIGHT
UH-60A USA S/N 77-22714

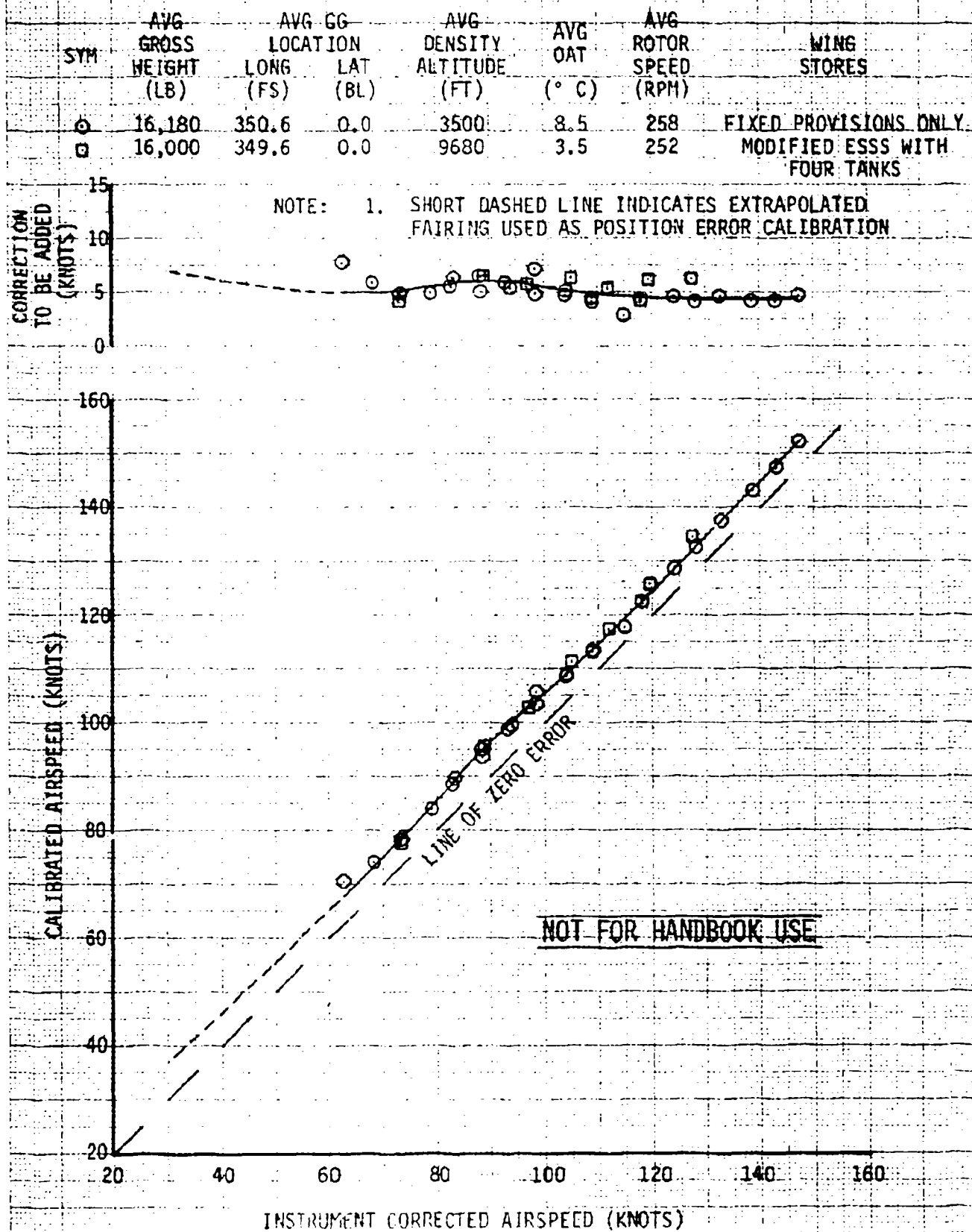


FIGURE 2
ENGINE TORQUEMETER CALIBRATION
T700-GE-700 S/N 207486

- NOTES: 1. DATA OBTAINED FROM ENGINE TEST SHEETS
2. ENGINE OUTPUT SPEED = 20,900 RPM

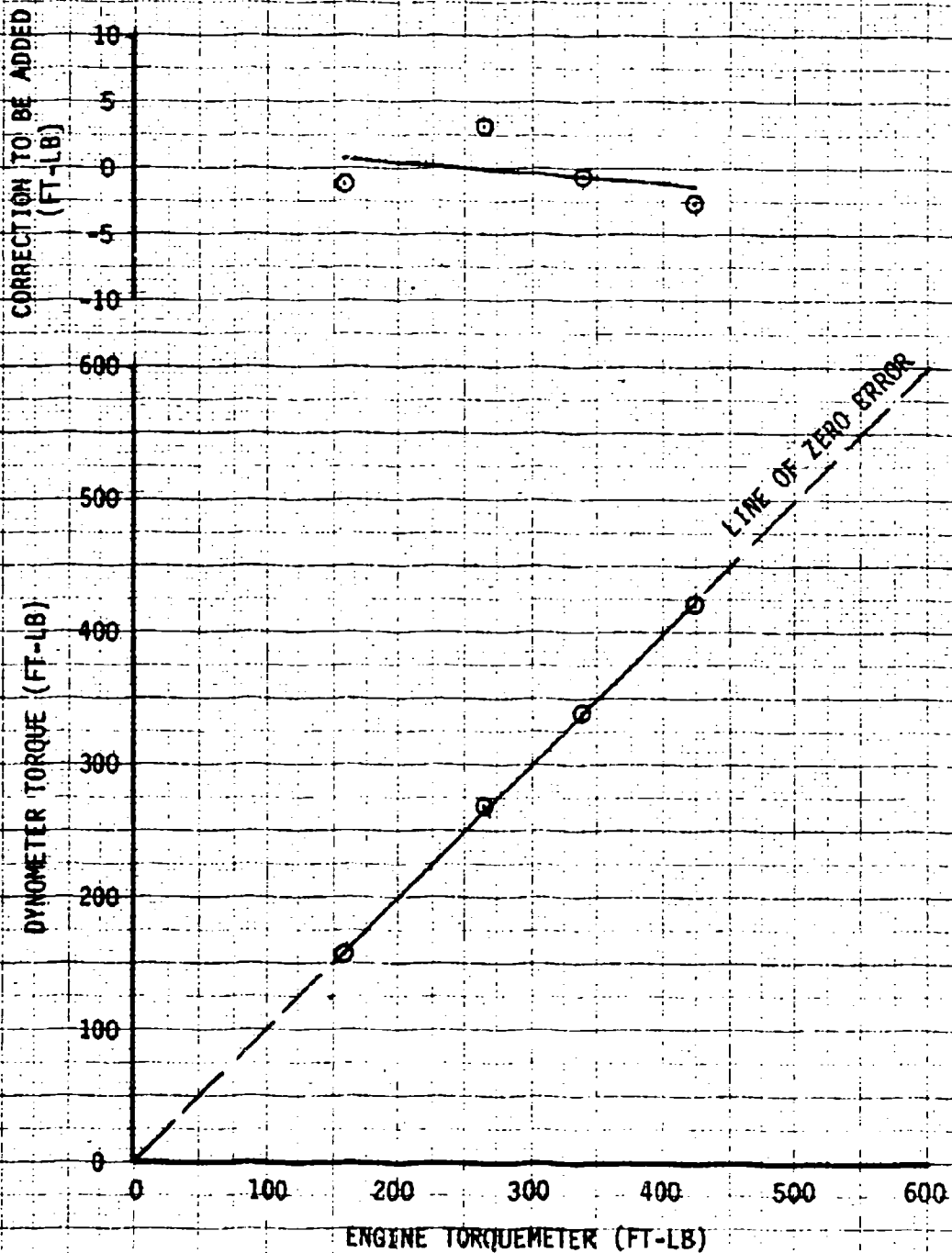
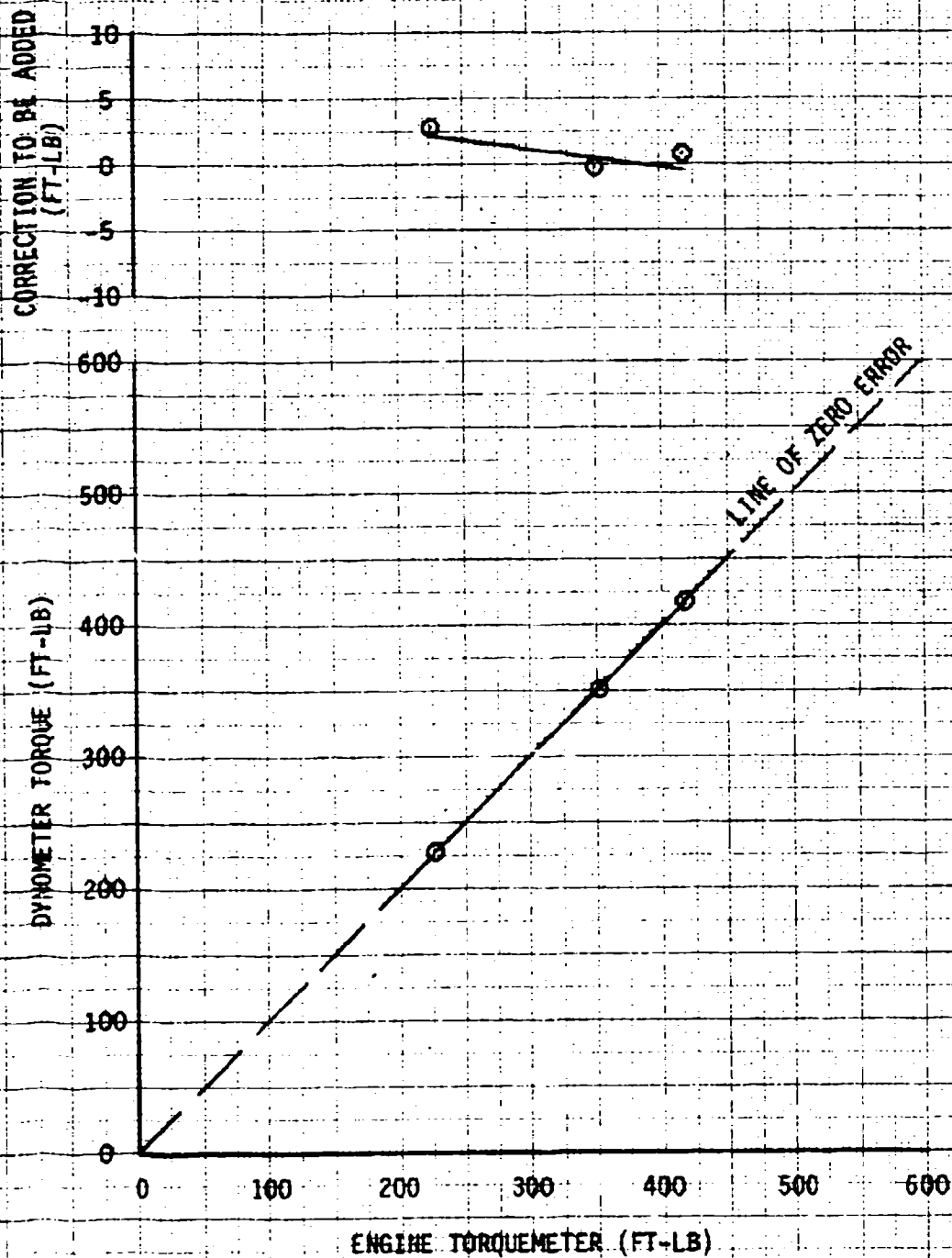


FIGURE 3.
ENGINE TORQUEMETER CALIBRATION
T700-GE-700 S/N 306006

- NOTES: 1. DATA OBTAINED FROM ENGINE
RUN SHEETS
2. ENGINE OUTPUT SPEED = 20,900 RPM



APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. Level flight performance and control positions in level flight were obtained in coordinated (ball-centered) flight and compared with the test results of the A&FC Evaluation of the UH-60A (Black Hawk) helicopter (ref 6, app A). Referred rotor speed was maintained constant for all tests at 258 RPM. Longitudinal CG was allowed to vary ± 1.0 inch during each test flight but for each data set, (consisting of several flights in the same aircraft configuration at different thrust coefficient values) the average cg location was maintained constant near the proposed mission value. The data were analyzed to determine the power required differences between the various aircraft configurations and the A&FC in terms of changes in equivalent flat plate area (ΔF_e).

Aircraft Weight and Balance

2. The test aircraft was weighed at the start of the test program with all instrumentation installed, full oil and fuel drained in the fixed provisions configuration. The initial weight of the aircraft was 12,068 pounds with the longitudinal CG located at FS 358.9 and the lateral cg located at BL 0.2. The aircraft was weighed in several other configurations periodically during the test. It was not possible to weigh the aircraft at the 24,500 pound gross weight since the only scales available required the aircraft to be supported at its jack points. The aircraft weight at the tail jack point exceeded the 5000 pound jack point limit. The fuel cells and external sight gauges were calibrated using a calibrated flow meter. The fuel weight for each test flight was determined prior to and after each flight using these external sight gauges to determine the fuel volume and measuring the specific gravity of the fuel.

Level Flight Performance

3. The engine output shaft torque was determined by use of the engine torque sensor. The output shaft horsepower was determined from the engine output shaft torque and rotational speed by the following equation:

$$\text{SHP} = \frac{2\pi (N_p) Q}{33,000} \quad (1)$$

Where:

Q = Engine output shaft torque (ft-lb)

N_p = Engine output shaft rotational speed (RPM)

33,000 - Conversion factor (ft-lb/min)/SHP

4. The level flight performance was generalized through the use of nondimensional coefficients as follows using the 1968 U.S. standard atmosphere:

$$C_P = \frac{\text{SHP (478935.3)}}{\delta \sqrt{\theta} \left[\frac{N_R}{\sqrt{\theta}} \right]^3 \rho_o A R^3} \quad (2)$$

$$C_T = \frac{\text{GW (91.19)}}{\delta \left[\frac{N_R}{\sqrt{\theta}} \right]^2 \rho_o A R^2} \quad (3)$$

$$\mu = \frac{V_T (16.12)}{R \sqrt{\theta} \frac{N_R}{\sqrt{\theta}}} \quad (4)$$

Changes in engine power coefficient due to changes in flat plate area were determined using the following equation:

$$\Delta C_P = \frac{\Delta F_e \mu^3}{2A} \quad (5)$$

Where:

$$\delta = \text{Pressure ratio} = \frac{P_a}{P_{a_o}}$$

$$\rho_0 = 0.0023769 \text{ slugs/ft}^3$$

$$A = \text{Main rotor disk area} = 2262.02 \text{ ft}^2$$

$$R = \text{Main rotor radius} = 26.833$$

$$P_A = \text{Ambient pressure in. -Hg}$$

$$P_{a_0} = 29.92126 \text{ in. -Hg}$$

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

$$\text{OAT} = \text{Ambient air temperature } (^{\circ}\text{C})$$

$$N_R = \text{Main rotor speed (rev/min)}$$

$$478935.3 = \text{Conversion factor (ft-lb-sec}^2 \text{ -rev}^3/\text{min}^3\text{-SHP)}$$

$$91.19 = \text{Conversion factor (sec}^2\text{-rev}^2/\text{min}^2)$$

$$16.12 = \text{Conversion factor (ft-rev/min-kt)}$$

$$\Delta F_e = \text{Change in equivalent flat plate area (ft}^2)$$

$$\mu = \text{Advance ratio}$$

5. Each speed power was flown in ball centered flight by reference to the ship's turn and bank indicator at a predetermined thrust coefficient (C_T) and referred rotor speed ($N_R/\sqrt{\theta}$). Both the pilot's and copilot's turn and bank indicators were checked for alignment with the aircraft positioned in a level attitude. To maintain the ratio of gross weight to pressure ratio (W/δ) constant, altitude was increased as fuel was consumed. To maintain $N_R/\sqrt{\theta}$ constant, rotor speed was varied as appropriate for the ambient air temperature. Corrections to power required were made for the installation of test instrumentation. The power consumption for the electrical operation of the instrumentation equipment was measured and determined to be 2.73 SHP and subtracted from the power required data. The effects of the external instrumentation and nonstandard aircraft equipment were estimated by SA to be the equivalent of 3.68 ft² of flat plate area. Paragraph 5, appendix B, lists the items included for this estimate.

6. Test-day level flight data was corrected to standard day conditions by the following equations:

$$SHP_s = SHP_t \frac{(\delta_s \sqrt{\theta_s}) \left[\frac{N_R}{\sqrt{\theta}} \right]_s^3}{(\delta_t \sqrt{\theta_t}) \left[\frac{N_R}{\sqrt{\theta}} \right]_t^3} \quad (6)$$

$$V_{T_s} = V_{T_t} \frac{\left[\frac{N_R}{\sqrt{\theta}} \right]_s}{\left[\frac{N_R}{\sqrt{\theta}} \right]_t} \quad (7)$$

Where:

Subscript t = Test day

Subscript s = Standard day

Test data corrected for instrumentation drag and corrected to standard altitude and ambient temperature are presented in figures 3 through 6, 11 through 15, 20 through 23 and 28 through 32 appendix E.

7. The data obtained for three configurations (the original ESSS with two and four fuel tanks installed and the modified ESSS with four fuel tanks) were analyzed by use of a three dimensional plot for each configuration. The power required data was plotted as a function of airspeed in terms of C_p versus μ at a constant C_T . These curves were then joined by lines of constant μ to form the carpet plot. The reduction of this carpet plot to a family of curves of C_T versus C_p , for a constant μ value, allows determination of the power required as a function of airspeed for any value of C_T . Except for one flight at a $C_T = 0.009033$ in the modified ESSS with four fuel tank configuration, longitudinal cg was maintained constant within each data set. For use in the carpet plot the power required data for this one flight was reduced by an amount, using equation 5, where

$\Delta F_e = 1.1 \text{ ft}^2$. This value was estimated from data available in the A&FC final report (ref 6, app A). The data obtained for the rest of the configurations tested (the original ESSS with no stores, original ESSS with four fuel tanks with the aircraft longitudinal cg at FS 343.0 and the fixed provisions) were analyzed by calculating an equivalent flat plat area change between the data points and a baseline fairing using equation 5.

8. The baseline fairing used to determine the difference between the fixed provisions configuration data and the normal utility configuration data of the A&FC consisted of three elements. The nondimensional data of the A&FC final report (ref 6, app A) at $N_R/\sqrt{\sigma} = 258 \text{ RPM}$ was used as the starting point. Then the power required data was corrected from a zero sideslip trim condition of this data plot to ball-centered trim conditions by using the inherent sideslip of the PAE test aircraft (figs. 33 and 34, app E). The power required due to sideslip relationship was assumed to be the same as that found for the A&FC test aircraft. Figure 46, appendix E, of the A&FC final report (ref 6, app A) was used to correct this data. Finally, a power required increase equivalent to $\Delta F_e = 0.5 \text{ ft}^2$ (estimated by the SA) was added because of an infrared jammer and chaff dispenser mounting bracket installed on the PAE test aircraft but not included in the A&FC test aircraft normal utility configuration. These are part of the proposed self deployment ferry mission. The following equation illustrates the components that determined the baseline for the fixed provisions configuration:

$$C_{P.F.P. \text{ Baseline}} = C_{PA\&FC} + C_{P_{\text{sideslip PAE}}} + C_{P_{\text{IR Jammer}}} \quad (8)$$

Where:

$C_{P.F.P. \text{ Baseline}}$ = Baseline power coefficient for fixed provisions only configuration

$C_{PA\&FC}$ = A&FC power coefficient at zero sideslip trim condition

$C_{P_{\text{sideslip PAE}}}$ = Power coefficient for conversion from zero sideslip to ball-centered trim condition, based on PAE sideslip data

$C_{P_{\text{IR Jammer}}}$ = Power coefficient for infrared jammer and chaff dispenser mounting bracket not included in A&FC normal utility configuration

The difference between this baseline and the flight test data for the fixed provisions configuration was expected to be 0.78 ft^2 of equivalent flat plate area (estimated by SA). The test results showed a ΔF_e in excess of the expected amount and to be dependent on airspeed (fig. 2, app E). A line was faired through all the fixed provisions data to represent a partially unexplained difference between the two test aircraft. This fairing was used as one of the factors in determining a baseline for the rest of the data obtained in the remaining aircraft configurations.

9. Up to six elements were used to determine a baseline for the data obtained in the ESSS only, original ESSS with two and four fuel tank, and modified ESSS with four fuel tank configurations. The first three elements were the same as those described in paragraph 8 (i.e. $C_{p_{A\&FC}}$, $\Delta C_{p_{\text{sideslip PAE}}}$ and $\Delta C_{p_{\text{IR Jammer}}}$). Then

the fairing through the data in figure 2, appendix E was applied to correct for the difference between the A&FC and the PAE level flight power required. Next, the drag estimate 0.78 ft^2 for the fixed provisions configuration was subtracted since the fixed provisions fairings are not used with any of the ESSS configurations and this estimate is included in the $C_{p_{A\&FC-PAE}}$ term

(para 8). The sixth element was an estimate for the difference in longitudinal cg location of the test data with the A&FC carpet plot (FS 347.0). This was applied as appropriate for each data set. The following equation shows the six elements that are included in the baseline for these data sets.

$$C_{p_{\text{baseline}}} = C_{p_{A\&FC}} + C_{p_{\text{sideslip PAE}}} + C_{p_{\text{IR Jammer}}} + C_{p_{A\&FC-PAE}} - C_{p_{0.78}} + C_{p_{\Delta cg}} \quad (9)$$

Where:

$C_{p_{\text{baseline}}}$ = Baseline power coefficient that includes all necessary corrections to compare similar data between the A&FC and PAE test results

$C_{p_{A\&FC}}$ = Same as described in paragraph 8

$C_{p_{\text{sideslip PAE}}}$ = Same as described in paragraph 8

$C_{p_{\text{IR Jammer}}}$ = Same as described in paragraph 8

$C_{p_{A\&FC-PAE}}$ = Power coefficient attributed to difference between A&FC and PAE data.

$C_{p_{0.78}}$ = Power coefficient determined for fixed provisions drag estimate of $\Delta F_e = 0.78 \text{ ft}^2$

$C_{p_{\Delta CG}}$ = Power coefficient determined for aircraft cg location difference

10. The specific range (SR) data for each level flight performance test were derived from the test level flight power required and fuel flow (W_{F_t}). Selected level flight performance SHP and fuel

flow data for each engine were referred as follows:

$$SHP_{REF} = \frac{SHP_t}{\delta \theta^{0.5}} \quad (10)$$

$$W_{F_{REF}} = \frac{W_{F_t}}{\delta \theta^{0.55}} \quad (11)$$

A curve fit was subsequently applied to this referred data and was used as the basis to correct W_{F_t} to standard day fuel flow using the following equation.

$$W_{F_s} = W_{F_t} + \Delta W_F \quad (12)$$

Where:

ΔW_F = Change in fuel flow between SHP_t and SHP_s

The following equation was used for determination of specific range.

$$SR = \frac{V_{T_s}}{W_{F_s}} \quad (13)$$

APPENDIX E. TEST DATA

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FIGURE 1
SUMMARY OF DRAG CHANGE FOR VARIOUS CONFIGURATIONS
 AT ADVANCE RATIO = 0.28
 UH-60A USA S/N 77-22714

| SYMBOL | CONFIGURATION | LONGITUDINAL CG LOCATION (FS) |
|--------|-------------------------------|-------------------------------------|
| ○ | FIXED PROVISIONS | 347.0 |
| □ | ORIGINAL ESSS WITH NO STORES | 347.0 |
| ◇ | ORIGINAL ESSS WITH TWO TANKS | 347.0 |
| △ | MODIFIED ESSS WITH FOUR TANKS | 350.0 |
| ▢ | ORIGINAL ESSS WITH FOUR TANKS | 350.0 |

- NOTES:
1. BALL-CENTERED TRIM CONDITION
 2. DATA OBTAINED FROM FIGURES 2 THROUGH 32
 3. BASELINE ($\Delta F_e = 0$) IS THE A&FC DATA FOR THE NORMAL UTILITY CONFIGURATION NORMALIZED TO THE PAE TEST AIRCRAFT (INHERENT SIDESLIP AND CONFIGURATION DIFFERENCES)
 4. A&FC DATA OBTAINED FROM USAAEFA TEST REPORT PROJECT 77-17

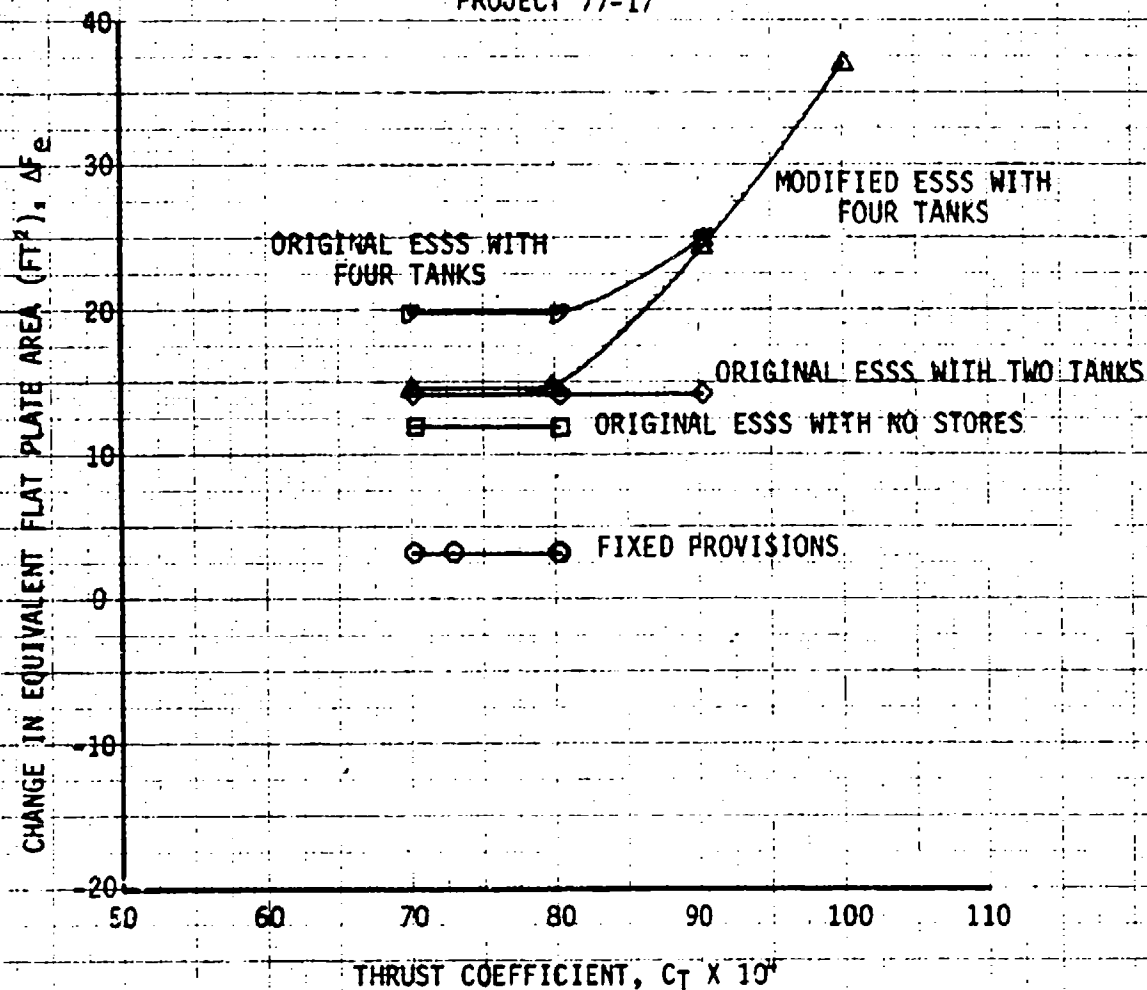


FIGURE 2
SUMMARY OF DRAG DIFFERENCE
BETWEEN PAE TEST AIRCRAFT AND A&FC TEST RESULTS
UH-60A USA S/N 77-22714

| CONFIGURATION | LONGITUDINAL CG LOCATION (FS) | THRUST COEFFICIENT $\times 10^5$ |
|---------------------|-------------------------------------|--|
| FIXED PROVISIONS | 347.2 | 70.20 |
| | 347.3 | 72.86 |
| | 346.8 | 80.10 |
| | 346.7 | 80.14 |

- NOTES:
1. FAIRING DERIVED FROM FIGURES 3 THROUGH 6
 2. BALL CENTERED TRIM CONDITION
 3. BASELINE ($\Delta F_e = 0$) IS THE A&FC DATA FOR THE NORMAL UTILITY CONFIGURATION NORMALIZED TO THE TEST AIRCRAFT (INHERENT SIDESLIP AND CONFIGURATION DIFFERENCES)
 4. A&FC DATA OBTAINED FROM USAAEFA TEST REPORT PROJECT 77-17

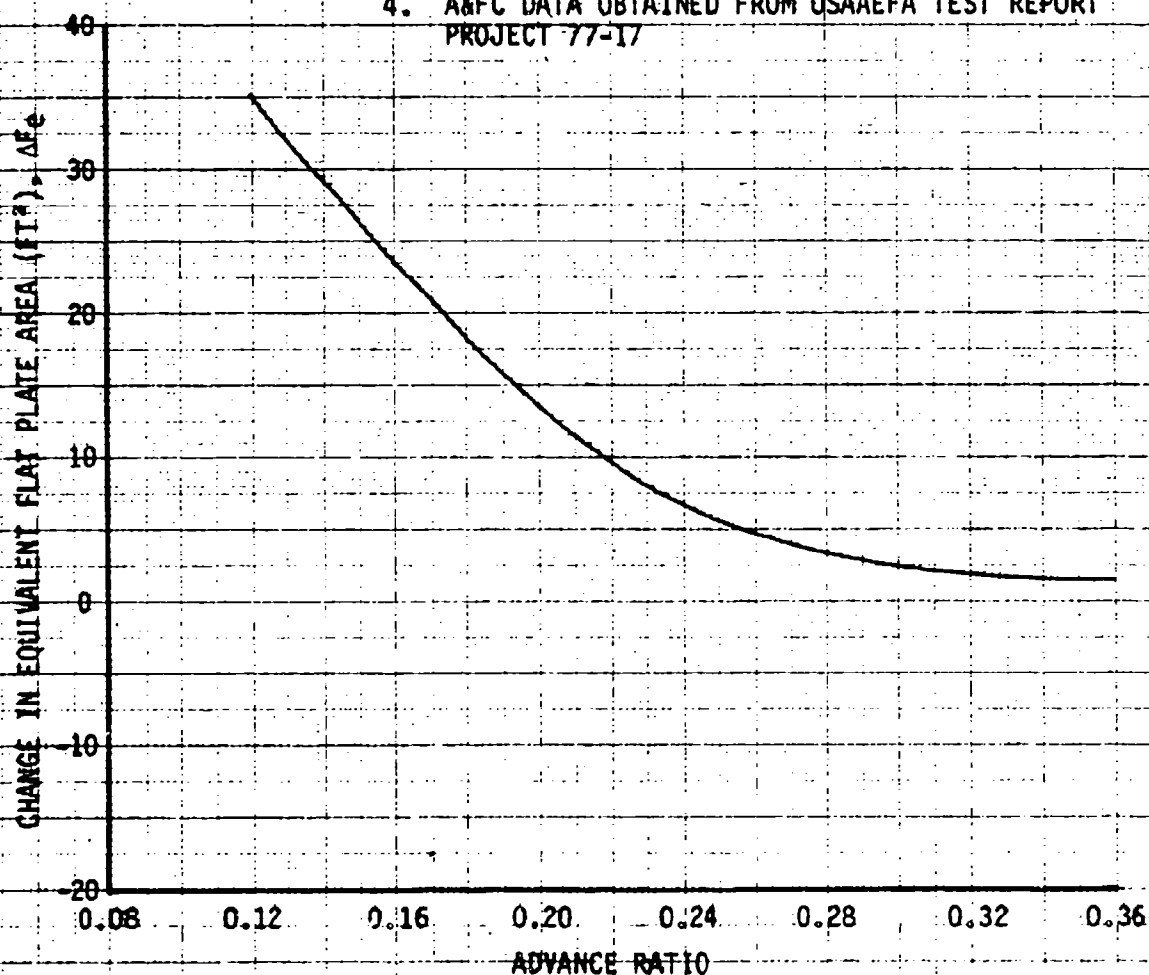


FIGURE 3
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT (°C) | AVG REFERRED ROTOR SPEED (RPM) | AVG C_r $\times 10^4$ | AIRCRAFT CONFIGURATION |
|-----------------------|-----------------|------|---------------------------|--------------|--------------------------------|-------------------------|------------------------|
| (FS) | (BL) | | | | | | |
| 16,040 | 347.2 | 0.2R | 6580 | 11.0 | 257.8 | 70.20 | FIXED PROVISIONS |

NOTE: BALL CENTERED TRIM CONDITION

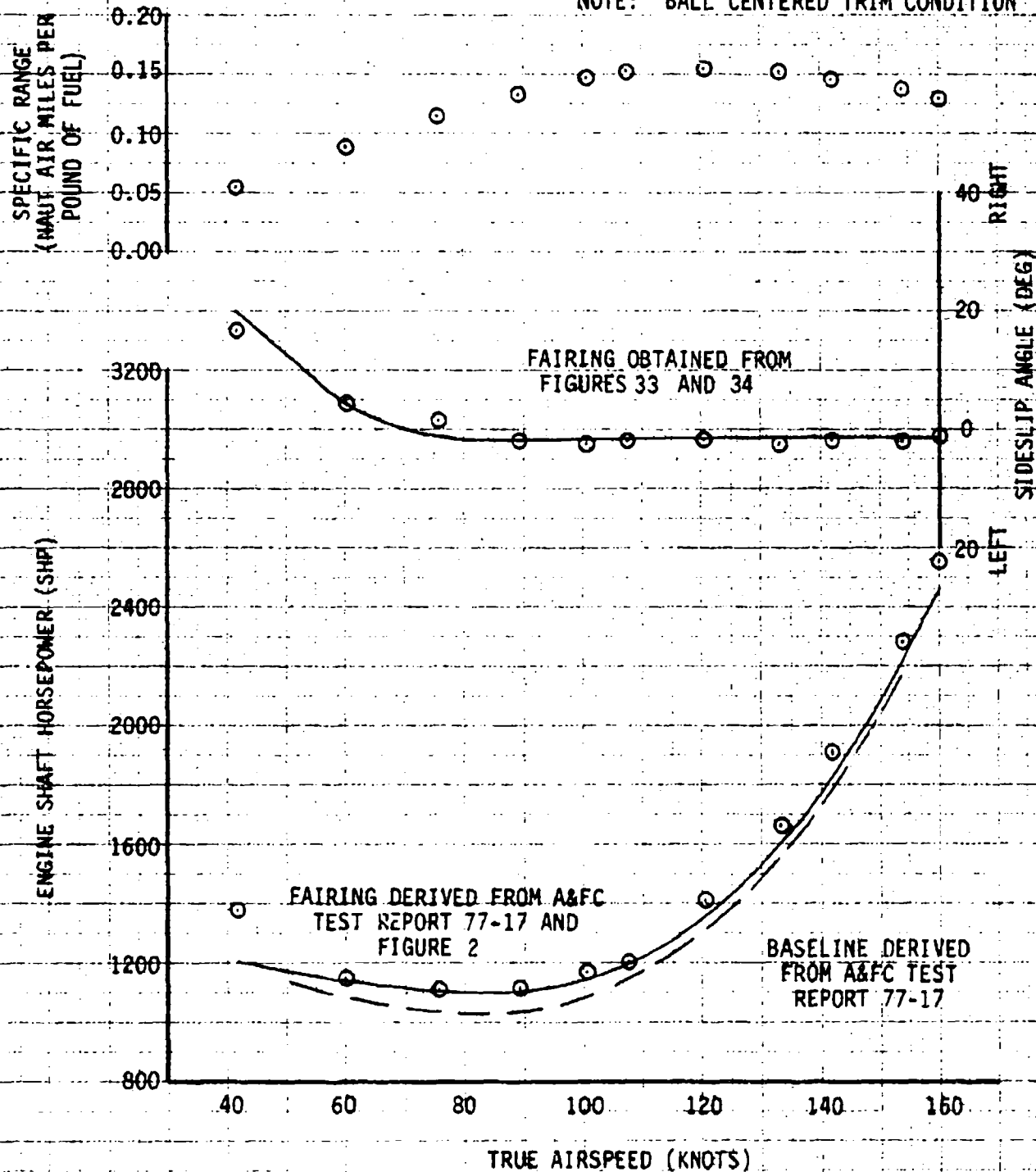


FIGURE 4
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT ($^{\circ}$ C) | AVG REFERRED ROTOR SPEED (RPM) | AVG $C_T \times 10^4$ | AIRCRAFT CONFIGURATION |
|-----------------------|-----------------|-----|---------------------------|-------------------------|--------------------------------|-----------------------|------------------------|
| LONG (FS) | LAT (BL) | | | | | | |
| 16,100 | 347.3 | 0.0 | 7660 | 10.5 | 258.0 | 72.86 | FIXED PROVISIONS |

NOTE: 1. BALL CENTERED TRIM CONDITION
2. THE BOOM SYSTEM WAS USED AS THE AIRSPEED SOURCE FOR THE NO. 2 STABILATOR AMPLIFIER

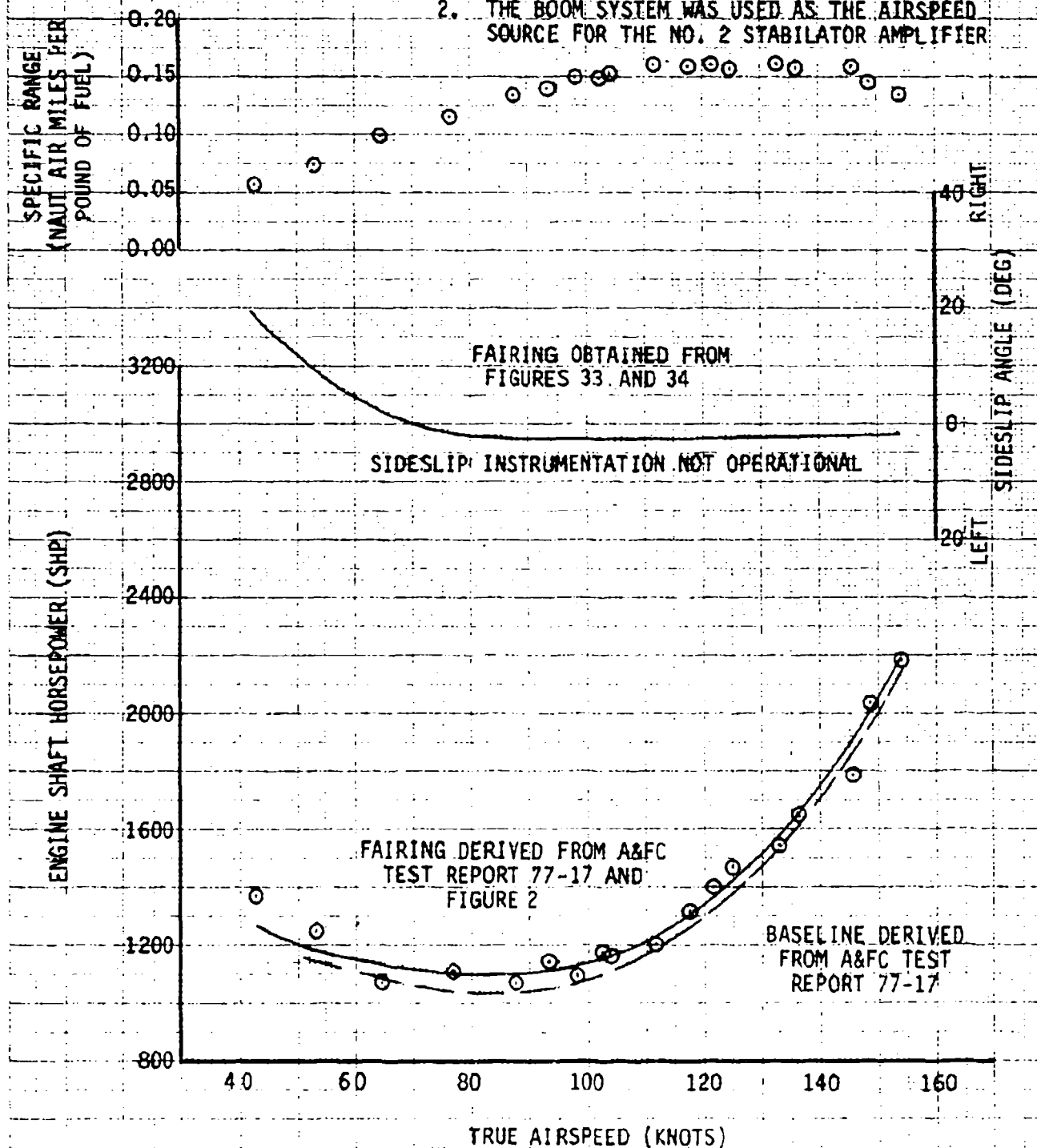


FIGURE 5
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT (° C) | AVG REFERRED ROTOR SPEED (RPM) | AVG $C_T \times 10^4$ | AIRCRAFT CONFIGURATION |
|-----------------------|-----------------|----------|---------------------------|---------------|--------------------------------|-----------------------|------------------------|
| 18,000 | LONG (FS) | LAT (BL) | 6880 | 8.5 | 257.9 | 80.10 | FIXED PROVISIONS |

NOTE: BALL CENTERED TRIM CONDITION

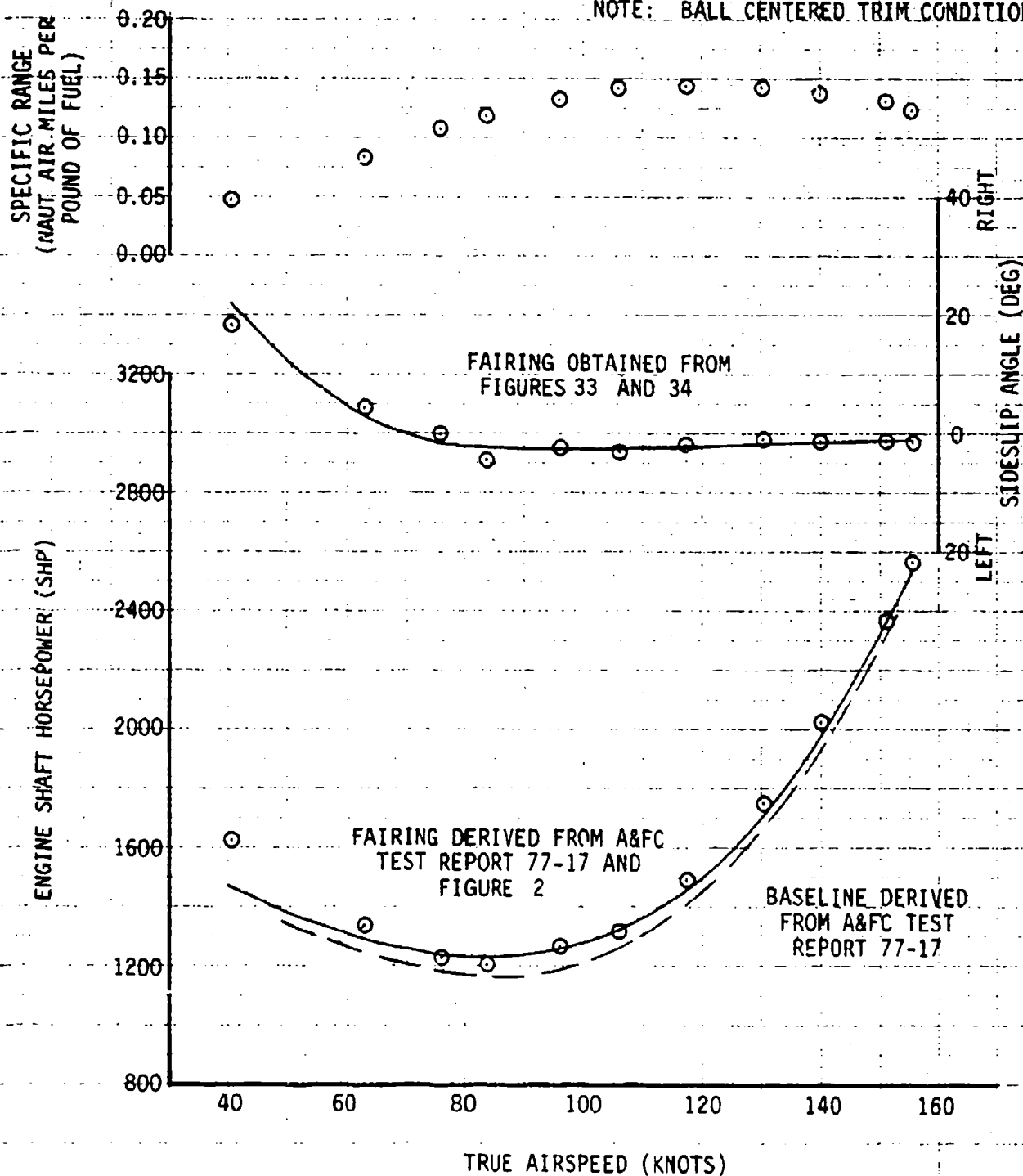


FIGURE 6
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT ($^{\circ}$ C) | AVG REFERRED ROTOR SPEED (RPM) | AVG $C_T \times 10^4$ | AIRCRAFT CONFIGURATION |
|-----------------------|-----------------|----------|---------------------------|-------------------------|--------------------------------|-----------------------|------------------------|
| 17,840 | LONG (FS) | LAT (BL) | 7680 | 13.0 | 257.9 | 80.14 | FIXED PROVISIONS |

- NOTE: 1. BALL CENTERED TRIM CONDITION
2. THE BOOM SYSTEM WAS USED AS THE AIRSPEED SOURCE FOR THE NO. 2 STABILATOR AMPLIFIER

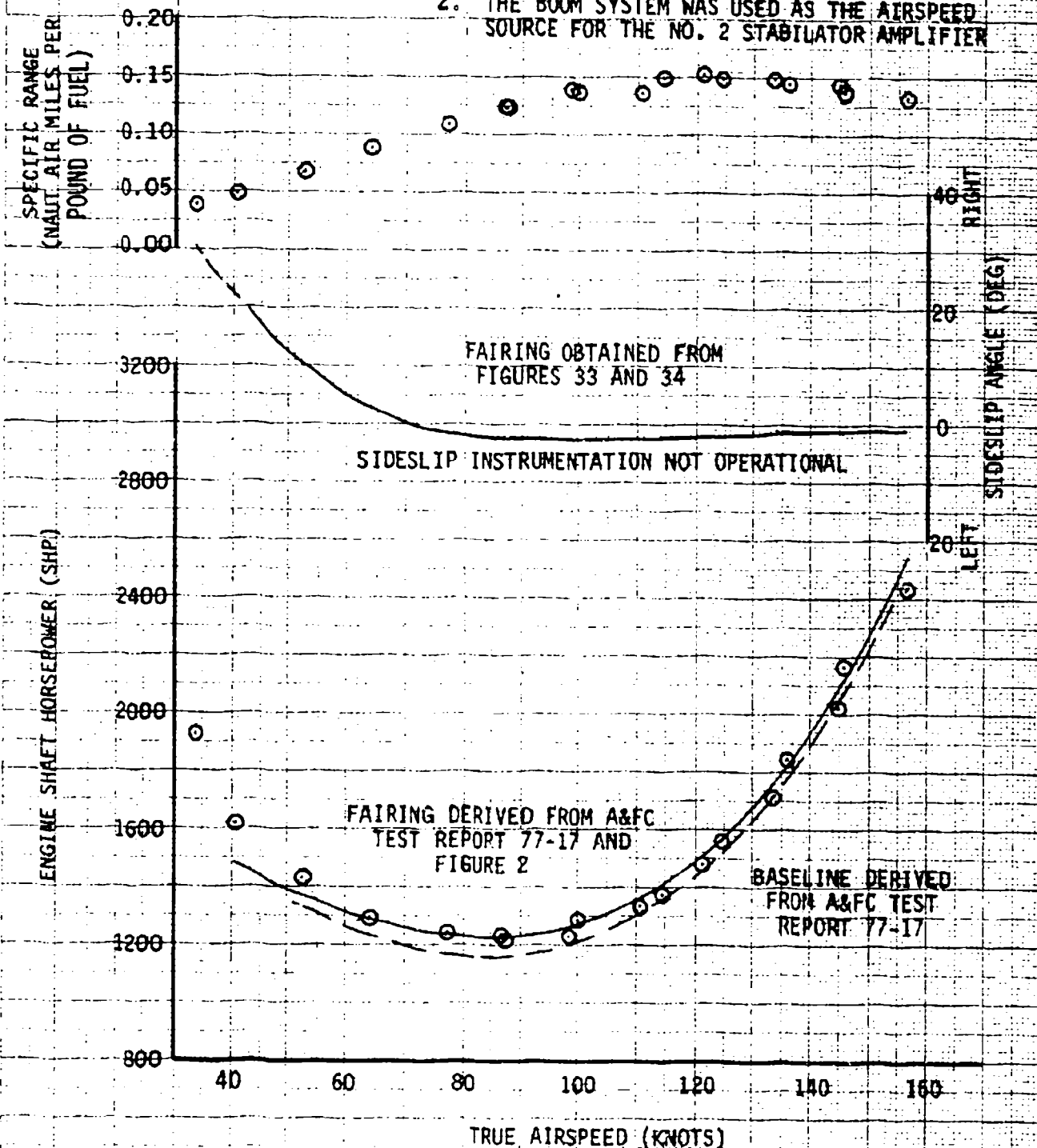


FIGURE 7
 DRAG CHANGE SUMMARY FOR ORIGINAL ESSS WITH FOUR TANKS
 UN-GOA USA S/N 77-22714

| CONFIGURATION | LONGITUDINAL CG LOCATION (FS) | THRUST COEFFICIENT $\times 10^4$ |
|-----------------|-------------------------------------|--|
| ORIGINAL ESSS | 349.7 | 69.91 |
| WITH FOUR TANKS | 350.2 | 80.23 |
| | 349.8 | 90.18 |

- NOTES:
1. BALL CENTERED TRIM CONDITION
 2. FAIRINGS DERIVED FROM FIGURES 8, 9 AND 10
 3. BASELINE ($\Delta C_D = 0$) IS THE ABTC DATA FOR THE NORMAL UTILITY CONFIGURATION NORMALIZED TO THE TEST AIRCRAFT (INHERENT SIDESLIP, CONFIGURATION DIFFERENCES, LONGITUDINAL CG AND UNEXPLAINED ΔC_D DIFFERENCE, FIGURE 2)

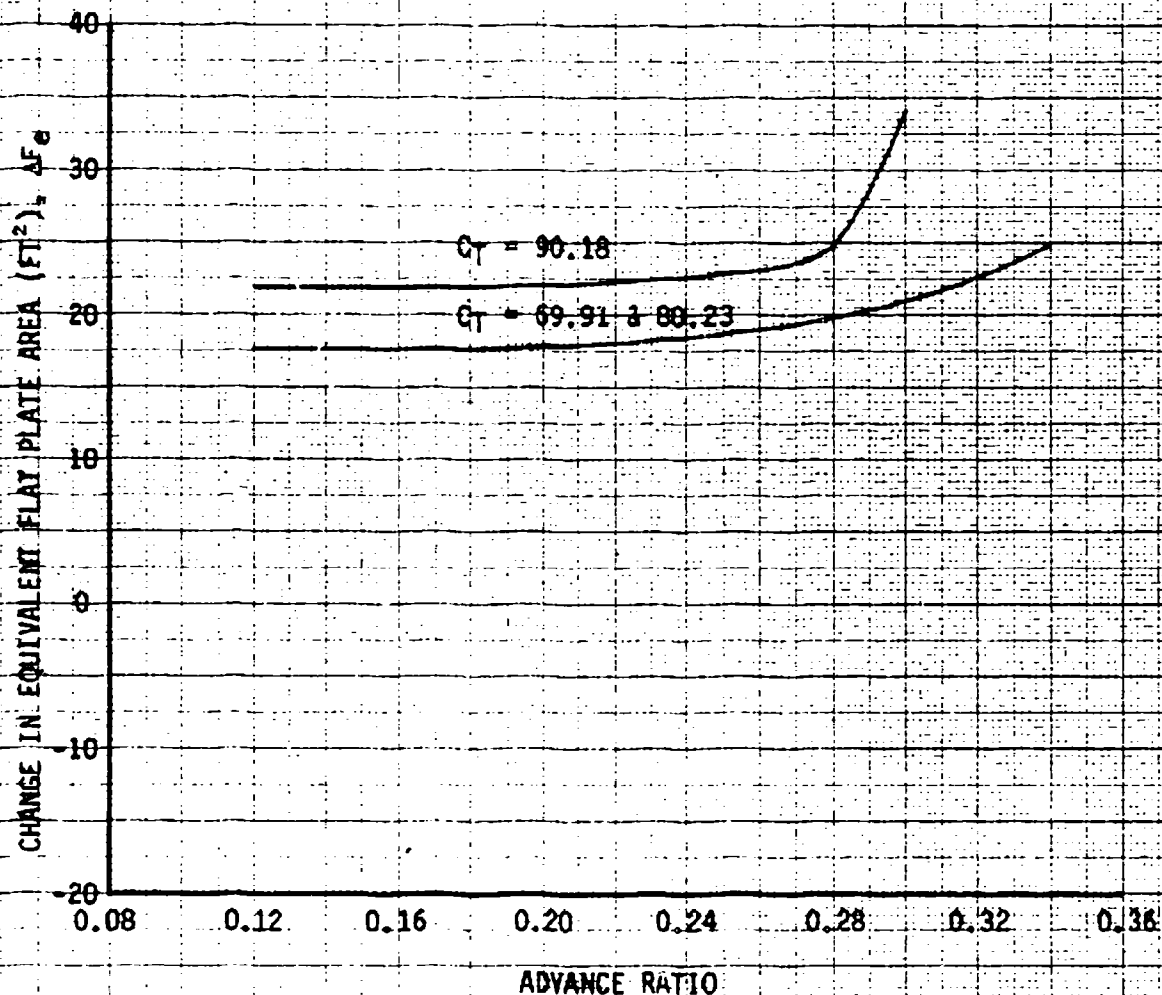


FIGURE 8
 NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
 UH-60A USA S/N 77-22714

CONFIGURATION: ORIGINAL ES55 WITH FOUR TANKS

- NOTES: 1. BALL-CENTERED TRIM CONDITION
 2. LONGITUDINAL CG (FS 350.0)
 3. MED LATERAL CG
 4. REFERRED ROTOR SPEED = 258 RPM
 5. POINTS DERIVED FROM FIGURES 11 THROUGH 15

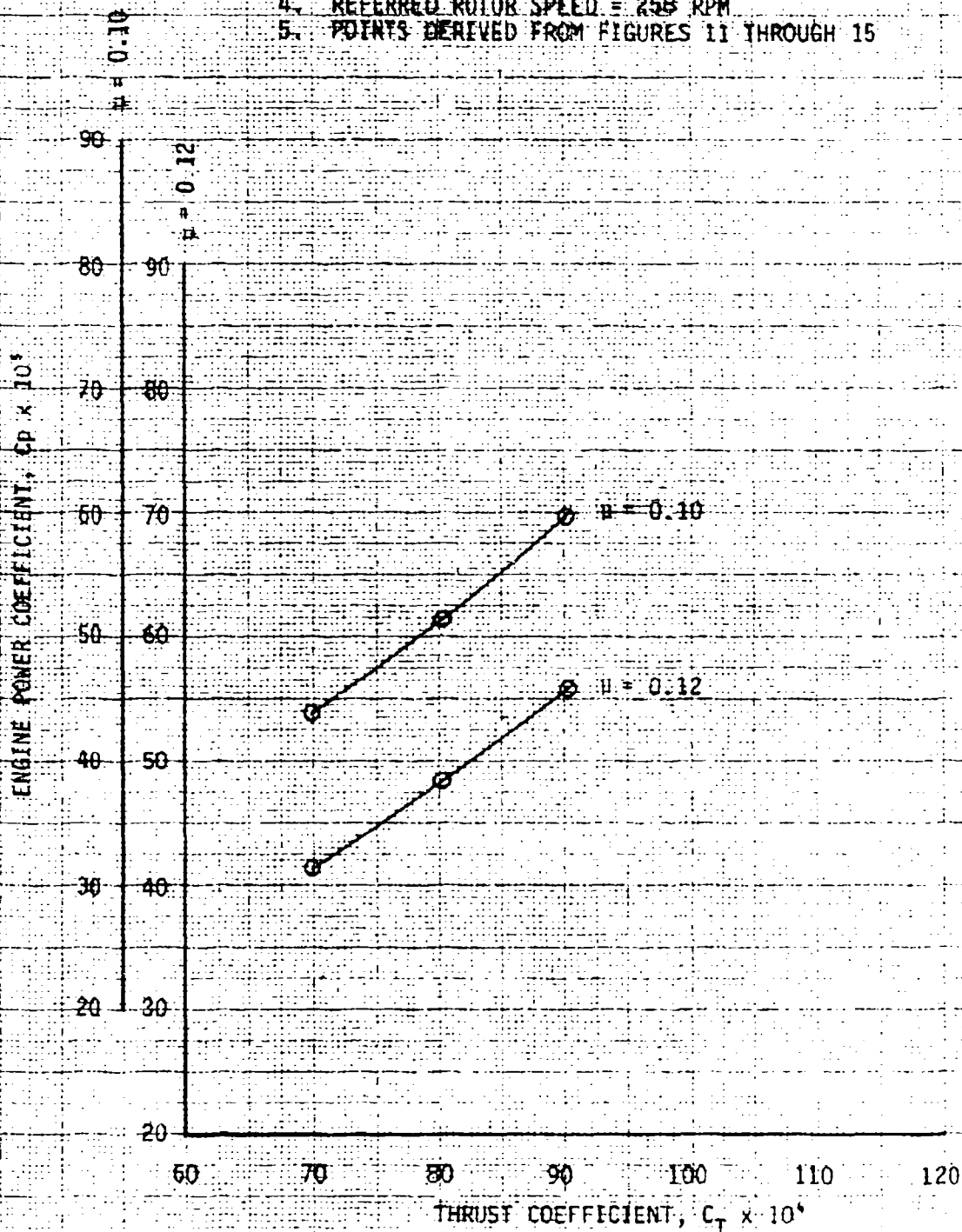


FIGURE 9
NONCONVENTIONAL LEVEL FLIGHT PERFORMANCE
ORIGINALLY BY N7-20714

CONFIGURATION: ORIGINAL CASE WITH FOUR TANKS

- NOTES: 1. WALL-CENTERED (W/C) CONDITION
2. LONGITUDINAL CASE (25-350-0)
3. MID-LATERAL CASE
4. ROTATED WING SPEED = 250 RPM
5. POINTS DERIVED FROM FIGURES 11 THROUGH 15

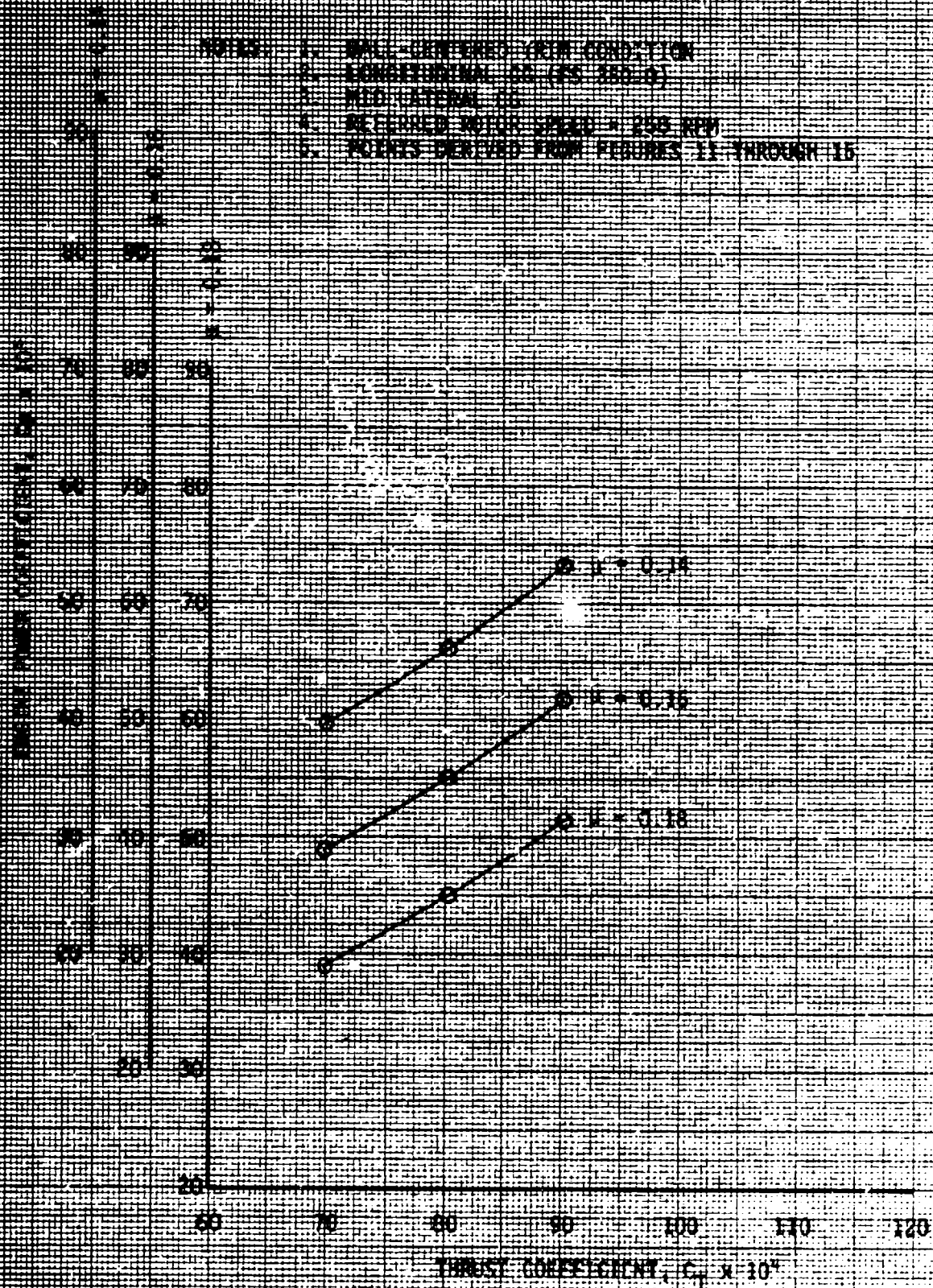


FIGURE 10
 NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
 OH-60A USA S/N 77-2271A

CONFIGURATION: ORIGINAL ESSS WITH FOUR TANKS

- NOTES: 1. BALL-CENTERED TRIM CONDITION
 2. LONGITUDINAL CG (FS 350.0)
 3. MID LATERAL CG
 4. REFERRED ROTOR SPEED = 250 RPM
 5. POINTS DERIVED FROM FIGURES 11 THROUGH 15

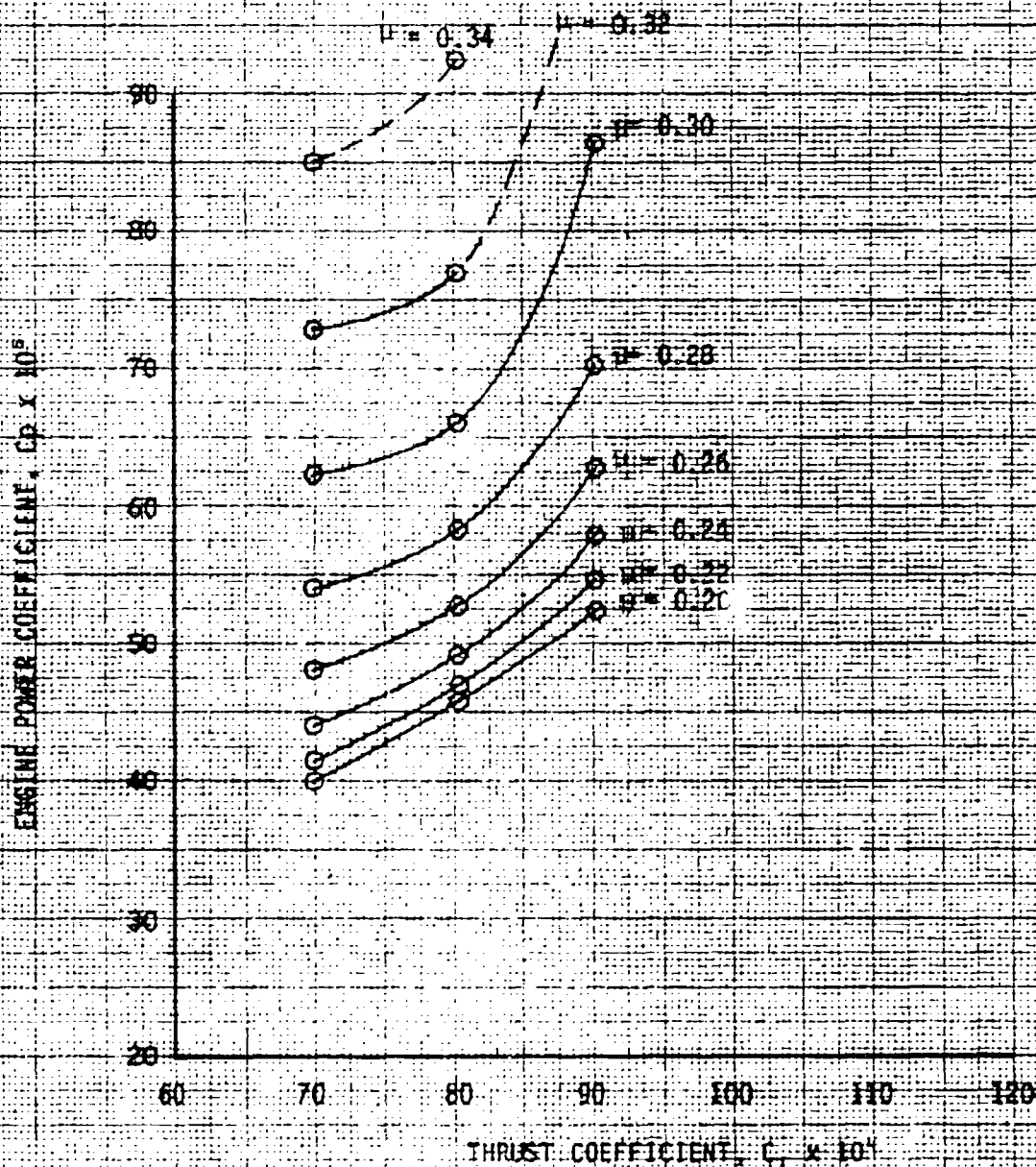


FIGURE 11
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT (°C) | AVG REFERRED ROTOR SPEED (RPM) | AVG $C_T \times 10^4$ | AIRCRAFT CONFIGURATION |
|-----------------------|-----------------|-----|---------------------------|--------------|--------------------------------|-----------------------|-------------------------------|
| LONG (FS) | LAT (BL) | | | | | | |
| 16,000 | 349.7 | 0.0 | 6540 | 10.0 | 258.3 | 69.92 | ORIGINAL ESSS WITH FOUR TANKS |

NOTE: BALL CENTERED TRIM CONDITION

SPECIFIC RANGE
(NAUT AIR MILES PER
POUND OF FUEL)

FUEL FLOW
INSTRUMENTATION NOT OPERATIONAL

ENGINE SHAFT HORSEPOWER (SHP)

FAIRING DERIVED FROM
FIGURES 8 THROUGH 10

FAIRING OBTAINED FROM
FIGURES 33 AND 34

BASELINE DERIVED
FROM A&FC TEST
REPORT 77-17

RIGHT

SIDESLIP ANGLE (DEG)

LEFT

TRUE AIRSPEED (KNOTS)

FIGURE 12
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT (° C) | AVG REFERRED ROTOR SPEED (RPM) | AVG CT x10 ⁶ | AIRCRAFT CONFIGURATION |
|--------------------------------|--------------------|-------------|------------------------------------|---------------------|---|-------------------------------|----------------------------------|
| 16,040 | LONG (FS) | LAT (BL) | 10,380 | 7.5 | 257.4 | 80.23 | ORIGINAL ESSS WITH FOUR TANKS |

NOTE: BALL CENTERED TRIM CONDITION

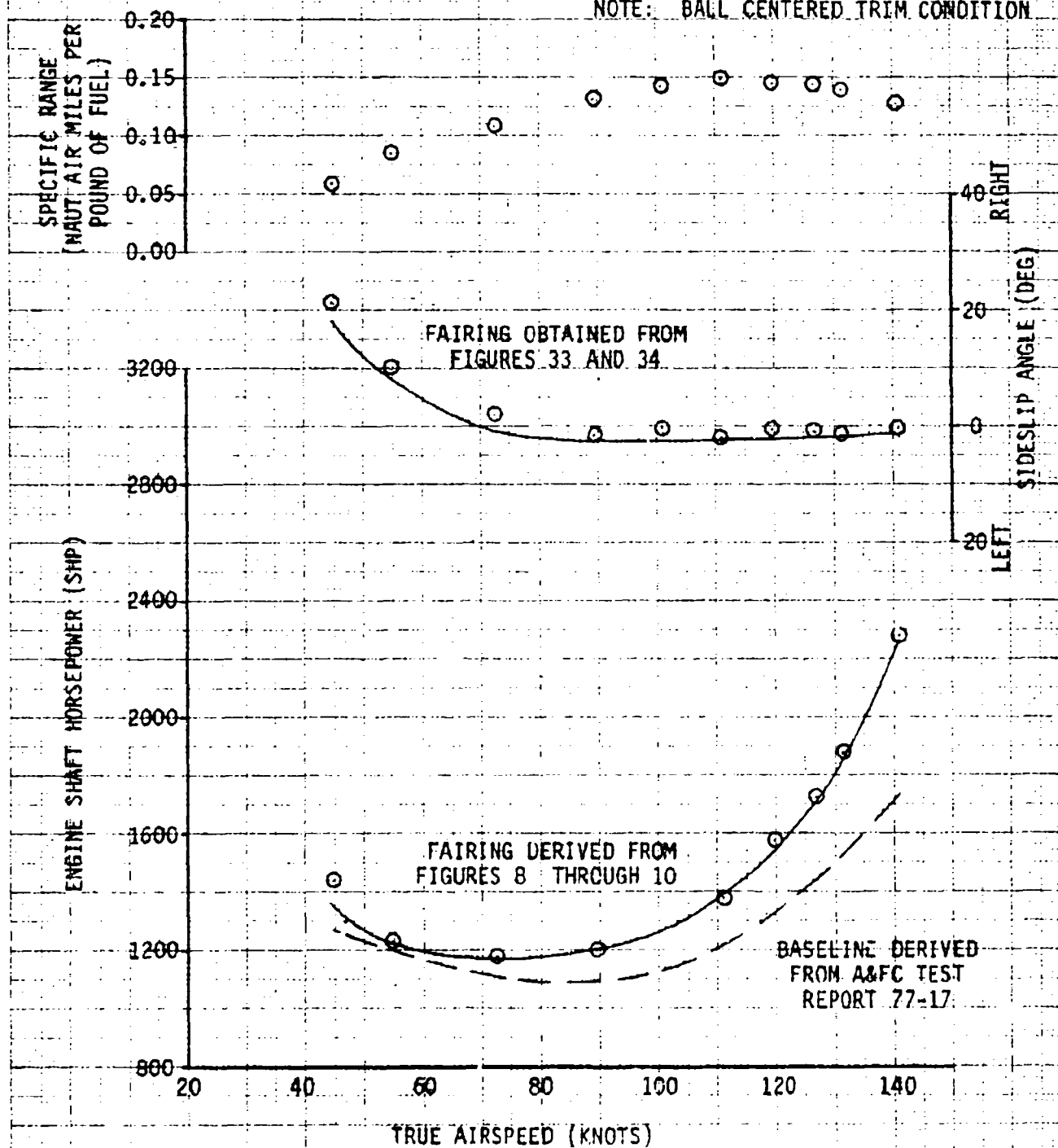


FIGURE 13
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT (°C) | AVG REFERRED ROTOR SPEED (RPM) | AVG C _T x10 ⁻⁴ | AIRCRAFT CONFIGURATION |
|--------------------------------|--------------------|-----|------------------------------------|--------------------|---|--|----------------------------------|
| LONG (FST) | LAT (BL) | | | | | | |
| 17,960 | 349.8 | 0.2 | 10,740 | 8.5 | 257.9 | 90.18 | ORIGINAL ESSS WITH FOUR TANKS |

NOTE: BALL CENTERED TRIM CONDITION

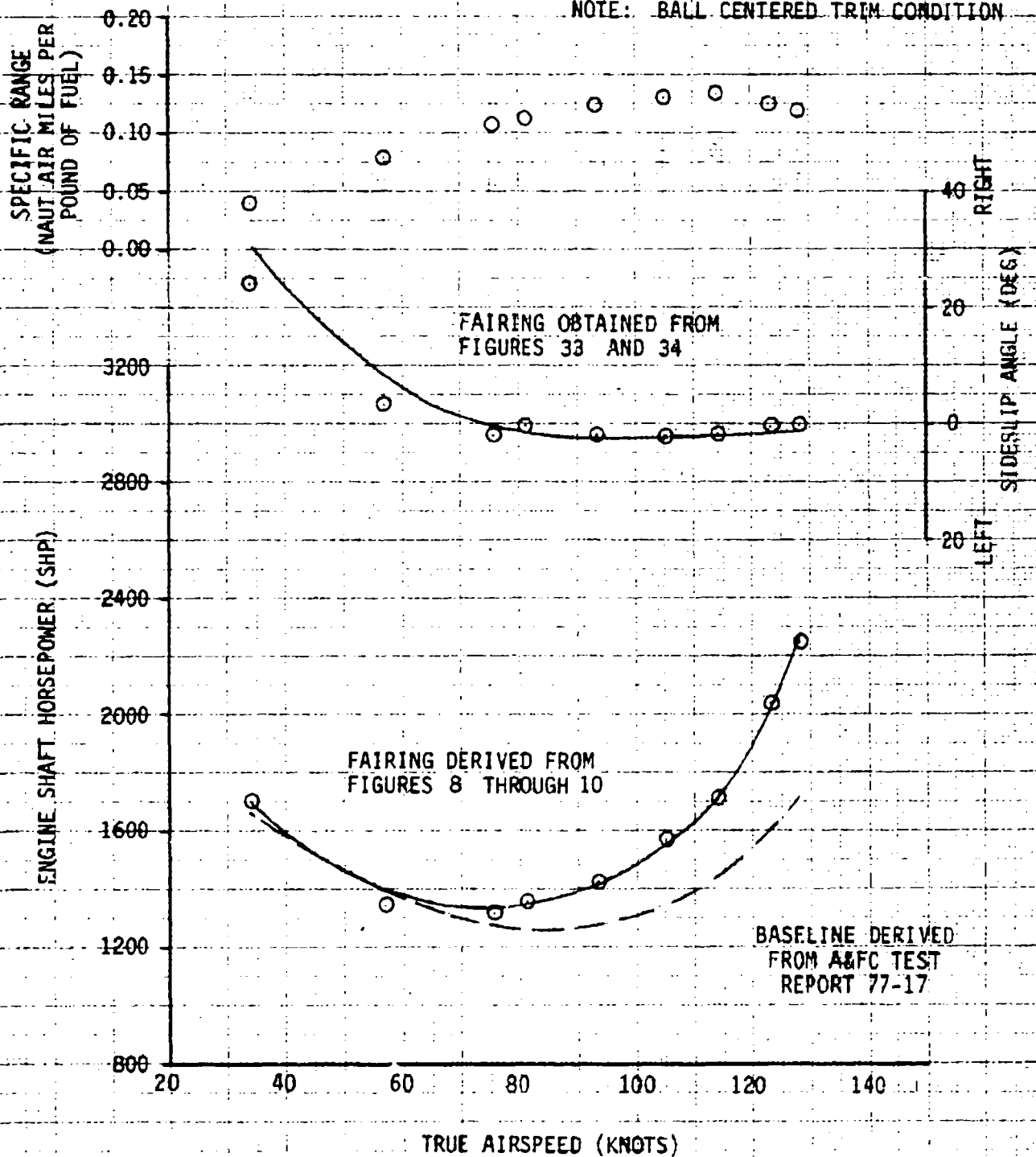


FIGURE 14
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT ($^{\circ}$ C) | AVG REFERRED ROTOR SPEED (RPM) | AVG CT $\times 10^3$ | AIRCRAFT CONFIGURATION |
|-----------------------|-----------------|------|---------------------------|-------------------------|--------------------------------|----------------------|-------------------------------|
| LONG (F8) | LAT (BL) | | | | | | |
| 17,960 | 343.0(FWD) | 0.2R | 10,740 | 7.5 | 258.4 | 90.15 | ORIGINAL PASS WITH FOUR TANKS |

NOTE: BALL CENTERED TRIM CONDITION

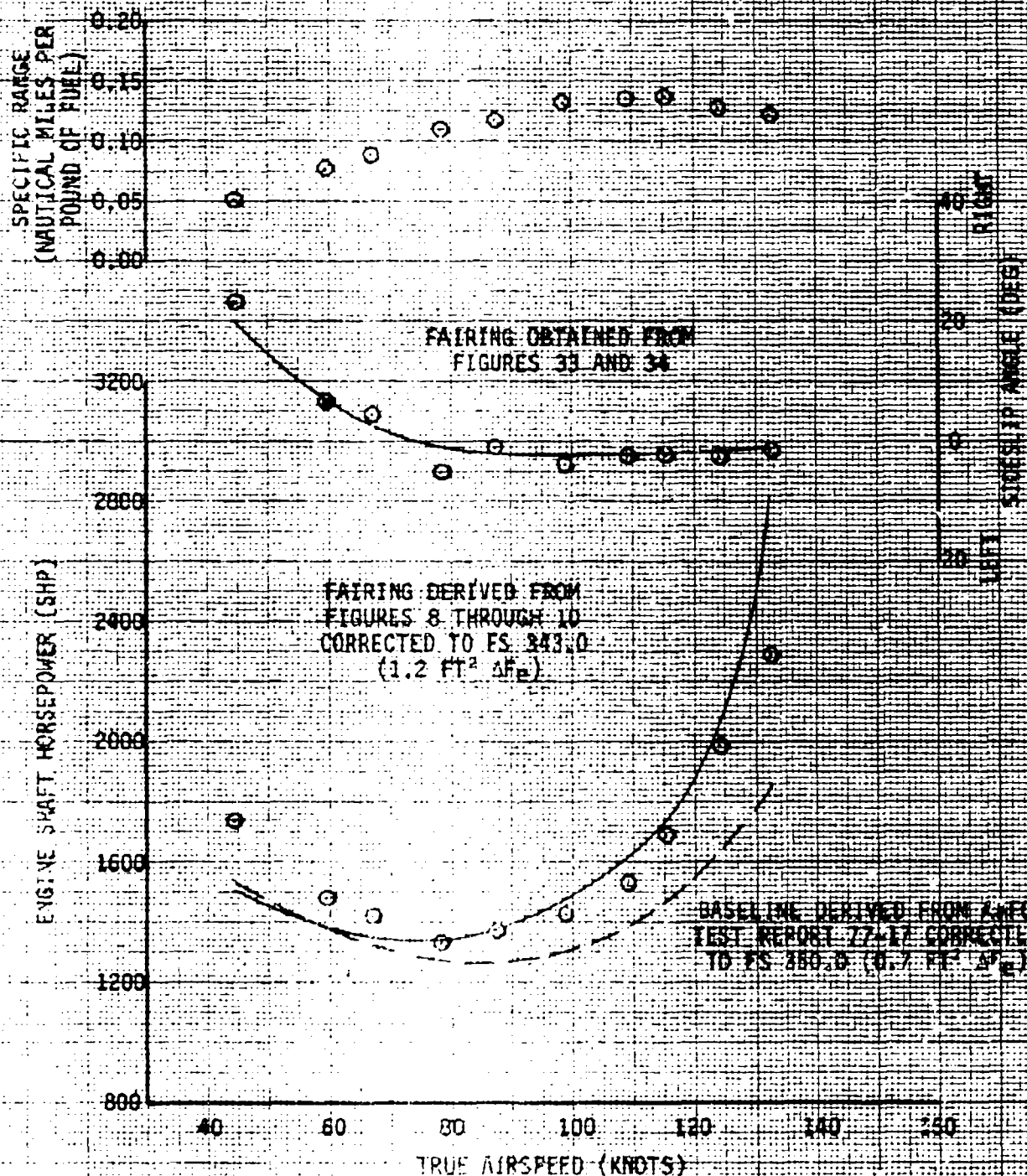


FIGURE 15
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22710

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION LONG (FS) | AVG CG LOCATION LAT (DEG) | AVG DENSITY ALTITUDE (FT) | AVG WIND (KT) | AVG REVERSED ROTOR SPEED (RPM) | AVG $C_T \times 10^4$ | AIRCRAFT CONFIGURATION |
|-----------------------|---------------------------|---------------------------|---------------------------|---------------|--------------------------------|-----------------------|-------------------------------|
| 24,580 | 343.3 (END) | 0.2R | 1380 | 16.5 | 257.3 | 90.61 | ORIGINAL ESSS WITH FOUR TANKS |

NOTE: BALL CENTERED TRIM CONDITION

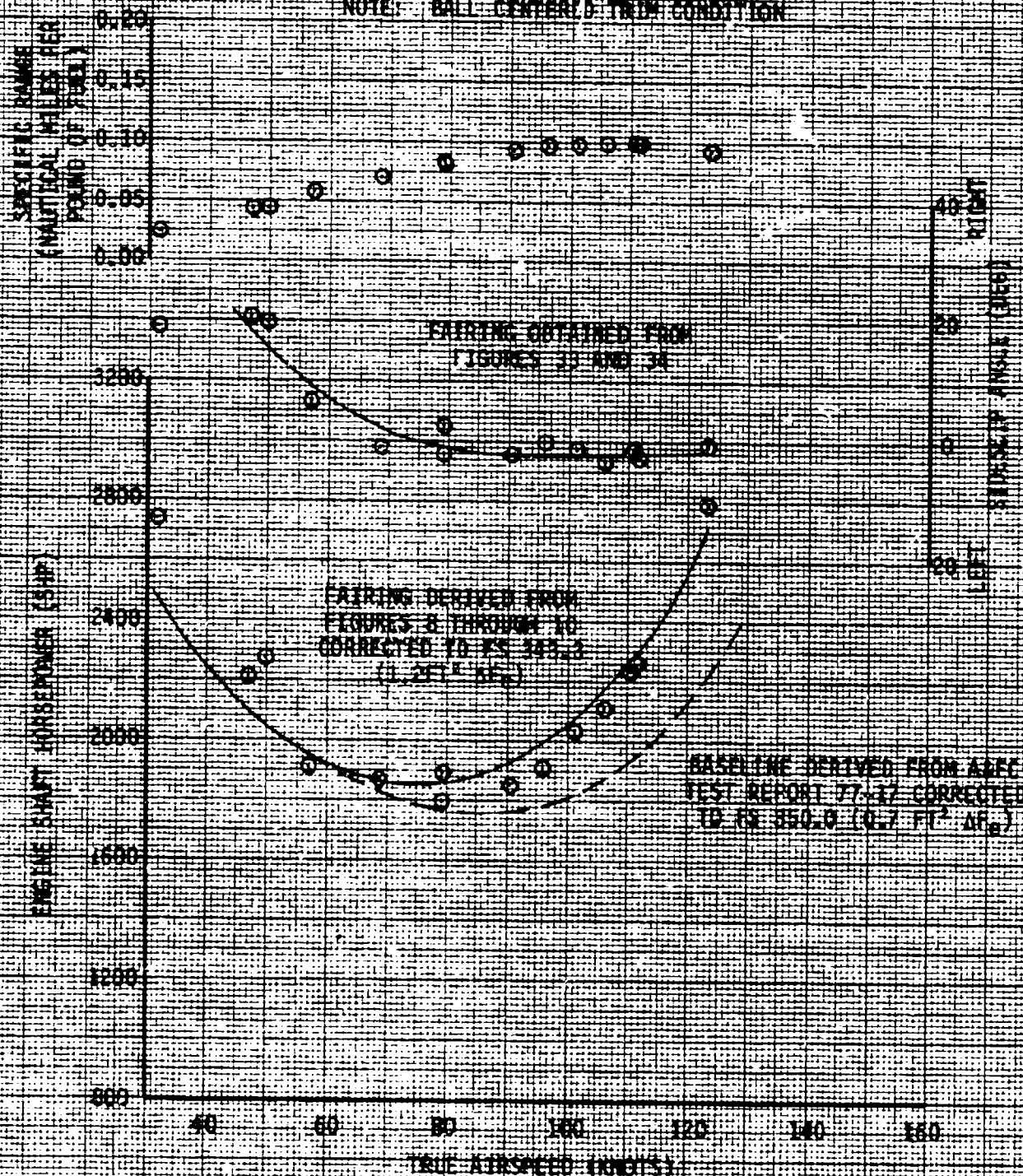


FIGURE 16
 DRAG CHANGE SUMMARY FOR MODIFIED ESSS WITH FOUR TANKS
 ON RMA USA S/N 77-22714

| CONFIGURATION | LONGITUDINAL CG LOCATION (FS) | THRUST COEFFICIENT $\times 10^4$ |
|-----------------|-------------------------------------|--|
| MODIFIED ESSS | 349.9 | 70.08 |
| WITH FOUR TANKS | 350.0 | 79.86 |
| | 350.0 | 90.38 |
| | 350.3 | 100.16 |

- NOTES:
1. WING CENTERED TRIM CONDITION
 2. KATINGS DERIVED FROM FIGURES 17, 18 AND 19
 3. BASELINE ($\Delta F_D = 0$) IS THE A&FC DATA FOR THE NORMAL UTILITY CONFIGURATION NORMALIZED TO THE TEST AIRCRAFT (INHERENT SIDELIP, CONFIGURATION DIFFERENCES, LONGITUDINAL CG AND UNEXPLAINED ΔF_D DIFFERENCE, FIGURE 2)
 4. DATA AT $C_T = 90.38$ CORRECTED FOR CG DIFFERENCE TO FS 350.0

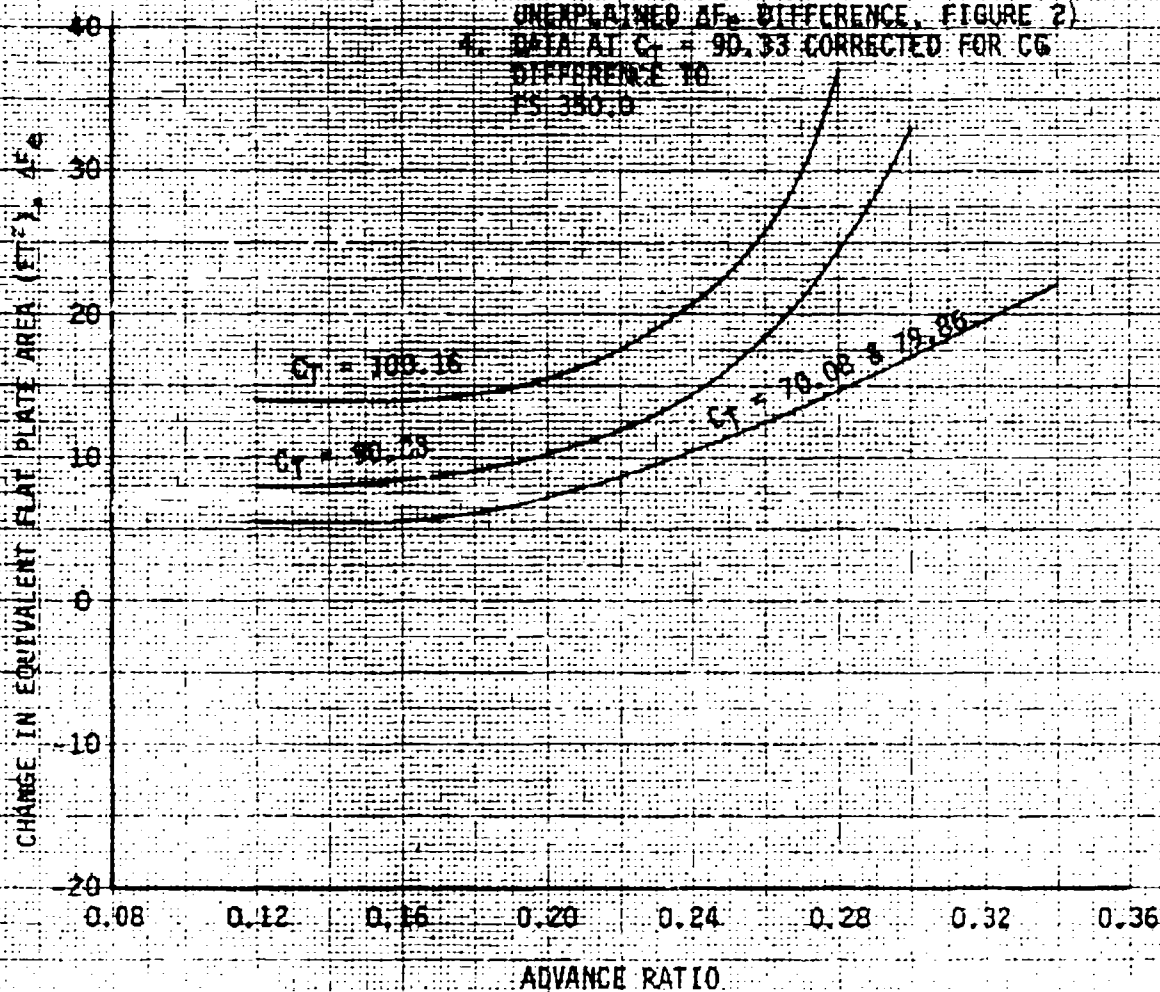


FIGURE 17
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

CONFIGURATION: MODIFIED ESSS WITH FOUR TANKS

- NOTES: 1. BALL-CENTERED TRIM CONDITION
2. LONGITUDINAL CG (FS 350.0)
3. MID LATERAL CG
4. REFERRED ROTOR SPEED = 258 RPM
5. POINTS DERIVED FROM FIGURES 20 THROUGH 23

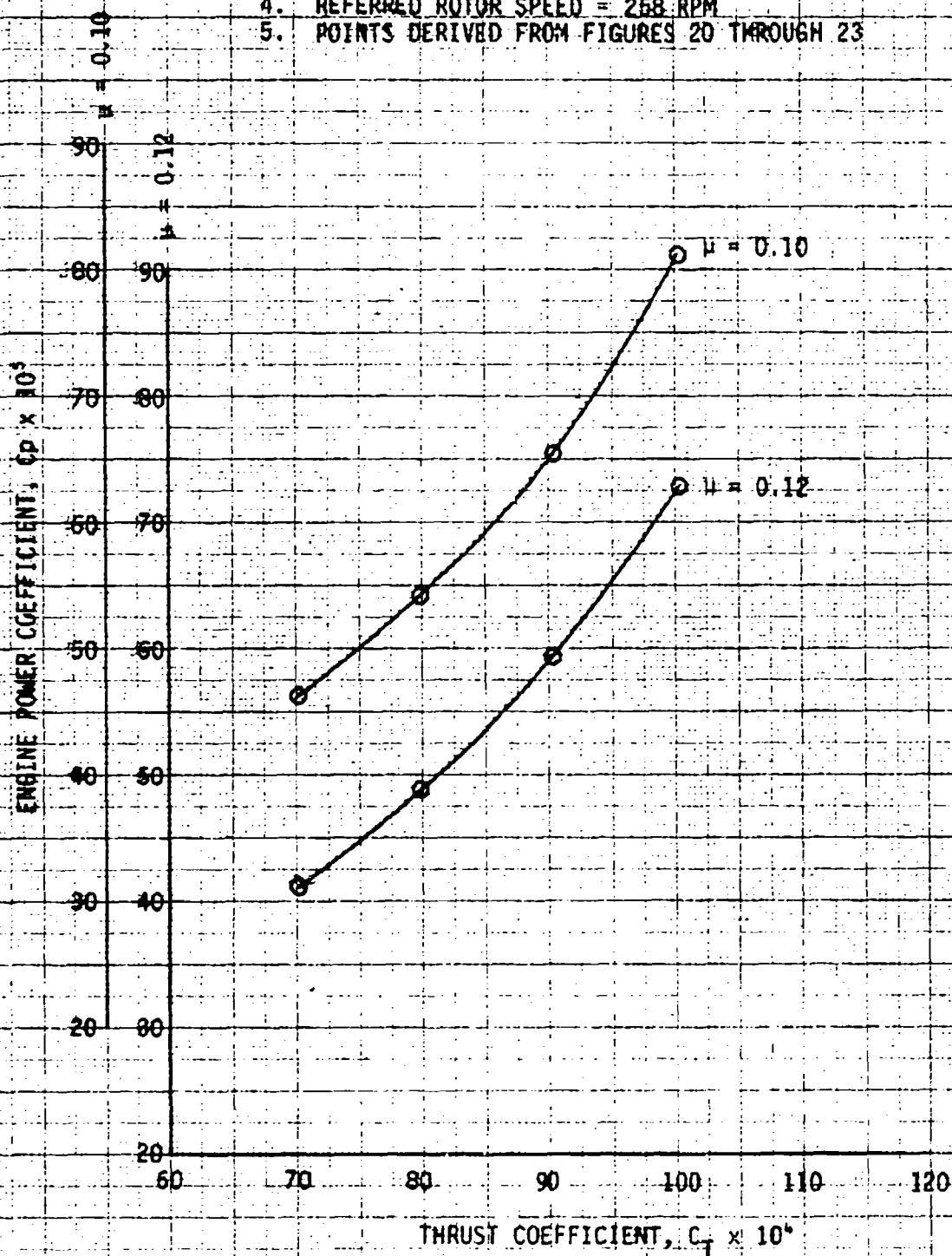


FIGURE 18
 NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
 UH-60A USA S/N 77-22714

CONFIGURATION: MODIFIED ESSS WITH FOUR TANKS

- NOTES:
1. BALL-CENTERED TRIM CONDITION
 2. LONGITUDINAL CG (FS 350.0)
 3. MID LATERAL CG
 4. REFERRED ROTOR SPEED = 258 RPM
 5. POINTS DERIVED FROM FIGURES 20 THROUGH 23

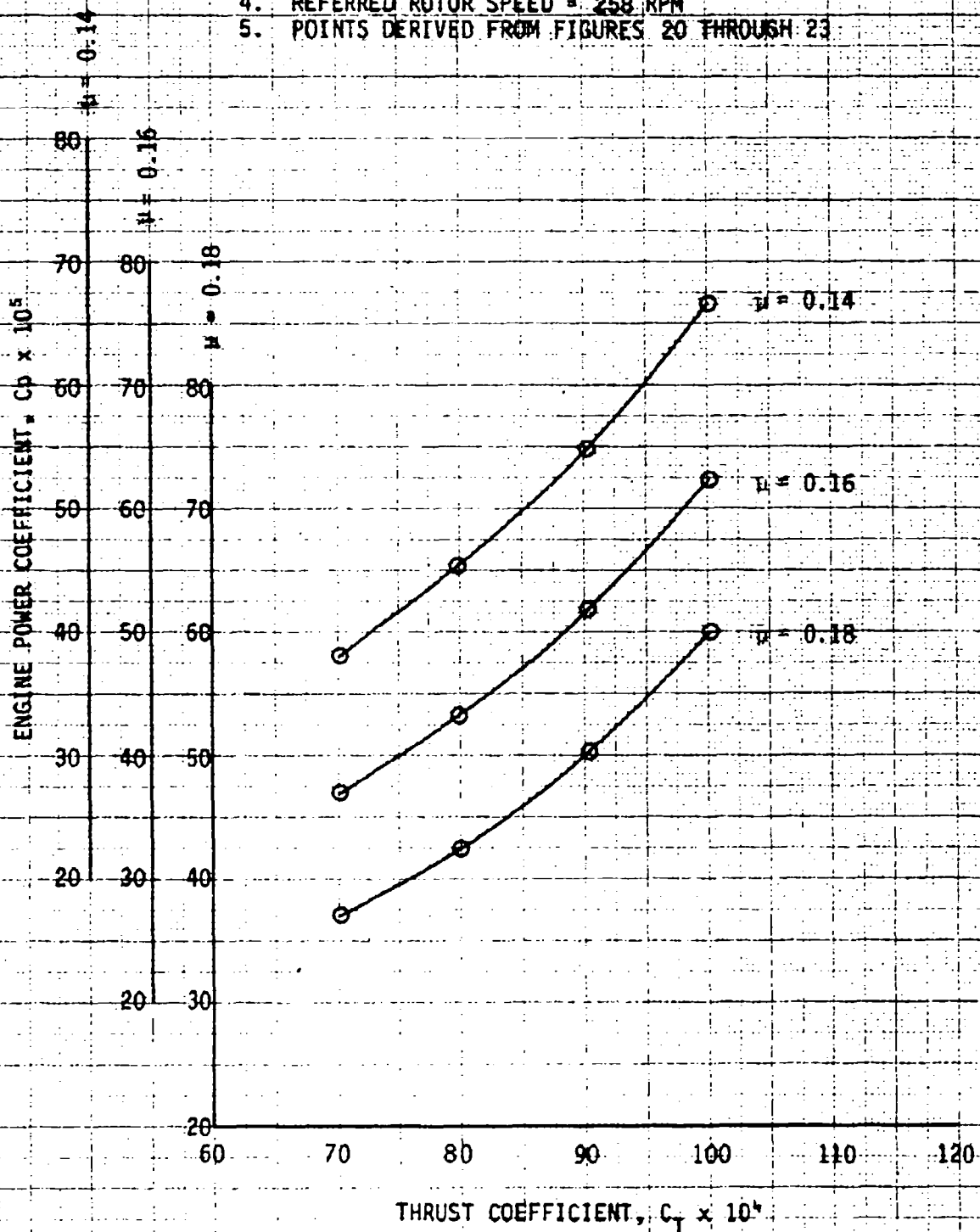


FIGURE 19
 NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
 UH-60A USA S/N 77-22714

CONFIGURATION: MODIFIED ESSS WITH FOUR TANKS

- NOTES:
1. BALL-CENTERED TRIM CONDITION
 2. LONGITUDINAL CG (FS 350.0)
 3. MID LATERAL CG
 4. REFERRED ROTOR SPEED = 258 RPM
 5. POINTS DERIVED FROM FIGURES 20 THROUGH 23

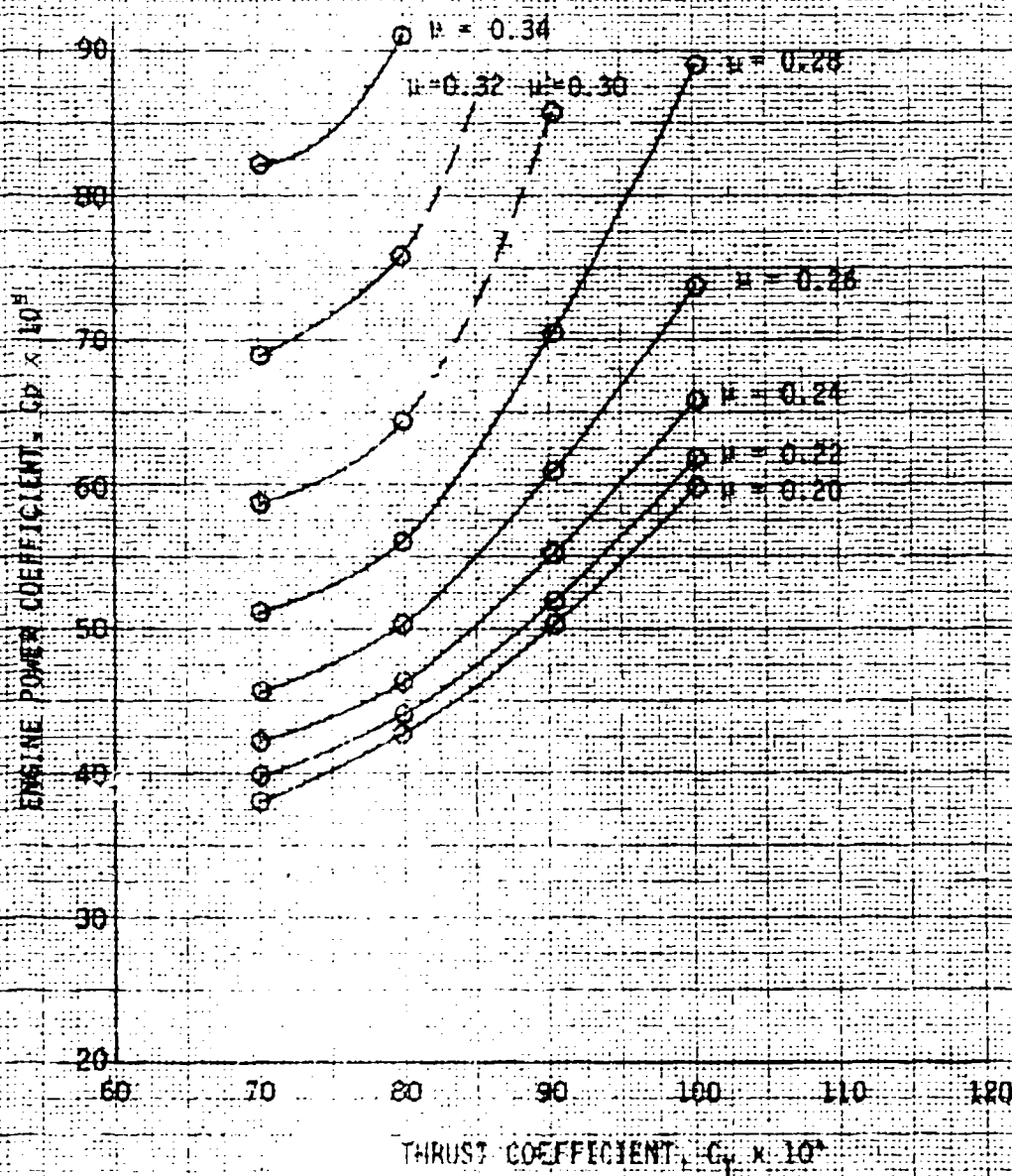


FIGURE 20
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT (°C) | AVG REFERRED ROTOR SPEED (RPM) | AVG $C_T \times 10^4$ | AIRCRAFT CONFIGURATION |
|-----------------------|-----------------|-----------|---------------------------|--------------|--------------------------------|-----------------------|-------------------------------|
| 16,080 | 349.9 (PS) | 0.2R (BL) | 5920 | 6.5 | 257.8 | 70.08 | MODIFIED ESSS WITH FOUR TANKS |

NOTE: BALL CENTERED TRIM CONDITION

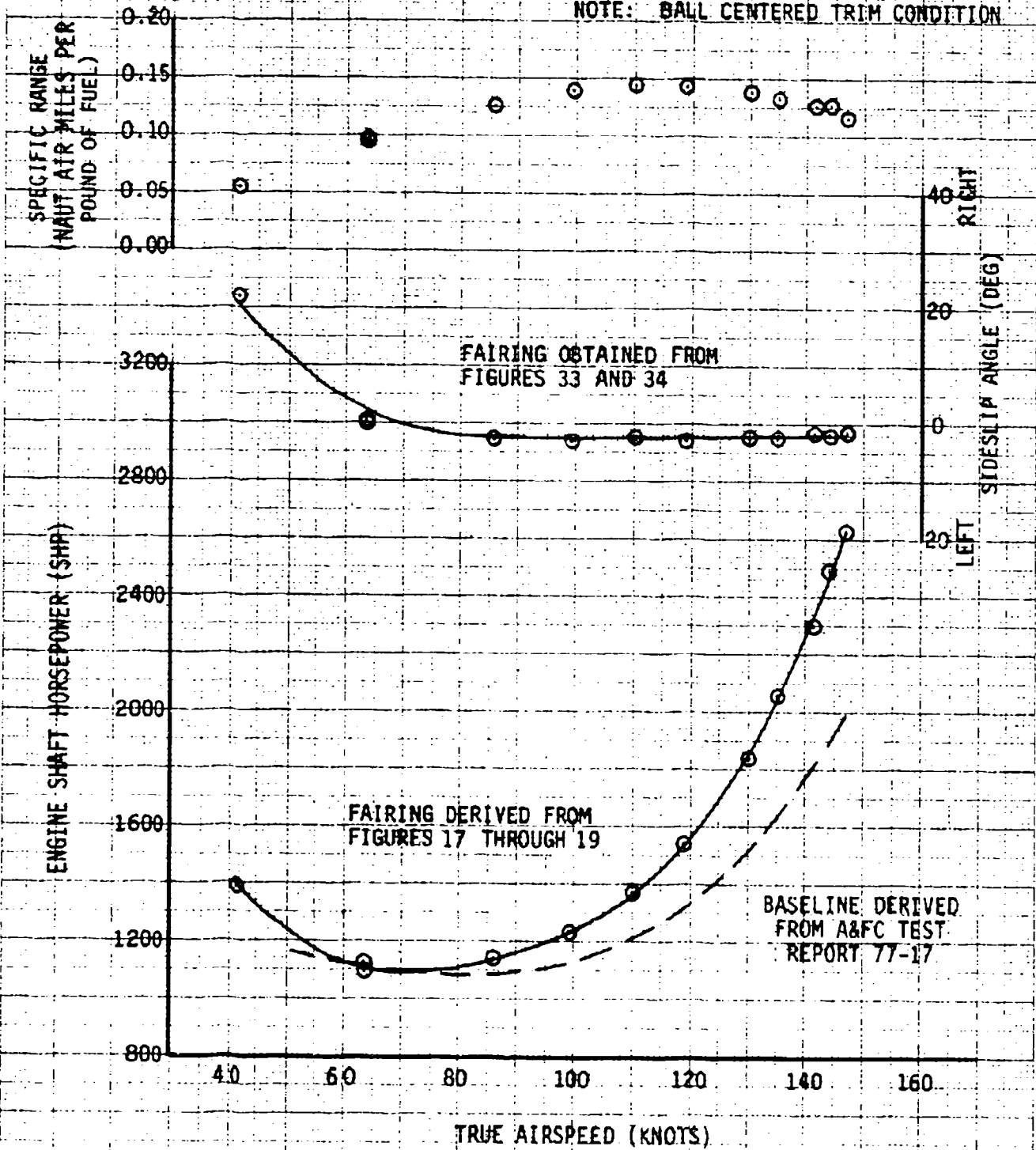


FIGURE 21
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT (°C) | AVG REFERRED ROTOR SPEED (RPM) | AVG $C_T \times 10^4$ | AIRCRAFT CONFIGURATION |
|-----------------------|-----------------|----------|---------------------------|--------------|--------------------------------|-----------------------|-------------------------------|
| (LB) | LONG (FS) | LAT (BL) | (FT) | (°C) | (RPM) | $\times 10^4$ | |
| 16,080 | 350.0 | 0.1R | 9640 | 1.5 | 258.1 | 79.86 | MODIFIED ESSS WITH FOUR TANKS |

NOTE: BALL CENTERED TRIM CONDITION

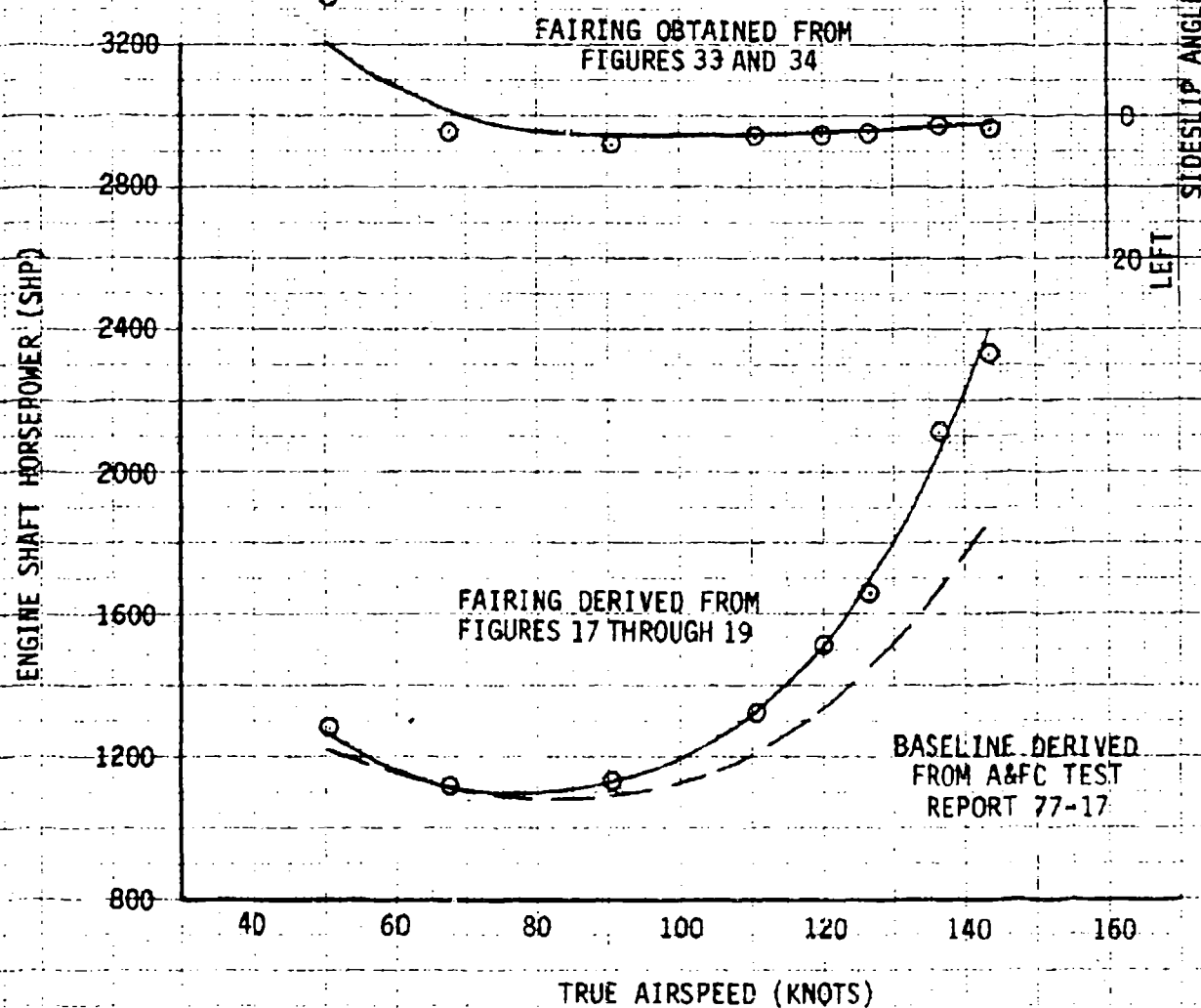
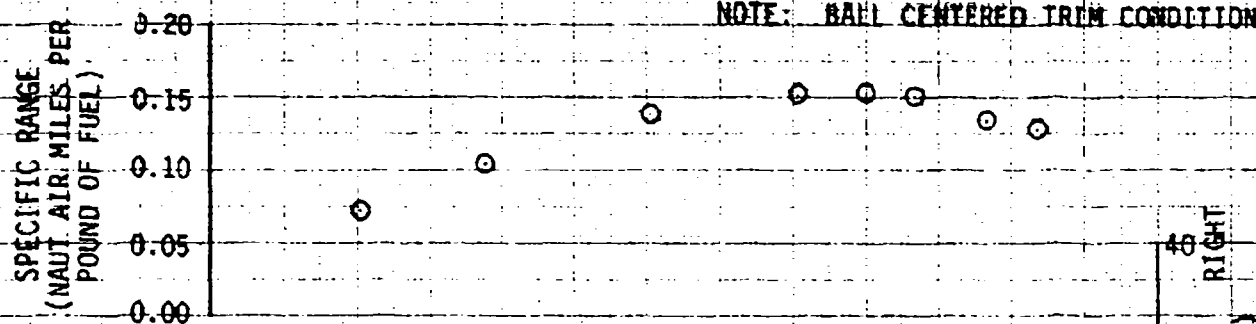


FIGURE 22
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

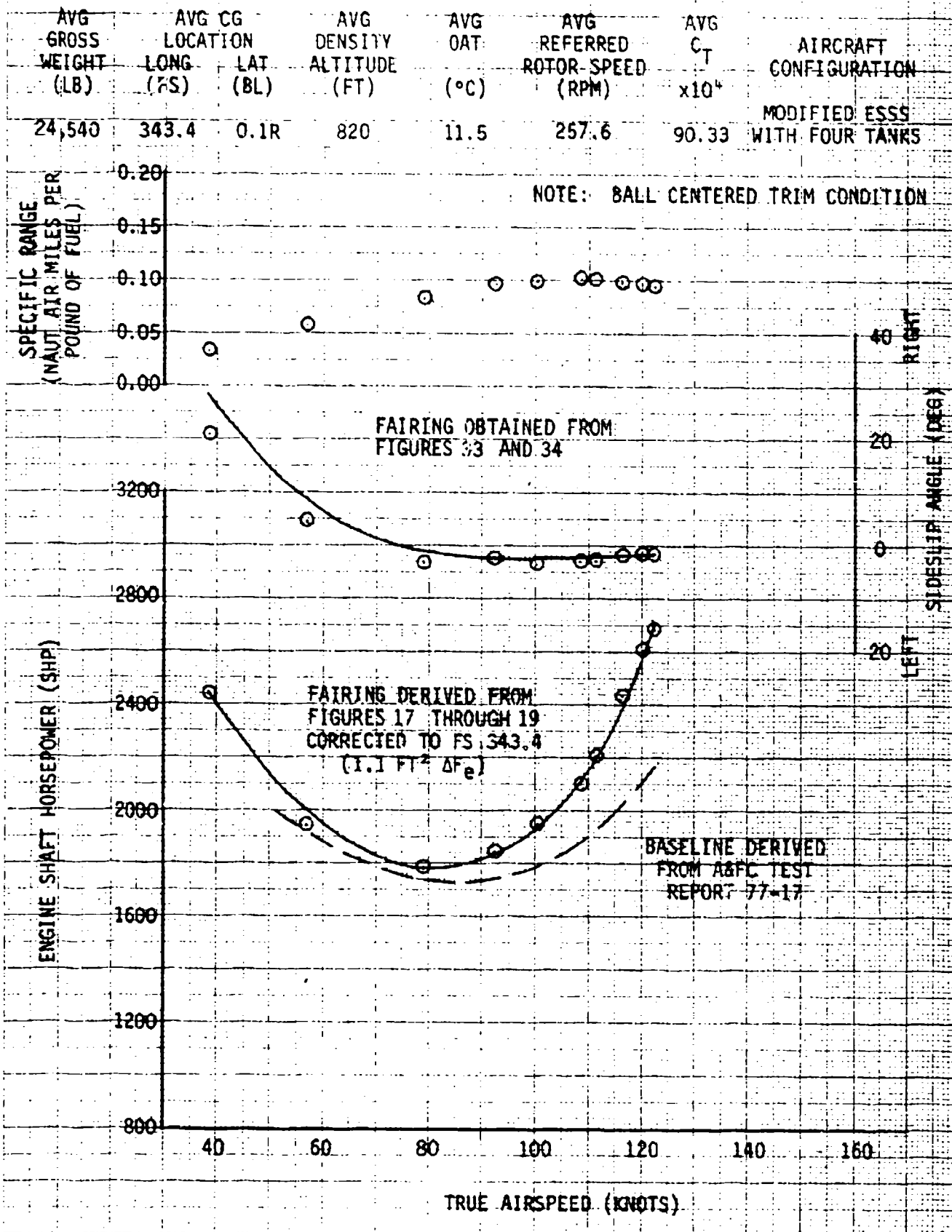


FIGURE 23
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT (°C) | AVG REFERRED ROTOR SPEED (RPM) | AVG $C_T \times 10^4$ | AIRCRAFT CONFIGURATION |
|-----------------------|-----------------|------|---------------------------|--------------|--------------------------------|-----------------------|-------------------------------|
| LONG (°S) | LAT (°N) | | | | | | |
| 22,480 | 350.3 | 0.2R | 6420 | 4.0 | 258.0 | 100.16 | MODIFIED ESSS WITH FOUR TANKS |

NOTE: BALL CENTERED TRIM CONDITION

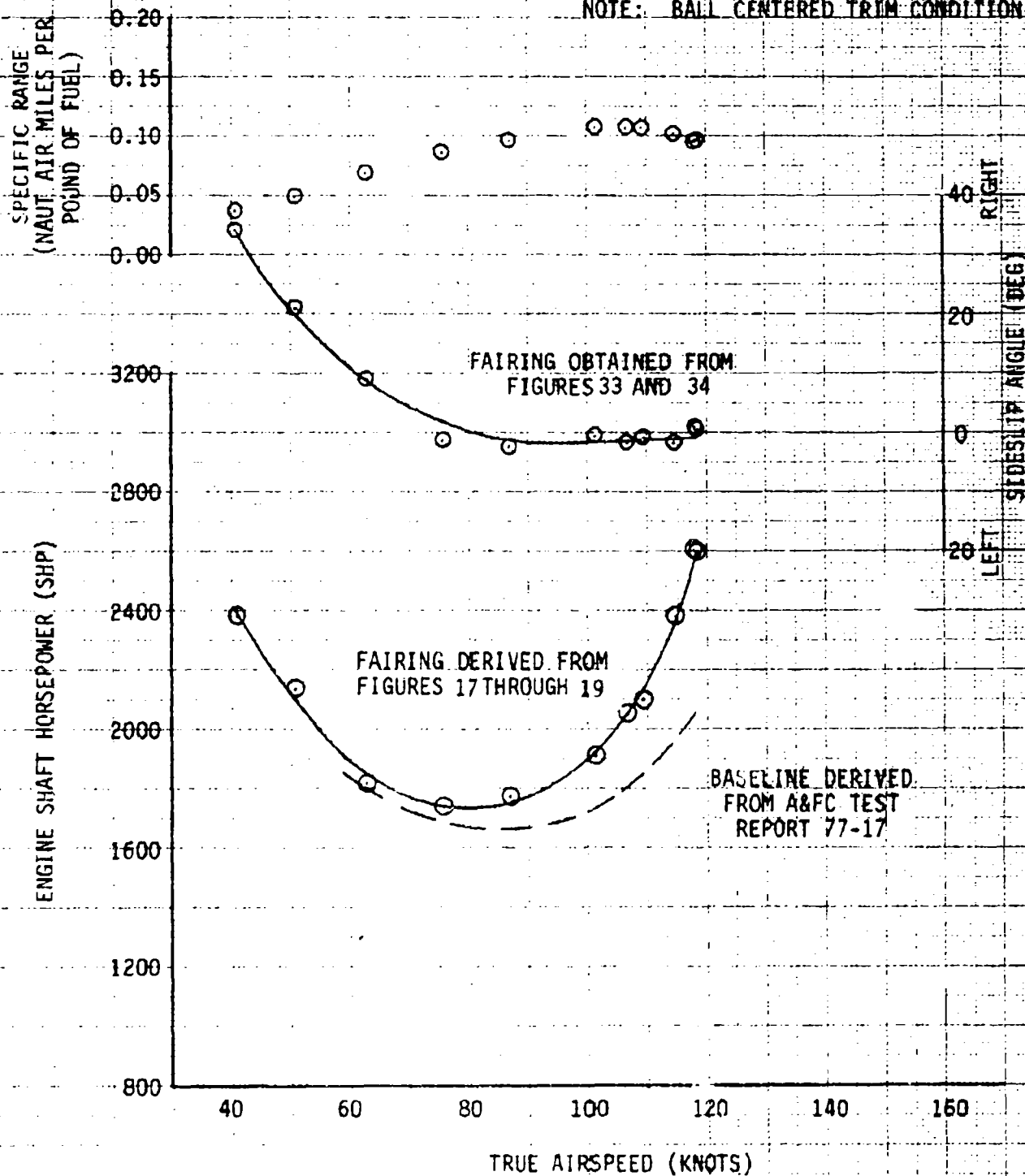


FIGURE 24
DRAG CHANGE SUMMARY FOR ORIGINAL ESSS ONLY AND WITH TWO TANKS
 UH-64A USA S/N 77-22714

| CONFIGURATION | LONGITUDINAL CG LOCATION (FS) | THRUST COEFFICIENT $\times 10^4$ |
|---------------------------------|-------------------------------------|--|
| ORIGINAL ESSS WITH NO STORES | 346.9 | 70.20 |
| | 347.0 | 80.32 |
| ORIGINAL ESSS WITH TWO TANKS | 346.7 | 70.14 |
| | 347.0 | 80.24 |
| | 347.2 | 90.18 |

- NOTES: 1. BALL CENTERED TRIM CONDITION
 2. FAIRINGS DERIVED FROM FIGURES 25 THROUGH 27 AND 31 AND 32
 3. BASELINE ($\Delta F_e = 0$) IS THE A&EC DATA FOR THE NORMAL UTILITY CONFIGURATION NORMALIZED TO THE TEST AIRCRAFT (INHERENT SIDESLIP, CONFIGURATION DIFFERENCES, LONGITUDINAL CG AND UNEXPLAINED ΔF_e DIFFERENCE, FIGURE 2)

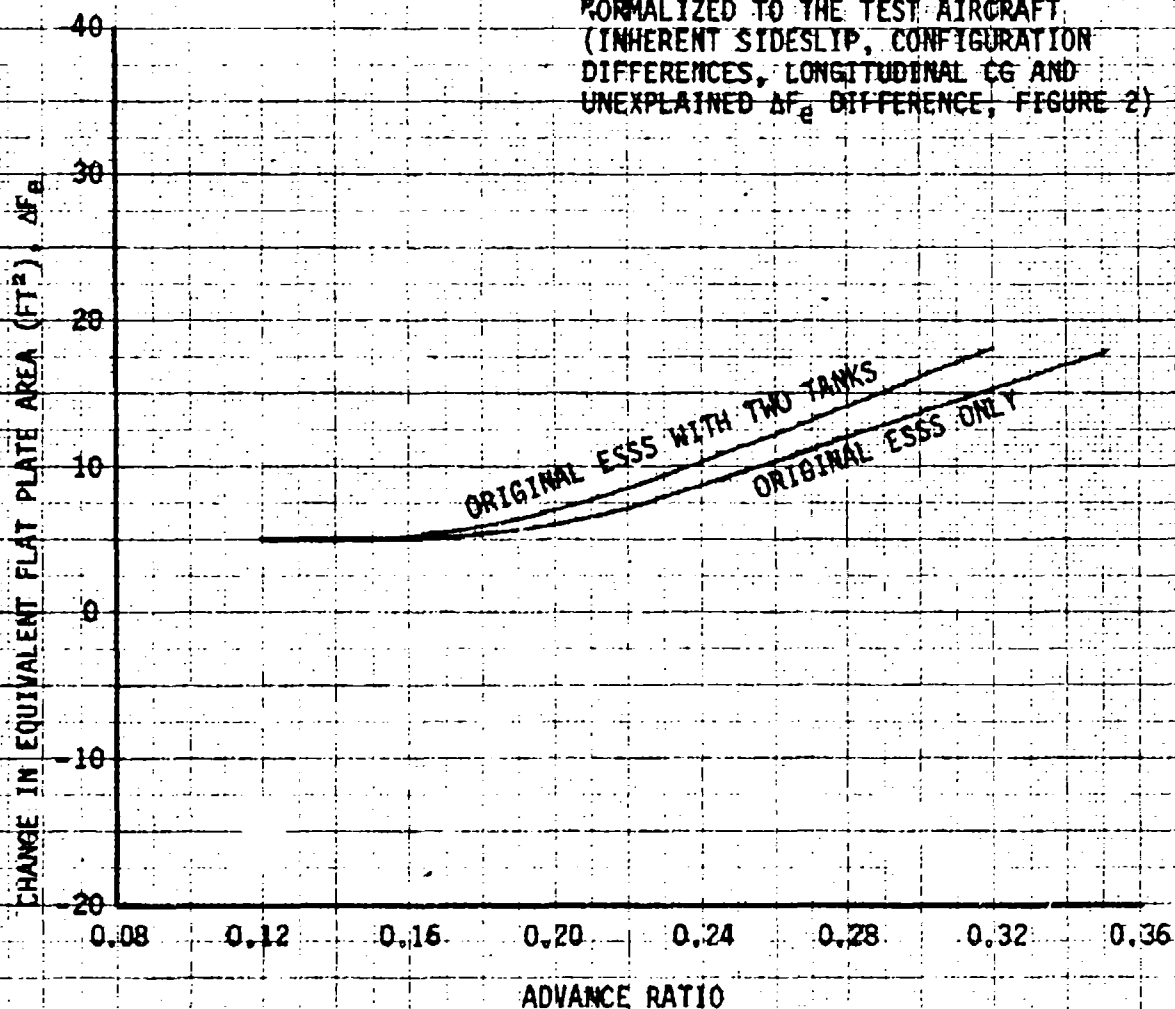


FIGURE 25
 NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
 UH-60A USA S/N 77-22714

CONFIGURATION: ORIGINAL ESSS WITH TWO 280 GAL TANKS

- NOTES: 1. BALL-CENTERED TRIM CONDITION
 2. LONGITUDINAL CG (FS 347.0)
 3. MID LATERAL CG
 4. REFERRED ROTOR SPEED = 258 RPM
 5. POINTS DERIVED FROM FIGURES 28 THROUGH 30

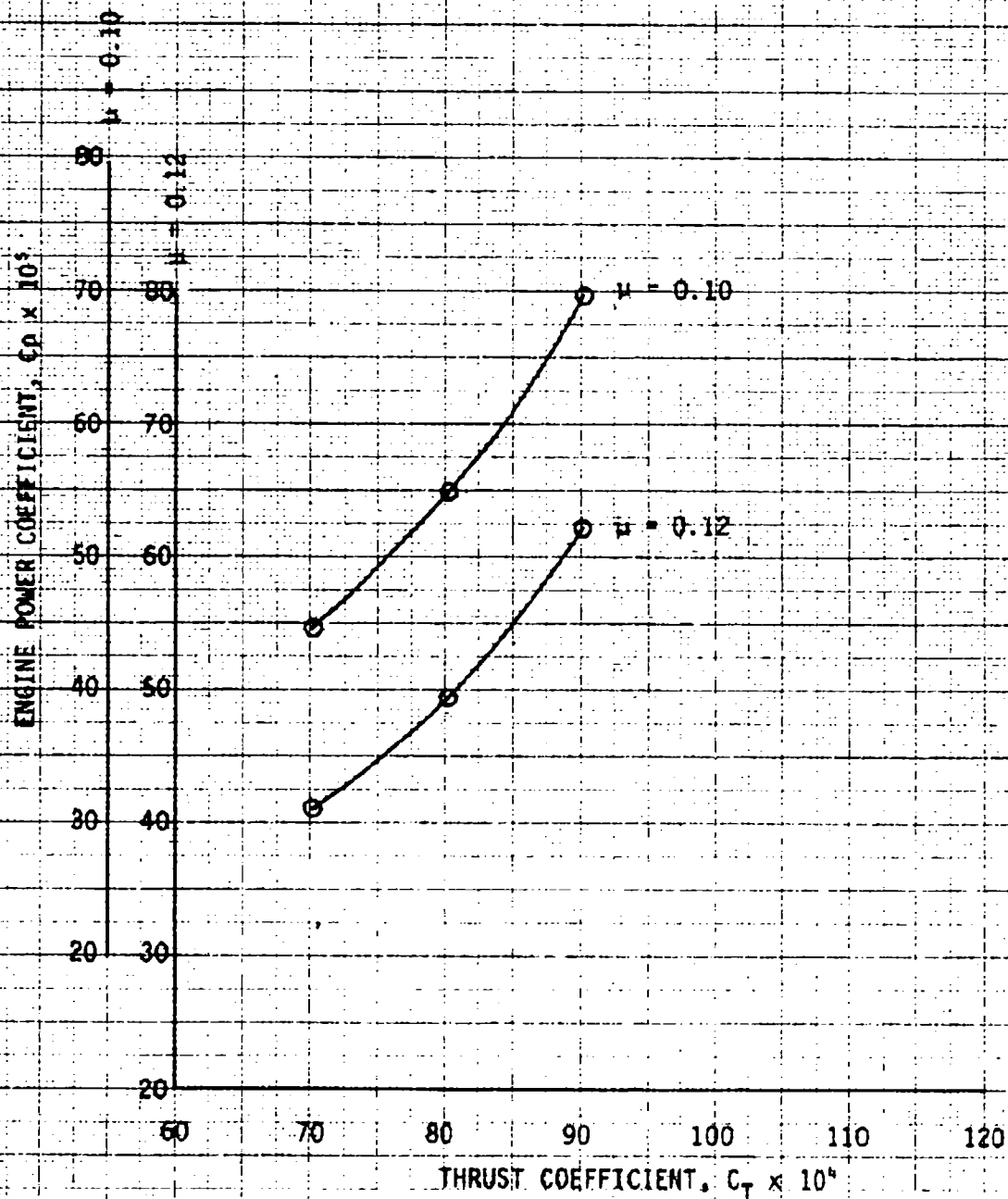


FIGURE 26
 NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
 UH-60A USA S/N 77-22714

CONFIGURATION: ORIGINAL ESSS WITH TWO 230 GAL TANKS

- NOTES: 1. BALL-CENTERED TRIM CONDITION
 2. LONGITUDINAL CG (FS 347.0)
 3. MID LATERAL CG
 4. REFERRED ROTOR SPEED = 258 RPM
 5. POINTS DERIVED FROM FIGURES 28 THROUGH 30

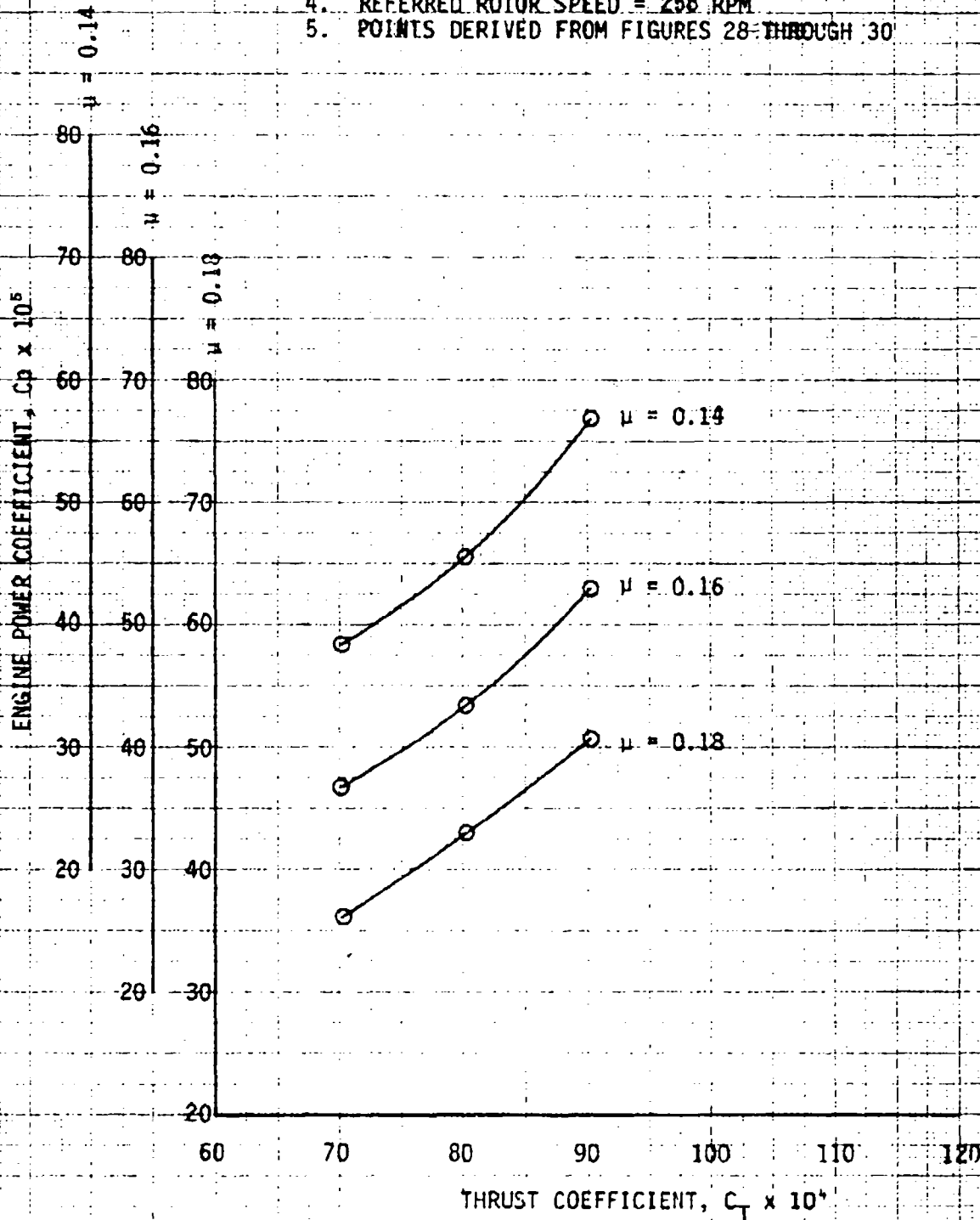


FIGURE 27
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

CONFIGURATION: ORIGINAL ESSS WITH TWO 230 GAL TANKS

- NOTES:**
1. BALL-CENTERED TRIM CONDITION
 2. LONGITUDINAL CG (FS 547.0)
 3. MID LATERAL CG
 4. REFERRED ROTOR SPEED = 288 RPM
 5. POINTS DERIVED FROM FIGURES 28 THROUGH 30

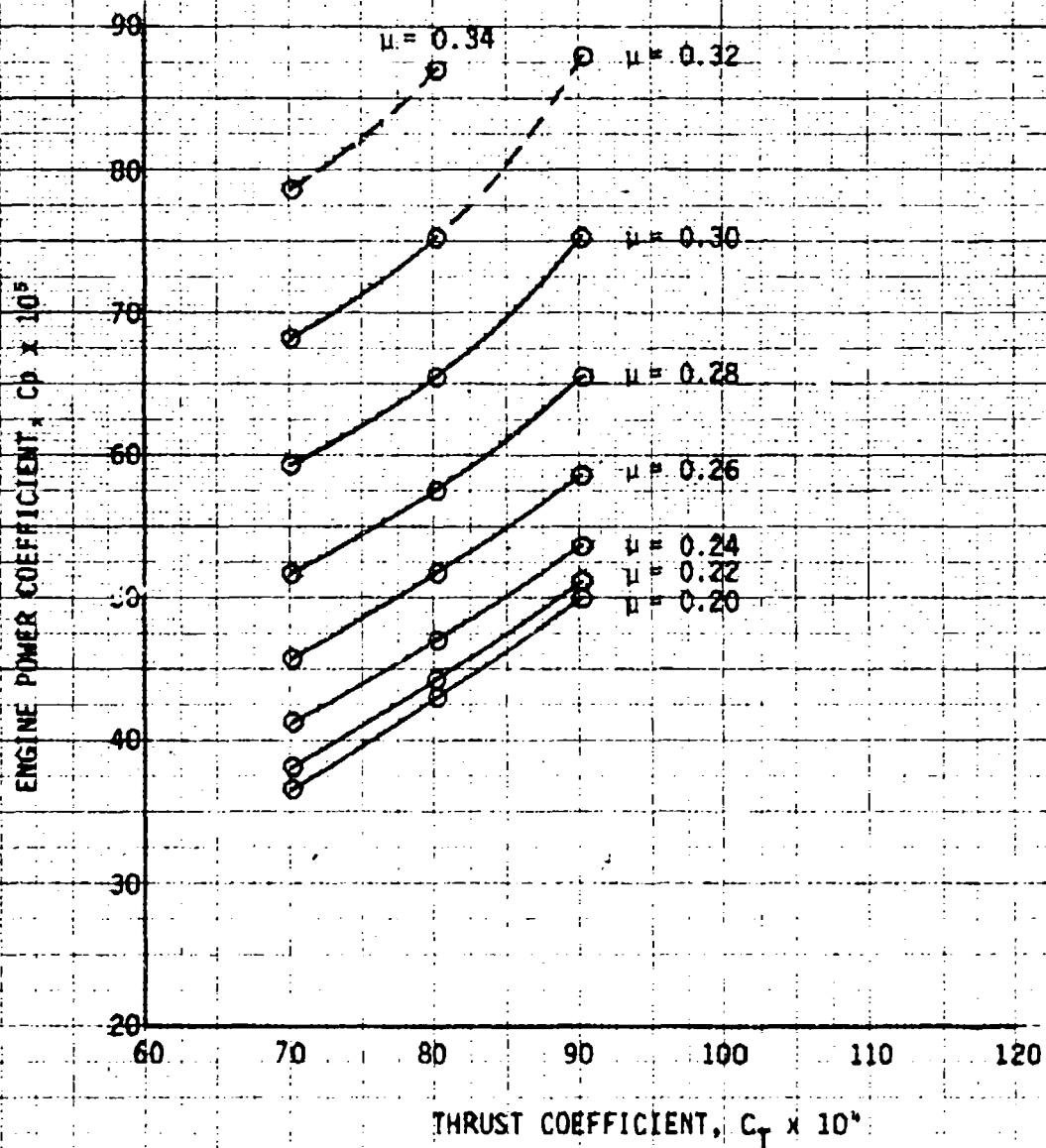


FIGURE 28
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT (° C) | AVG REFERRED ROTOR SPEED (RPM) | AVG $C_T \times 10^4$ | AIRCRAFT CONFIGURATION |
|-----------------------|-----------------|------|---------------------------|---------------|--------------------------------|-----------------------|------------------------------|
| LONG (FS) | LAT (BL) | | | | | | |
| 17,900 | 346.7 | 0.2R | 2660 | 9.0 | 257.7 | 70.14 | ORIGINAL ESSS WITH TWO TANKS |

NOTE: BALL CENTERED TRIM CONDITION

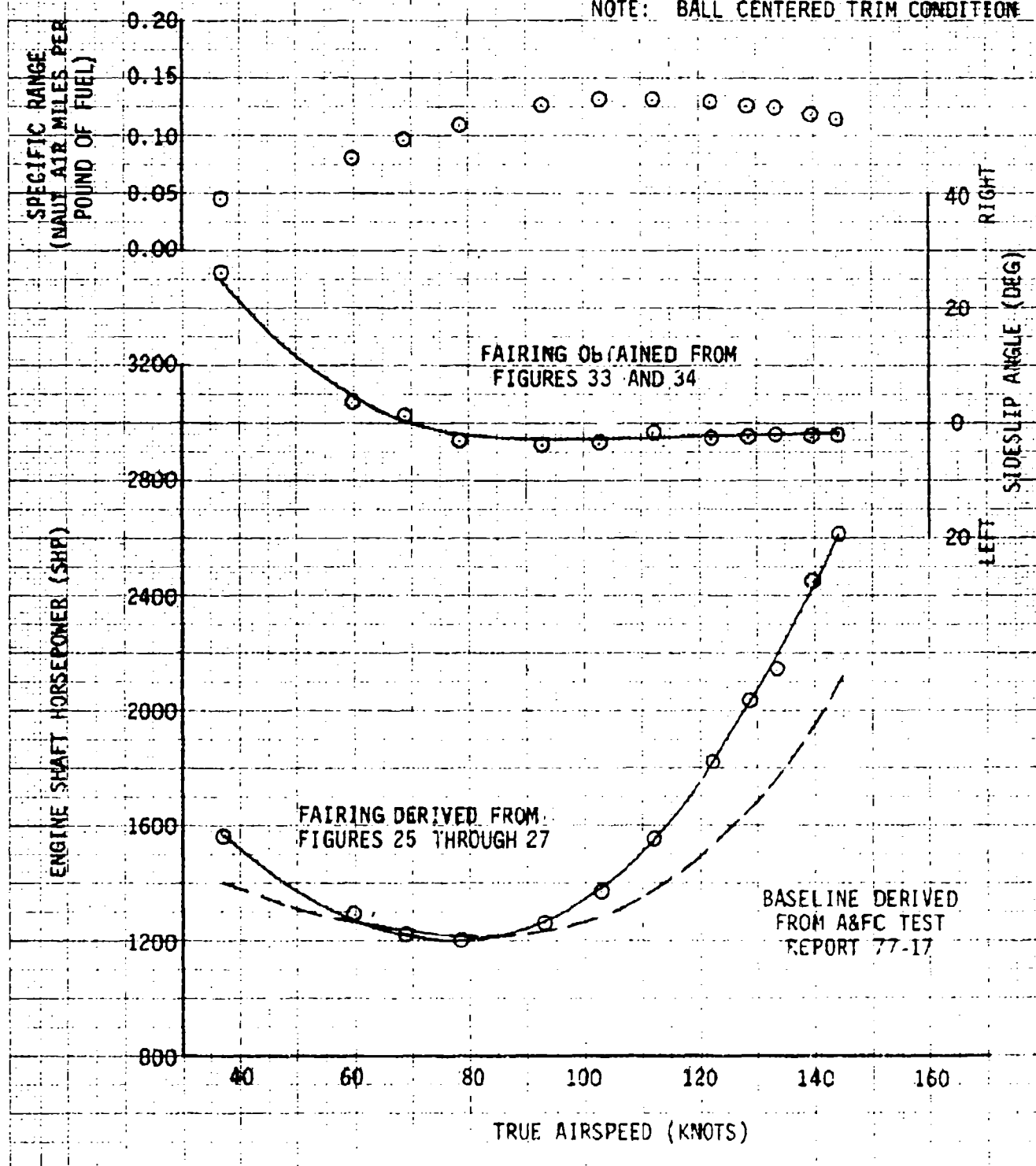


FIGURE 29
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT ($^{\circ}$ C) | AVG REFERRED ROTOR SPEED (RPM) | AVG $C_T \times 10^4$ | AIRCRAFT CONFIGURATION |
|-----------------------|-----------------|------|---------------------------|-------------------------|--------------------------------|-----------------------|------------------------------|
| 19,920 | 347.0 | 0.2R | 4360 | 15.0 | 258.0 | 80.24 | ORIGINAL ESSS WITH TWO TANKS |

NOTE: BALL CENTERED TRIM CONDITION

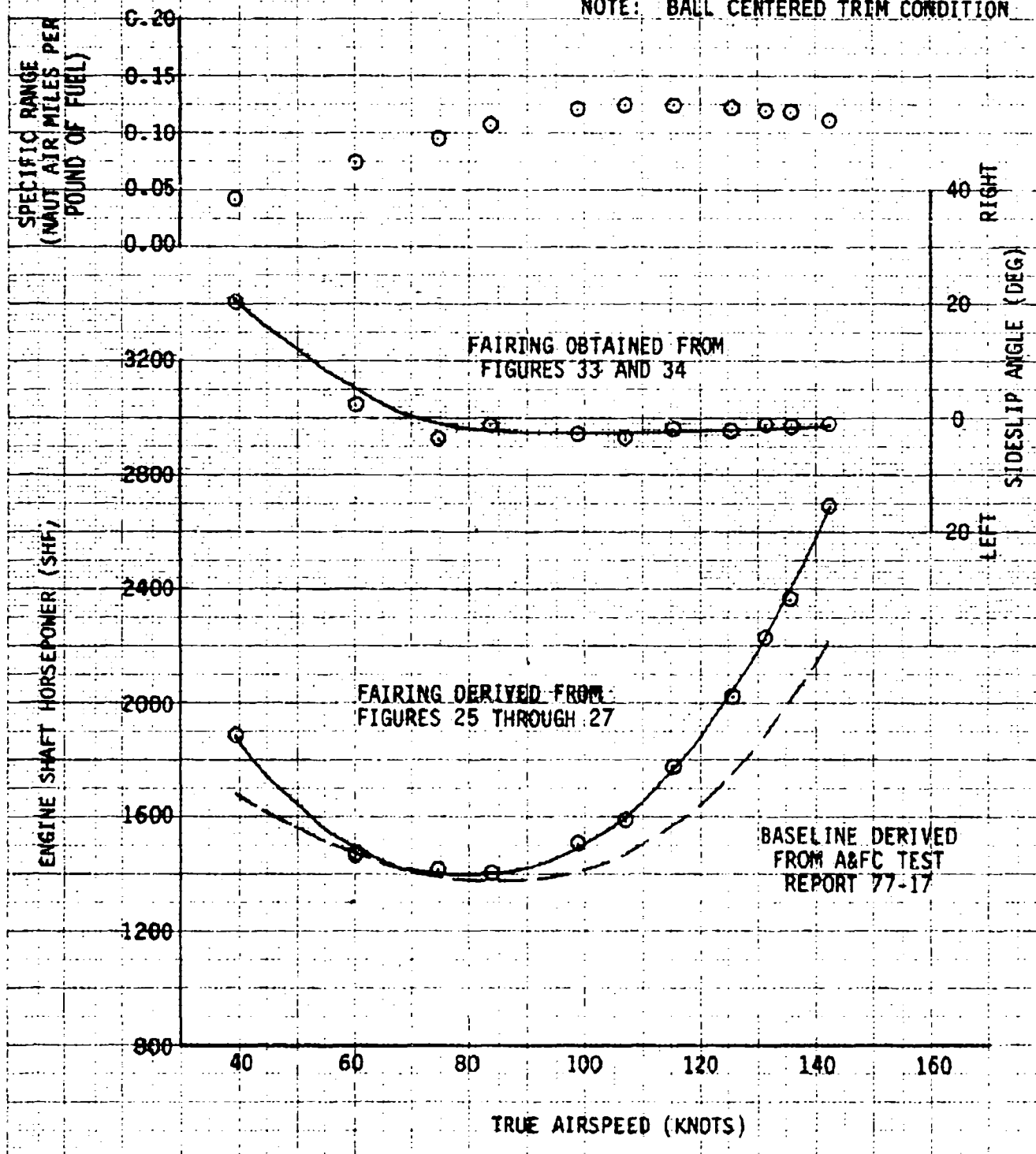


FIGURE 30
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT (° C) | AVG REFERRED ROTOR SPEED (RPM) | AVG $C_T \times 10^3$ | AIRCRAFT CONFIGURATION |
|-----------------------|-----------------|------|---------------------------|---------------|--------------------------------|-----------------------|------------------------------|
| LONG (PS) | LAT (BL) | | | | | | |
| 21,880 | 347.2 | 0.1R | 5120 | 14.5 | 258.2 | 90.18 | ORIGINAL ESSS WITH TWO TANKS |

NOTE: BALL CENTERED TRIM CONDITION

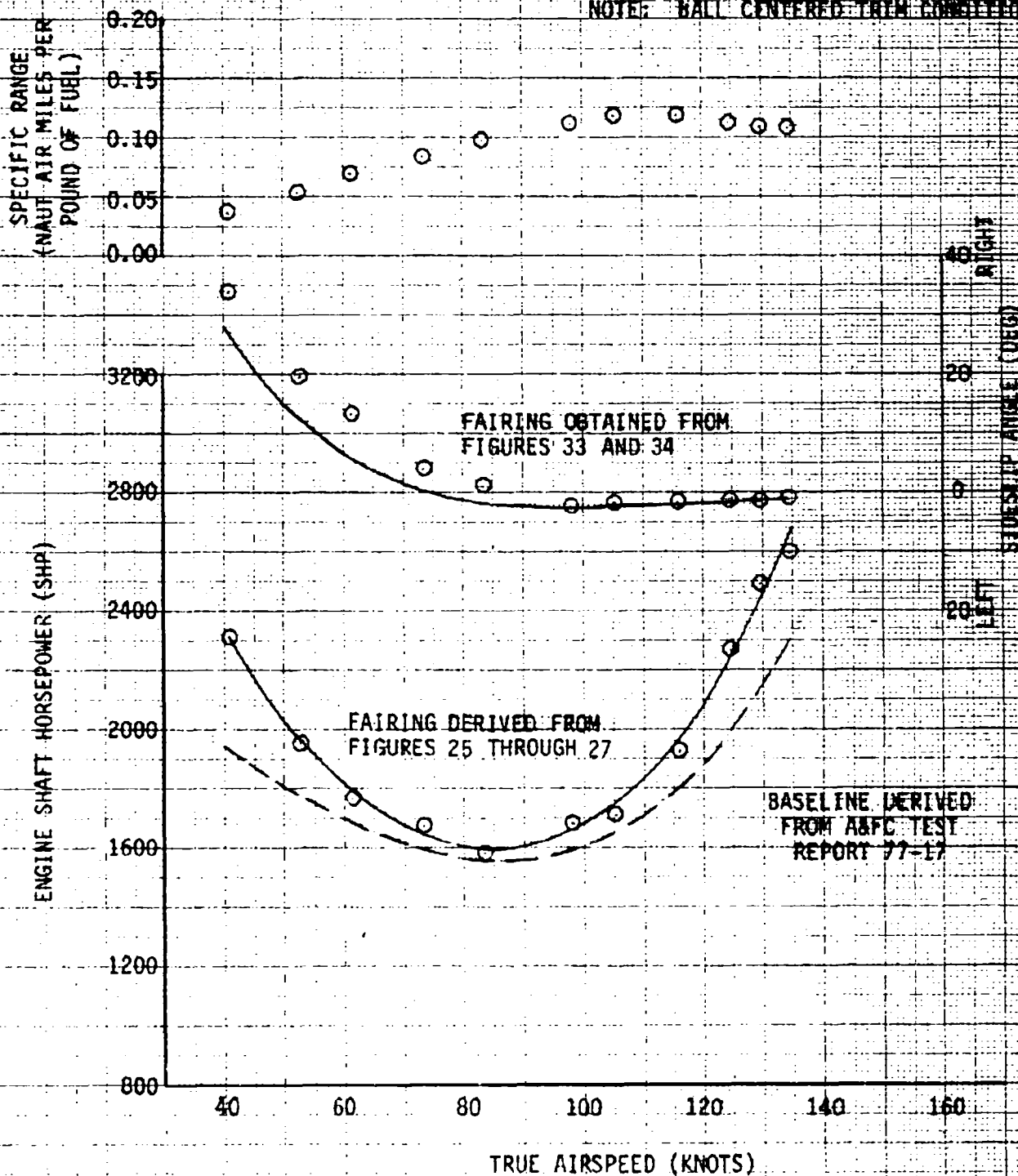


FIGURE 31
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT (°C) | AVG REFERRED ROTOR SPEED (RPM) | AVG $C_T \times 10^4$ | AIRCRAFT CONFIGURATION |
|-----------------------|-----------------|------|---------------------------|--------------|--------------------------------|-----------------------|------------------------------|
| LONG (FS) | LAT (BL) | | | | | | |
| 16,080 | 346.9 | 0.3R | 6740 | 12.0 | 258.3 | 70.20 | ORIGINAL ESSS WITH NO STORES |

NOTE: BALL CENTERED TRIM CONDITION

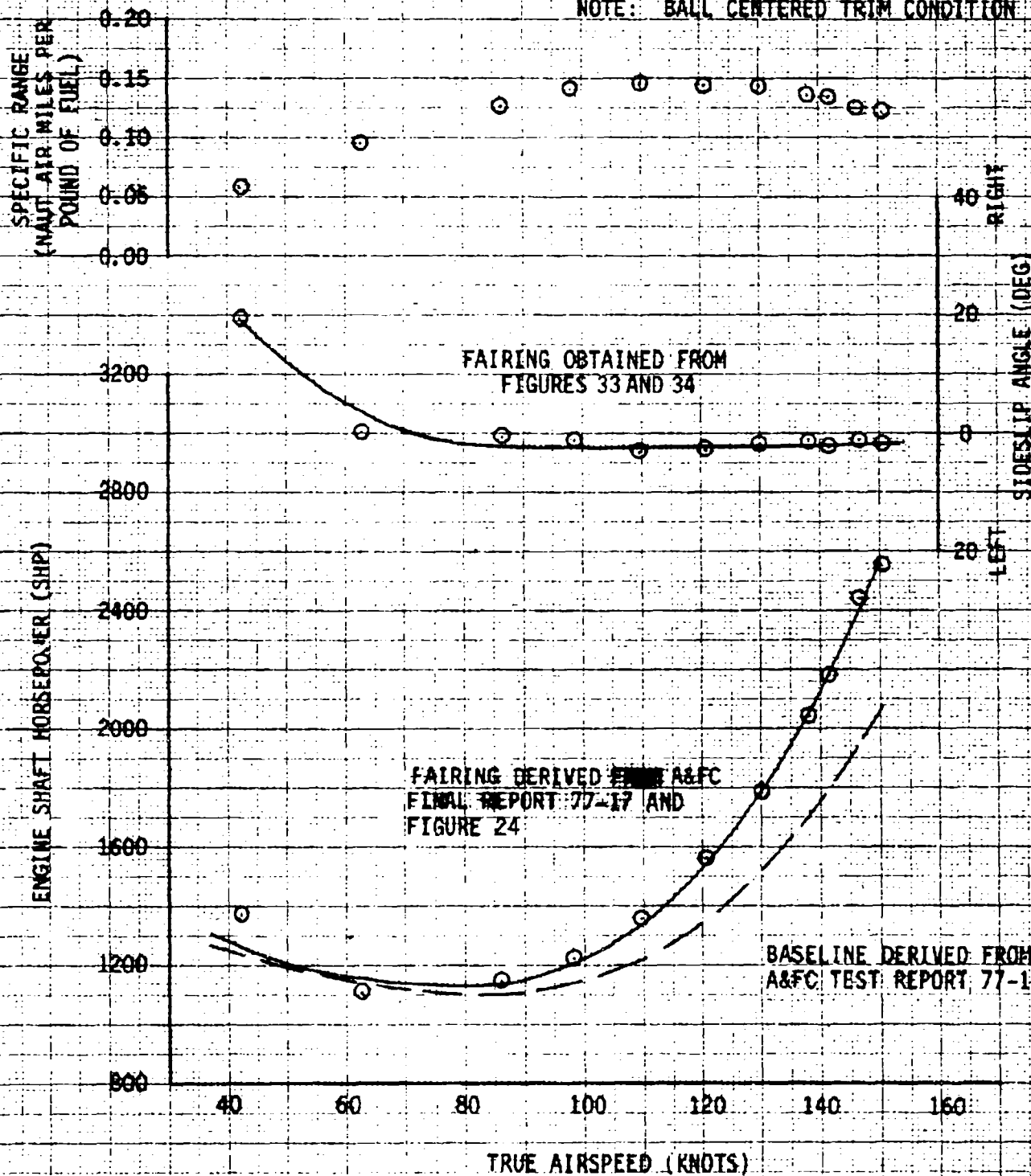


FIGURE 32
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT (° C) | AVG REFERRED ROTOR SPEED (RPM) | AVG $C_T \times 10^4$ | AIRCRAFT CONFIGURATION |
|-----------------------|-----------------|----------|---------------------------|---------------|--------------------------------|-----------------------|------------------------------|
| (LB) | LONG (FS) | LAT (BL) | (FT) | (° C) | (RPM) | $\times 10^4$ | |
| 17,960 | 347.0 | 0.2 R | 7300 | 10.0 | 258.3 | 80.32 | ORIGINAL ESSS WITH NO STORES |

NOTE: BALL CENTERED TRIM CONDITION

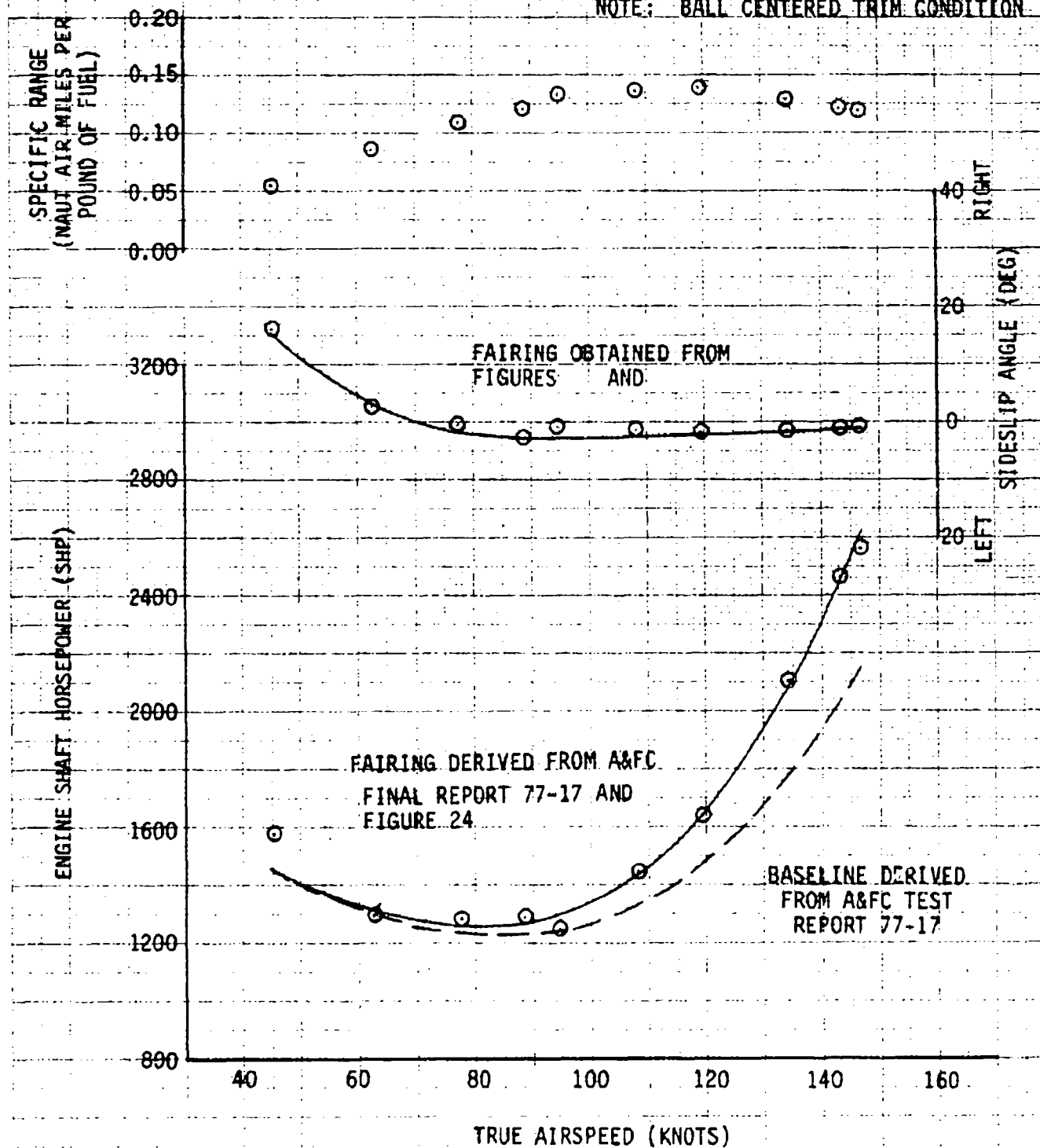


FIGURE 33
INHERENT SIDESLIP ANGLE
UH-60A USA S/N 77-22714

- NOTES: 1. FAIRINGS DERIVED FROM FIGURES 3 THROUGH 32 AND ARE REPRESENTATIVE OF ALL AIRCRAFT CONFIGURATIONS AND LONGITUDINAL CG LOCATIONS TESTED
2. MID LATERAL CG

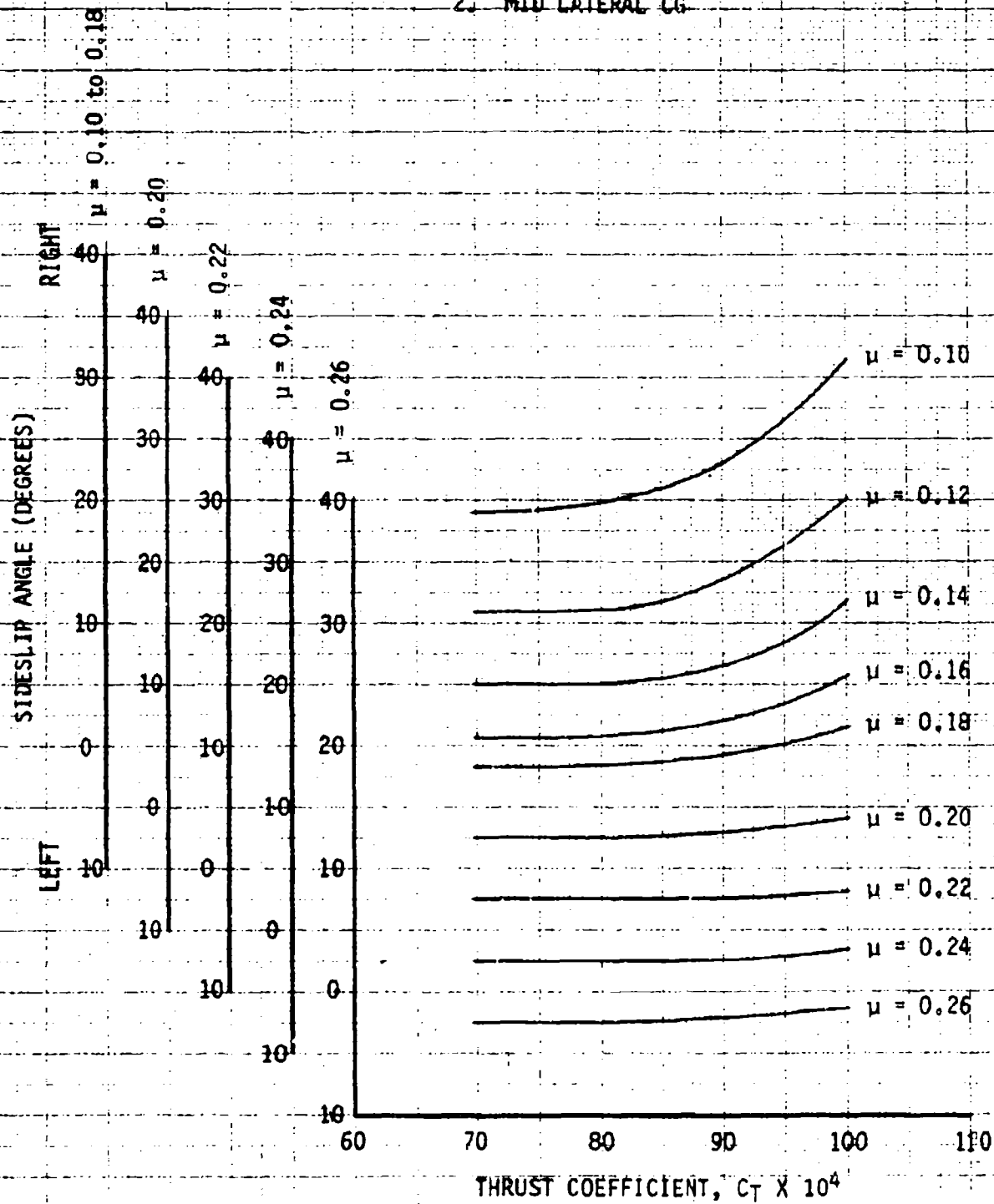


FIGURE 34
INHERENT SIDESLIP ANGLE
UH-60A USA S/N 77-22714

- NOTES: 1. FAIRINGS DERIVED FROM FIGURES 3 THROUGH 32 AND ARE REPRESENTATIVE OF ALL AIRCRAFT CONFIGURATIONS AND LONGITUDINAL CG LOCATIONS TESTED
2. MID LATERAL CG

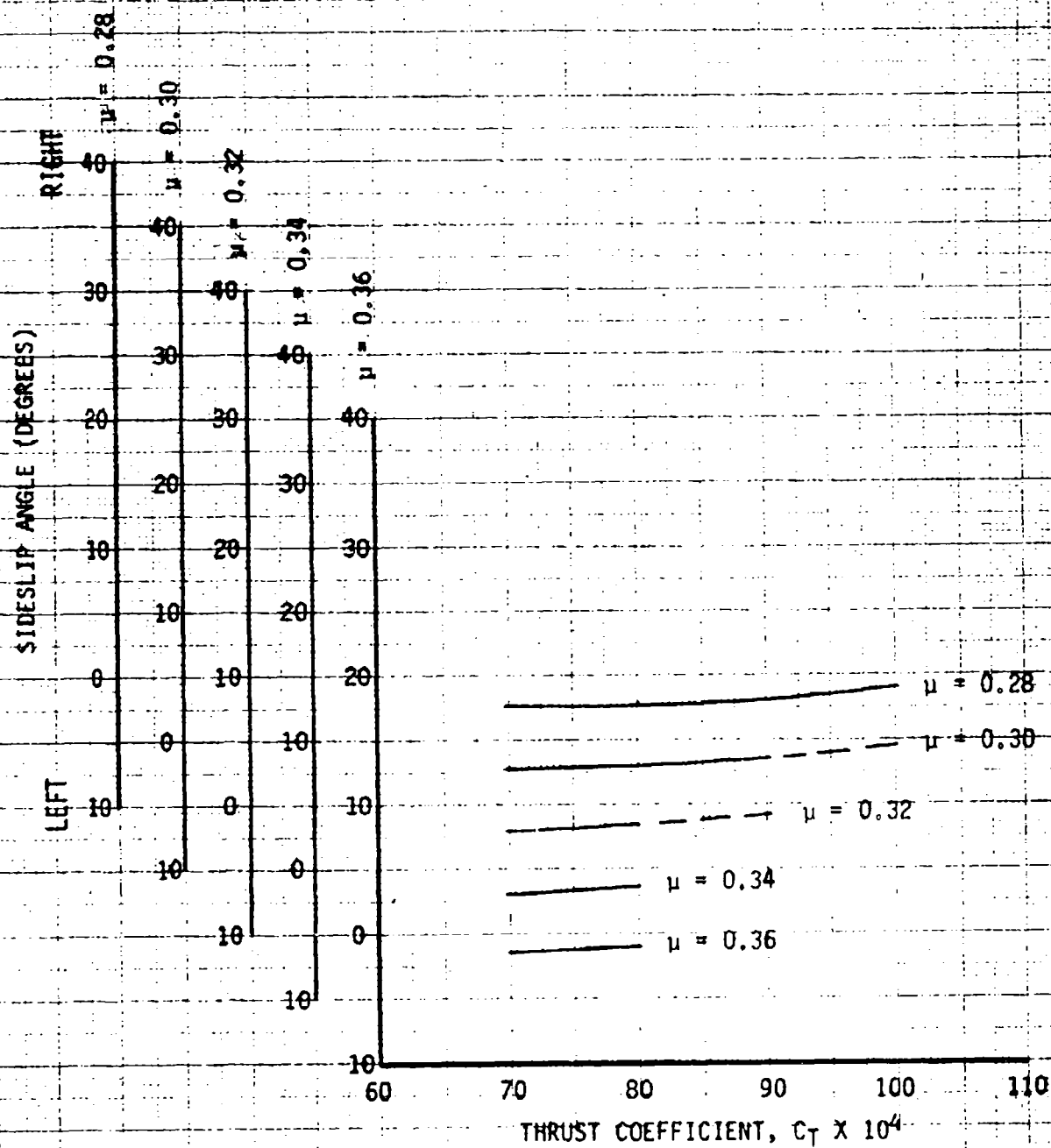


FIGURE 88
CONTROL POSITIONS IN LEVEL FLIGHT
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION LONG (FS) | AVG CG LOCATION LAT (BL) | AVG DENSITY ALTITUDE (FF) | AVG DAY (+/-) | AVG ROTOR SPEED (RPM) | CONFIGURATION |
|-----------------------|---------------------------|--------------------------|---------------------------|---------------|-----------------------|------------------|
| 18,000 | 346.8 | 0.2 RT | 6080 | 0.5 | 255 | FIXED PROVISIONS |

NOTE: BALL CENTERED TRIM CONDITION

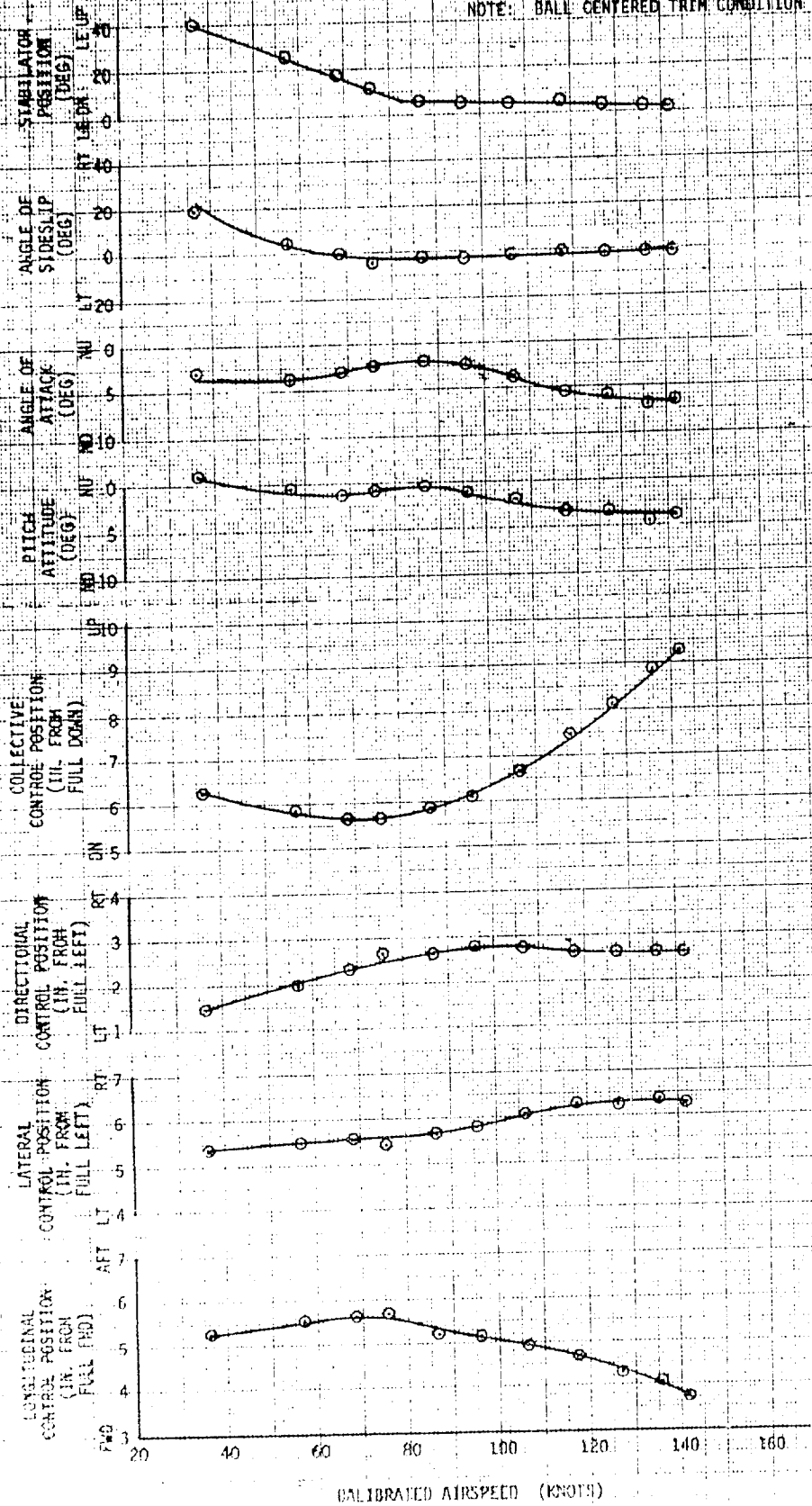


FIGURE 16
CONTROL POSITIONS IN LEVEL FLIGHT
UH-60A USA S/N 77-22714

| AVG GROSS WEIGHT (LBS) | CG LOCATION LONG (IN) | AVG LAT (DEG) | DENSITY ALTITUDE (FT) | AVG OAT (°C) | AVG ROTOR SPEED (RPM) | CONFIGURATION |
|------------------------|-----------------------|---------------|-----------------------|--------------|-----------------------|------------------------------|
| 27,500 | 247.0 | 0.2 NT | 7300 | 10.0 | 256 | ORIGINAL ESSS WITH NO STORES |

NOTE: BALL CENTERED TRIM CONDITION

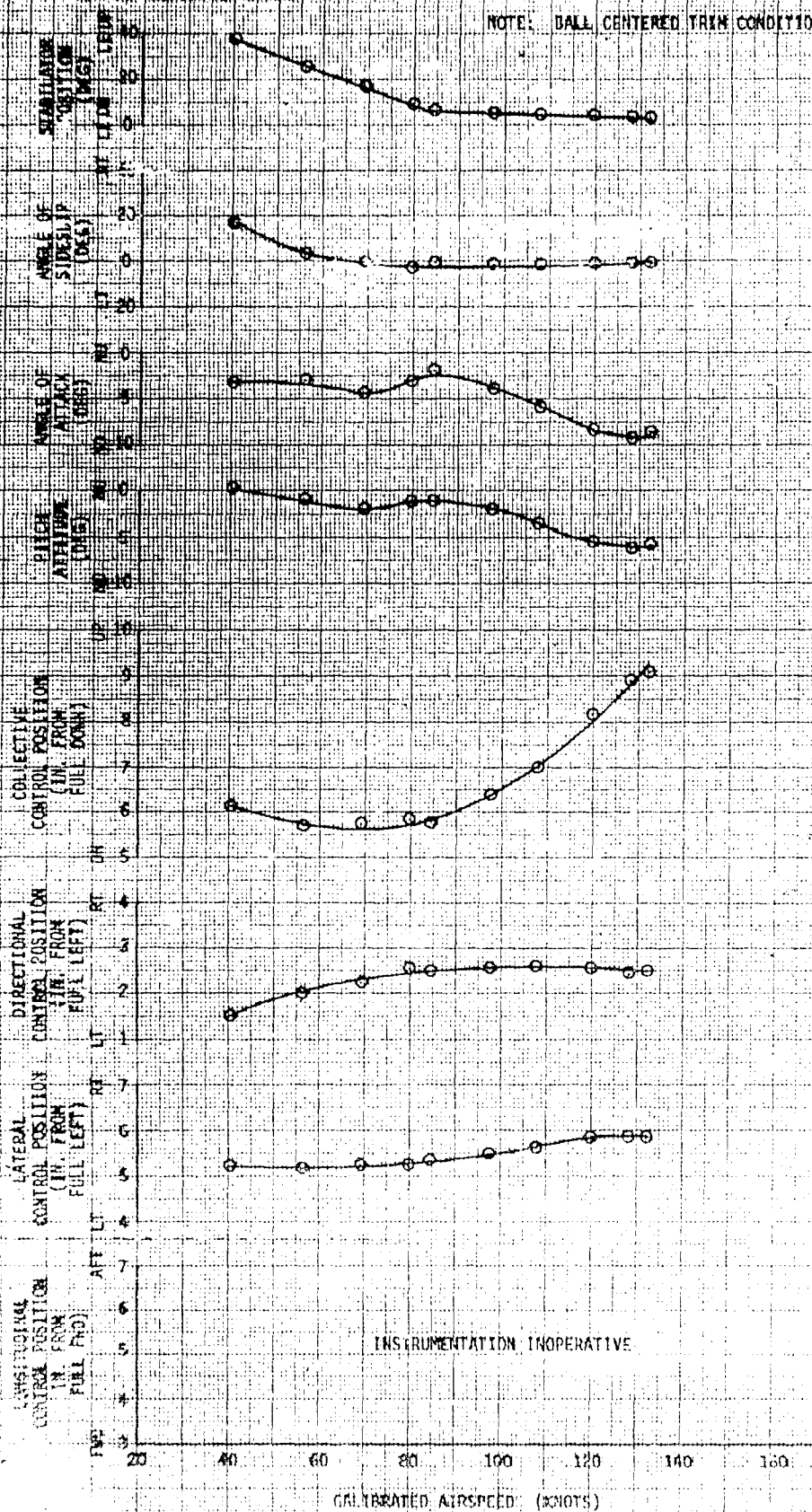


FIGURE 32
CONTROL POSITIONS IN LEVEL FLIGHT
UH-60A USA S/N: 77-22714

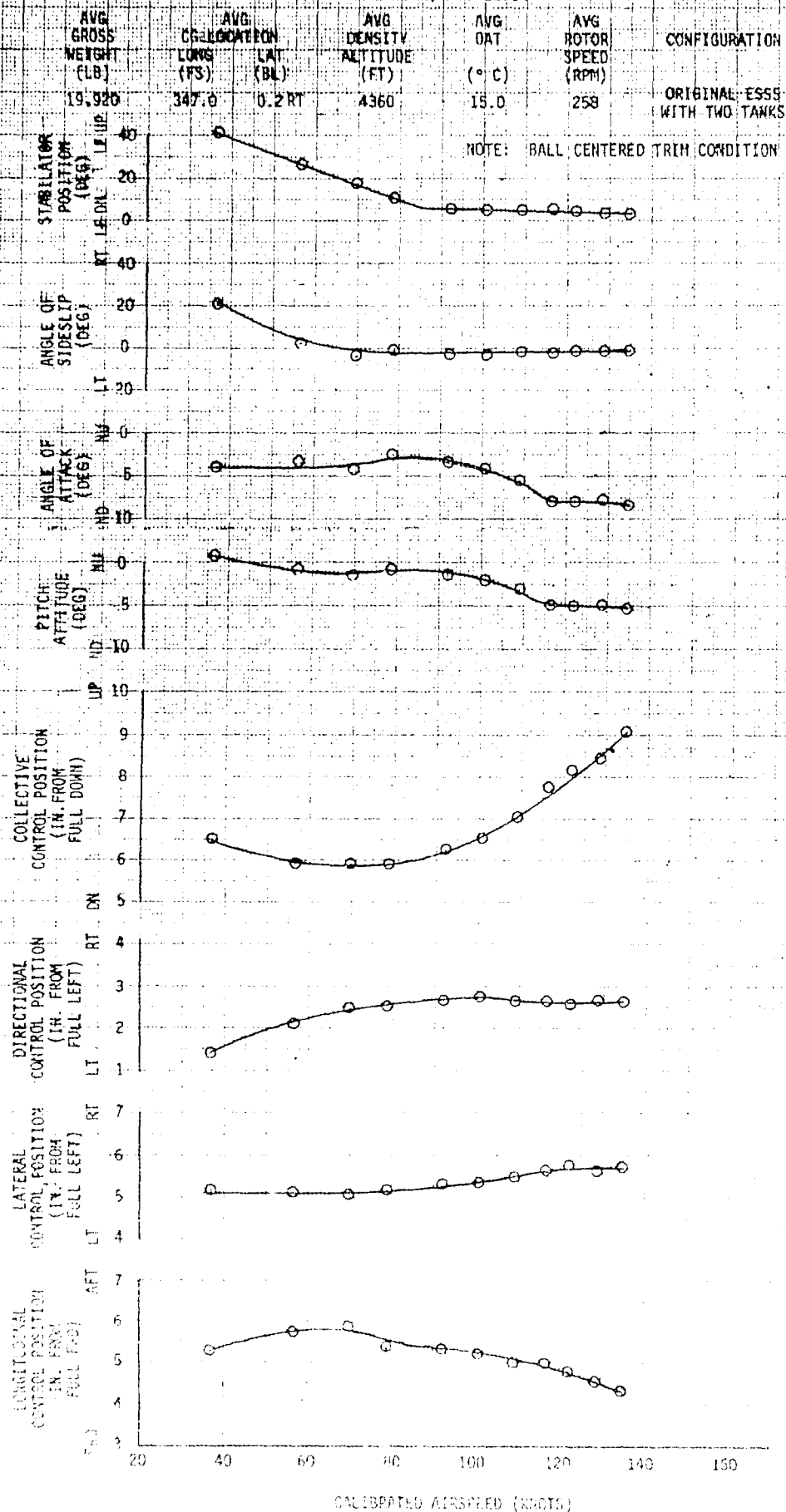


FIGURE 48
CONTROL POSITIONS IN LEVEL FLIGHT
UH-80A USA S/N 77-22714

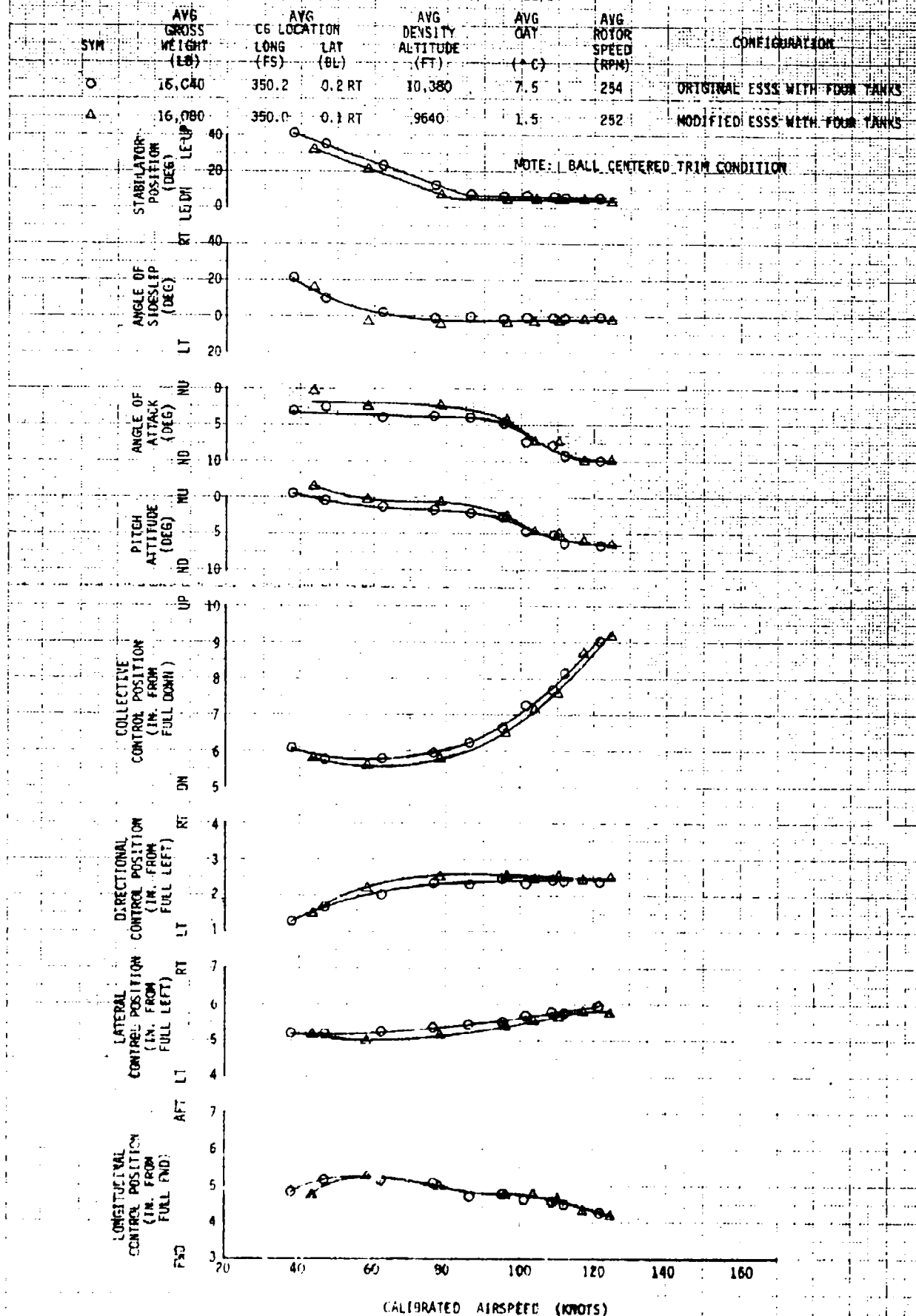
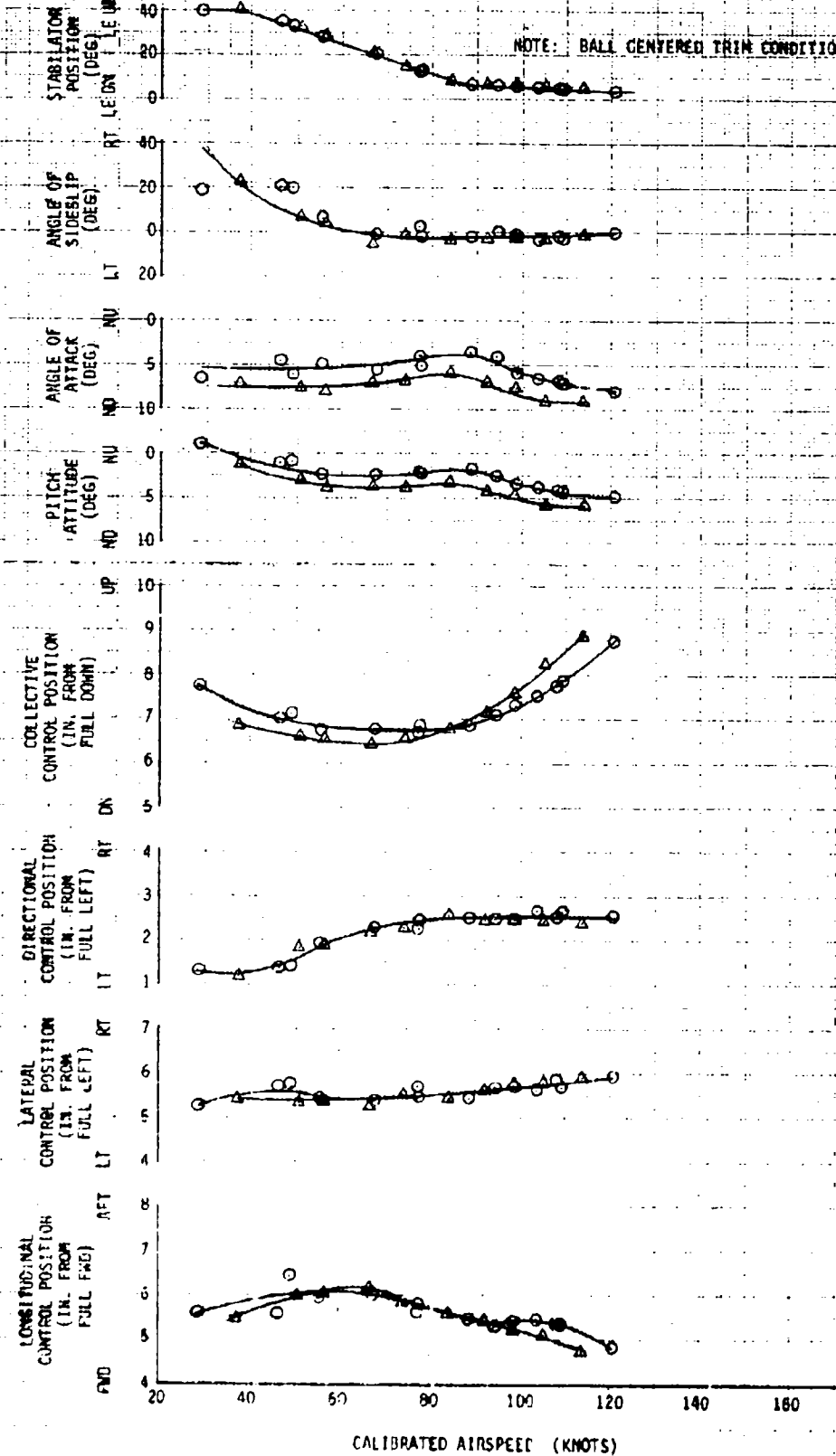


FIGURE 89
CONTROL POSITIONS IN LEVEL FLIGHT
UH-60A USA S/N 77-22714

| SYM | AVG GROSS WEIGHT (LB) | AVG CG LOCATION LONG (FS) | AVG CG LOCATION LAT (BL) | AVG DENSITY ALTITUDE (FT) | AVG OAT (°C) | AVG ROTOR SPEED (RPM) | CONFIGURATION |
|-----|-----------------------|---------------------------|--------------------------|---------------------------|--------------|-----------------------|-----------------|
| ○ | 24,580 | 343.3 (FWD) | 0.2 RT | 1380 | 16.5 | 258 | ORIGINAL ESS |
| △ | 17,960 | 343.0 (FWD) | 0.2 RT | 10,740 | 7.5 | 255 | WITH FOUR TANKS |

NOTE: BALL CENTERED TRIM CONDITION



APPENDIX F. GLOSSARY

| | |
|----------------|--|
| A&FC | Airworthiness and Flight Characteristics |
| app | appendix |
| AVRADCOM | US Army Aviation Research and Development Command |
| BL | buttlane |
| CG | center of gravity |
| C _T | thrust coefficient |
| ESSS | External Stores Support System |
| fig. | figure |
| FS | fuselage station |
| ft | feet |
| GE | General Electric |
| KT | knot |
| KTAS | knots true airspeed |
| lb | pound |
| PAE | Preliminary Airworthiness Evaluation |
| RPM | revolutions per minute |
| SA | Sikorsky Aircraft Division of United Technologies |
| SHP | shaft horsepower |
| ΔF_e | change in equivalent flat plate area |

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| US Army Materiel Systems Analysis Agency (DRXSY-AAM) | 2 |
| US Army Operational Test and Evaluation Agency (CSTE-TM-AV) | 2 |
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