PRELIMINARY AIRWORTHINESS EVALUATION AH-64/2S(AH-64(A) PROOF) HELICOPTER EDWARDS AFB, CA F/6-113

P M MORRIS, R WORATSCHUK, J NIEHAN

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PRELIMINARY AIRWORTHINESS EVALUATION
AH-1S (PROD) HELICOPTER EQUIPPED WITH
A SUBSTITUTE STRAIGHT EXHAUST PIPE

FINAL REPORT

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JUNE 1980

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UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
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**Supplementary Notes:**

Hot Metal Plus Plume (HMPP) Suppressor
Substitute Straight Exhaust Pipe

**Abstract:**

A limited performance and handling qualities evaluation and an engine and transmission cooling survey of an AH-1S (PROD) Helicopter equipped with a substitute straight exhaust pipe was performed at Edwards Air Force Base between 20 and 23 August 1979. A total of 8 hours, 6.3 of which were productive, was required. No significant changes in performance or handling qualities were found as a result of the substitute straight exhaust pipe installation. The engine and transmission cooling characteristics were similar to those of a production AH-1S and were satisfactory. No previously unreported shortcomings or deficiencies were identified.

SEE DISTRIBUTION

1. The purpose of this letter is to establish the Directorate for Development and Qualification position on the subject report. The evaluation was conducted to evaluate the suitability of a substitute straight exhaust pipe for production AH-1S helicopters as a result of delivery delays of the standard Hot Metal Plus Plume (HMPF) IR suppressors. The straight pipe characteristics were acceptable, as determined by the subject evaluation, and it was subsequently used so that production AH-1S helicopters could be functionally flight tested and thereby minimize delivery delays.

2. This Directorate agrees with the report findings and conclusions. Based on the test results, the AH-1S handling qualities and performance with the substitute straight pipe installed were not degraded and engine and transmissions temperatures were within acceptable limits.

FOR THE COMMANDER:

[Signature]
CHARLES C. CRAWFORD, JR.
Director of Development and Qualification
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## DISTRIBUTION
INTRODUCTION

BACKGROUND

1. The United States Army is under contract with Garrett AirResearch Manufacturing Company of California (GAMC) for the development of a hot metal plus plume (HMPP) suppressor for installation on the AH-1S (Prod) helicopter. The United States Army Aviation Engineering Flight Activity (USAAEFA) conducted a Preliminary Airworthiness Evaluation (PAE) of the AH-1S (Prod) helicopter with the HMPP suppressor installed in March 1978 (Reference 1, Appendix A). The suppressor will be provided to Bell Helicopter Textron (BHT) for installation on the AH-1S (Prod) helicopter as government furnished equipment. Qualification problems and delays in awarding a production contract have resulted in delivery delays of the suppressor to BHT. To minimize impact on BHT functional and acceptance flight testing and subsequently scheduled delivery of the AH-1S (Prod) helicopter, a substitute straight exhaust pipe was designed by GAMC and fabricated by Corpus Christi Army Depot. It is not expected that the Army will take actual delivery of the AH-1S (Prod) helicopter with the substitute straight exhaust pipe installed. In May 1979, the United States Army Aviation Research and Development Command (AVRADCOM) tasked USAAEFA to conduct a PAE on the AH-1S (Prod) helicopter with the substitute straight exhaust pipe installed (Reference 2, Appendix A) in accordance with the approved test plan (Reference 3, Appendix A). Heat damage to the test helicopter tailboom insulation and interior surface was detected during initial aircraft preparation for testing with the substitute straight exhaust pipe installed. This prompted conducting an unscheduled tailboom temperature survey (Project No. 79-14) which was conducted in July 1979 (Reference 7, Appendix A) prior to commencement of the substitute straight exhaust pipe evaluation.

TEST OBJECTIVES

2. The objectives of the PAE were as follows:
   a. Conduct limited handling qualities testing to determine any significant variations attributable to installation of the substitute straight exhaust pipe.
   b. Conduct limited performance testing to determine the change in level flight performance attributable to the substitute straight exhaust pipe installation.
   c. Conduct a limited engine and transmission survey to evaluate their cooling characteristics with the substitute exhaust pipe installed.

DESCRIPTION

3. The AH-1S (Prod) helicopter is a tandem-seat, two-place helicopter with a two-bladed teetering main rotor and a two-bladed tractor tail rotor. The helicopter is powered by a Lycoming T-53-L-703 turboshaft engine derated from 1800 shaft horsepower (SHP) at sea-level standard-day conditions, to the main transmission torque limit of 1290 SHP. Distinctive features of the helicopter include a narrow fuselage, stub wings with four stores stations, a flat-plate canopy, and an infrared (IR) exhaust system. A more detailed description of the AH-1S (Prod) helicopter is presented in the Operator's Manual (Reference 4, Appendix A) with a description of the substitute straight exhaust pipe contained in Appendix B.
4. The production HMPP suppressor consists of three major components: an engine exhaust-duct assembly, an aft engine cowling, and a plug assembly. The substitute straight exhaust pipe replaces the plug assembly component and attaches to the test helicopter in the same manner and using the same hardware required for the production HMPP suppressor plug assembly installation. The AN/ALQ-144 IR jammer installed on the HMPP suppressor during USAAEFA Project No. 77-33 (Reference 1, Appendix A) was not installed during this evaluation.

**TEST SCOPE**

5. The PAE was conducted between 20 and 23 August 1979 at Edwards Air Force Base, California. Six flights were conducted for a total flight time of 8 hours, of which 6.3 hours were productive. Table 1 presents the general performance and handling qualities test conditions and Table 2 presents the results of the engine and transmission survey. The performance and handling qualities results were compared with the results contained in Reference 1, Appendix A. The helicopter engine cooling characteristics were tested for compliance with Lycoming Model Specification No. 104.43 for T53-L-703 engines, revised 15 October 1978 (Reference 5). Flight restrictions of the Operator’s Manual and the airworthiness release (Reference 6) were observed throughout the test program.

<table>
<thead>
<tr>
<th>TEST</th>
<th>AVERAGE DENSITY ALTITUDE (M)</th>
<th>IFRM AIRSPEED (KIAS)</th>
<th>CENTER OF GRAVITY LOCATION</th>
<th>CONFIGURATION</th>
<th>REMARKS</th>
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<tr>
<td>Level Flight Performance</td>
<td>400 and 9100</td>
<td>40 to 134</td>
<td>FWD</td>
<td>Clean</td>
<td>Constant w. &amp; N x 1.4</td>
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<td>Static Longitudinal Stability</td>
<td>6500 and 2000</td>
<td>60 to 124</td>
<td>All</td>
<td>C-10B</td>
<td></td>
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<tr>
<td>Static Lateral-Directional Stability</td>
<td>6C20</td>
<td>123</td>
<td>All</td>
<td>C-10B</td>
<td></td>
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<tr>
<td>Dynamics Stability</td>
<td>4500</td>
<td>0.5</td>
<td>FWD</td>
<td>Clean</td>
<td>Qualitative only</td>
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1 Engine start gross weight = 10,000 lb
2 KIAS = knots calibrated airspeed
TABLE 2. ENGINE AND TRANSMISSION COOLING SURVEYS TEST RESULTS

<table>
<thead>
<tr>
<th>TEST</th>
<th>OAT MAX TEMP Recorded °F</th>
<th>TEMP Corrected to 125°F Ambient °F</th>
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<tr>
<td></td>
<td>FNG COMP</td>
<td>IGN UNIT</td>
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<tr>
<td>GROUND (1000' RPM)</td>
<td>84/124</td>
<td>84/111</td>
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<tr>
<td>CLIMB</td>
<td>70/122</td>
<td>70/100</td>
</tr>
<tr>
<td>LEVEL FLIGHT</td>
<td>64/115</td>
<td>64/99</td>
</tr>
<tr>
<td>DESCENT</td>
<td>75/117</td>
<td>70/91</td>
</tr>
<tr>
<td>RAMP PRIOR TO SHUTDOWN</td>
<td>88/136</td>
<td>90/100</td>
</tr>
</tbody>
</table>

1 OAT = outside air temperature
2 Corrected temperature = test temperature + (125° - OAT)
3 Max allowable temperature = 230° F
4 Max allowable temperature = 199.4° F

TEST METHODOLOGY

6. Standard performance and handling qualities test techniques were employed (References 8 and 9). Prior to flight testing the aircraft, during the engine and transmission survey, the oil cooler thermostatic bypass valve in the engine oil cooling system was blocked closed to prevent oil cooler bypass flow. Temperatures were allowed to stabilize for a minimum of two minutes prior to recording temperature data. All temperature data were compared against specification requirements (Reference 5) and results of Reference 7. Data were recorded on magnetic tape in a pulse-code modulated format and manually on flight data cards. The instrumentation used is listed in Appendix C. The test techniques and data analysis methods are discussed in Appendix D.
RESULTS AND DISCUSSION

GENERAL

7. Limited performance and handling qualities tests, and an engine and transmission cooling survey were performed on an AH-1S (Prod) helicopter with a substitute straight exhaust pipe installed. The tests were conducted to determine the effects on the handling qualities, engine and transmission cooling characteristics, and performance of the AH-1S (Prod) helicopter with the substitute straight exhaust pipe installed. No change in handling qualities or performance was noted by the substitute straight exhaust pipe installation. The engine and transmission cooling characteristics are similar to those of a production AH-1S and are documented in Reference 7, Appendix A.

LEVEL FLIGHT PERFORMANCE

8. The level flight performance of the AH-1S (Prod) helicopter with substitute straight exhaust pipe installed was evaluated at the general conditions listed in Table 1. Level flight performance was flown, at thrust coefficients \((C_T)\) of approximately 0.0052 and 0.0056. Results are presented in Figures 1 and 2, Appendix E. No change in equivalent flat plate area between the substitute straight exhaust pipe and the HMPP suppressor was apparent from a comparison of Figures 1 and 2 with data from Reference 10, Appendix A.

HANDLING QUALITIES

Control Positions in Trimmed Forward Flight

9. Control positions in trimmed forward flight were evaluated in conjunction with level flight performance tests at the conditions on Table 1. Test data are presented in Figures 3 and 4, Appendix F. The control positions in trimmed forward flight were not significantly affected by installation of the substitute straight exhaust pipe.

Static Longitudinal Stability

10. Static longitudinal stability characteristics were evaluated at the conditions listed in Table 1. Test techniques are described in Appendix D. The variation of control positions with airspeed is presented in Figures 5 and 6, Appendix E. A comparative evaluation of these curves with those of USAAEFA Project Report No. 77-33 at any given airspeed show a distinct similarity in gradient but a minor difference in control displacement for cyclic and pedal controls. The static longitudinal stability of the AH-1S (Prod) helicopter was not significantly affected by installation of the substitute straight exhaust pipe and is satisfactory.

Static Lateral-Directional Stability

11. Static lateral-directional stability characteristics were evaluated at the conditions listed in Table 1, using the techniques described in Appendix D. Test results are presented in Figure 7, Appendix F. A comparative evaluation of this curve to that of Figure 23, USAAEFA Project Report No. 77-33, shows a distinct
similarity in gradient with a minor difference in control displacement. The static lateral-directional stability of the AH-1S (Prod) helicopter was not significantly affected by installation of the substitute straight exhaust pipe and is satisfactory.

Dynamic Stability

12. The lateral-directional (Dutch roll) characteristics were evaluated at the conditions listed in Table 1 using the techniques described in Appendix D. The lateral-directional oscillation observed was characterized by an approximately three-second period and a roll to yaw ratio of one to two. Damping of the lateral-directional oscillation was acceptable at all airspeeds tested. An annoying Dutch roll oscillation (reported in USAAEFA Project Report No. 77-33) was observed during initial testing, but was eliminated by changing the stability augmentation system (SAS) amplifier sensor box. Within the scope of this test, the dynamic stability characteristics of the AH-1S (Prod) helicopter with substitute straight exhaust pipe installed are satisfactory.

ENGINE AND TRANSMISSION COOLING SURVEY

13. An engine and transmission cooling survey of the AH-1S (Prod) with substitute straight exhaust pipe installed was conducted at the conditions listed in Table 2. Temperatures were obtained from thermocouples located as indicated in Appendix C and Reference 7, Appendix A. Engine and transmission temperatures were recorded during ground run, climb, level flight, descent, and prior to engine shutdown. Additional engine and transmission cooling data were obtained during an unscheduled tailboom temperature survey conducted on the test helicopter in July 1979 (Reference 7, Appendix A). During testing ambient temperatures ranged from 64° to 90° Fahrenheit (F). The engine compartment ambient temperature remained below 137° F, and the ignition unit box temperature was less than 112° F. Transmission oil (IN) temperature and engine oil (IN) temperature stabilized during all flights at approximately 160° and 140° F, respectively. All engine temperatures were below maximum allowable engine specification requirements (Reference 5, Appendix A) and below those reported in Reference 7. Within the scope of this test, AH-1S (Prod) helicopter substitute straight exhaust pipe allows adequate engine and transmission cooling.
CONCLUSIONS

GENERAL

14. No significant changes in performance, handling qualities, or engine and transmission cooling characteristics were found as a result of the substitute straight exhaust pipe installation. No previously unreported shortcomings or deficiencies were identified.

SPECIFICATION COMPLIANCE

15. The engine cooling characteristics of the AH-1S (Prod) helicopter with substitute straight exhaust pipe installed met the requirements of the engine specification (Reference 5, Appendix A).
RECOMMENDATIONS

16. The substitute straight exhaust pipe can be used in lieu of the HMPP suppressor during BHT functional and acceptance testing of the AH-1S (Prod) helicopter.
APPENDIX A. REFERENCES

1. Final Report, United States Army Aviation Engineering Flight Activity (USAAEFA), Project No. 77-33, Preliminary Airworthiness Evaluation of the AH-1S Helicopter Equipped with a Garrett Infrared Radiation Suppressor and AN/ALQ-144 Jammer, May 1978.


APPENDIX B. DESCRIPTION

GENERAL

1. The test helicopter, U.S. Army SN 76-22573, was an AH-1S (Prod) modified to accommodate the infrared (IR) suppressor. The principal structural modification was the redesign of the cowling which provided support for the IR suppressor. Photos 1 through 4 show the test helicopter with the substitute straight exhaust pipe installed.

IR SUPPRESSOR SYSTEM

2. The IR suppressor system consisted of three major components: the cowling assembly, the exhaust duct, and the substitute straight exhaust pipe. The substitute pipe replaced the plug-typed IR suppressor used on the Hot Metal Plus Plume (HMPP) suppressor during USAAEFA Project No. 77-23 (Reference 1, Appendix A). The substitute pipe was attached to the test helicopter in the same manner and using the same hardware as the HMPP suppressor.
Photo 2. Left View of Substitute Straight Exhaust Pipe
APPENDIX C. INSTRUMENTATION

1. Test instrumentation was installed, calibrated, and maintained by USAAEFA personnel. The main instrumentation package (Photo 1) was located in the ammunition compartment area (FS 115) and a visual display located in the engineer flight station (FS 60) provided temperature parameters onboard the aircraft. Thermocouples were located in the engine compartment and on the tailboom and were manually recorded in the cockpit by the flight engineer. The engine torquemeter calibration is shown in Figure 1. Boom airspeed system calibration is shown in Figure 2.

2. The following test instrumentation and special equipment were installed:

Pilot Panel

Airspeed (boom)
Altitude (boom)
Rate of climb (boom)
Rotor speed (test)
Engine torque
Engine gas producer speed
Engine turbine gas temperature
Free air temperature
Angle of sideslip
Event Switch

Copilot Panel

Airspeed (boom)
Altitude (boom)
Rotor speed (test)
Engine torque (test)
Engine gas producer speed
Engine turbine gas temperature
Free air temperature (test)
Fuel used
Run number
Time code display
Instrumentation control
Event switch
Cable tension

Thermocouples:

Engine compartment (right hand side aft firewall)
Ignition unit skin (between lower support clamp and ignition box)
Transmission oil "in" (one inch upstream of standard transmission oil thermocouple)
Engine oil "in" (same location as standard engine oil thermocouple)
Approximate boom station 63 (inside skin left and right)
Approximate boom station 80.4 (inside skin left and right)
Approximate boom station 95 (inside skin left and right)
Photo 1: PCM Instrumentation Package in Ammunition Bay
FIGURE 1
ENGINE TORQUEMETER CALIBRATION
AM-15 USA S/N 76-22673
INCOMING ENGINE MODEL 153-C-703 SN 131452

NOTE: 1. TORQUEMETER CALIBRATION DATA
       PROVIDED BY LYCOMING BASED ON
       TEST CONDUCTED 13 JULY 1978;

2. $n_p$ - 6604 RPM
FIGURE 2
BOOM AIRSPEED CALIBRATION
AH-13 USA S/N 76-22973

<table>
<thead>
<tr>
<th>CORRECTION TO BE ADDED (KNOTS)</th>
<th>0</th>
<th>5</th>
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<table>
<thead>
<tr>
<th>GROSS WEIGHT (LB)</th>
<th>CG LOCATION</th>
<th>DENSITY (PSI)</th>
<th>AVG. ROTOR FLIGHT</th>
<th>LVL FLT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3340</td>
<td>195.2 (FWD)</td>
<td>0.1 RT</td>
<td>3520</td>
<td>524</td>
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</table>

BOOM PITOT-STATIC SYSTEM

NOTES:
1. CLEAN CONFIGURATION
2. K747 BLADES S/N A2016 and A2025
3. GROUND SPEED COURSE UTILIZED
4. DATA NOT FOR HANDBOOK USE

CALIBRATED AIRSPEED (KNOTS)
(INCLUDED FOR ENTRAPMENT ERROR)
Approximate boom station 80.4 (outside skin right)
Approximate boom station 115 (inside skin left and right)
Approximate boom station 135 (inside left and right)
Approximate boom station 155 (inside left and right)
Approximate boom station 175 (inside left and right)

Magnetic Tape

Time code
Run number
Event
Airspeed (boom)
Altitude (boom)
Total air temperature
Rotor RPM
Fuel used
Fuel temperature
Engine torque
Engine turbine gas temperature
Engine gas producer speed ($N_1$)
Engine output shaft speed ($N_2$)
Control Positions
  Longitudinal
  Lateral
  Directional
  Collective
Angle of attack
Angle of sideslip
APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. Conventional test techniques were used in the tests. Detailed descriptions of all test techniques are contained in References 8 and 9, Appendix A, except where referred to in the following paragraphs.

LEVEL FLIGHT PERFORMANCE

2. Each level flight performance flight was designed to obtain one curve of $C_p$ versus $\mu$ at a constant value of $C_T$. The flight technique was to stabilize at zero sideslip at incremental airspeeds from approximately 40 knots indicated airspeed (KIAS) to the maximum level flight airspeed attainable. At each test condition, torque, altitude, airspeed, and rotor speed were held constant for at least one minute prior to recording data. Altitude was increased between data points as a function of fuel burnoff in order to maintain a constant ratio of gross weight to air pressure ratio ($w/\delta$). Also, main rotor speed ($N$) was varied as a function of ambient air temperature in order to maintain a constant ratio of main rotor speed to the square root of the air temperature ratio ($N/\sqrt{\delta}$).

3. The nondimensional coefficients listed below were used to generalize the level flight performance data obtained during this evaluation.

   a. Coefficient of power ($C_p$):

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

   b. Coefficient of thrust ($C_T$):

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

   c. Advance ratio ($\mu$):

      $$\mu = \frac{1.6878 V_T}{\Omega R}$$

   d. Advancing blade tip mach number ($M_{tip}$):

      $$M_{tip} = \frac{1.6878 V_T + (\Omega R)}{a}$$

Where:

$SHP =$ Engine output shaft horsepower
$550 = \text{Conversion factor (ft lb/sec/ShP)}$

$\rho = \text{Air density (slug/ft}^3\text{)}$

$A = \text{Main rotor disc area (ft}^2\text{)}$

$\Omega = \text{Main rotor angular velocity (radian/sec)}$

$R = \text{Main rotor radius (ft)}$

$GW = \text{Aircraft gross weight (lb)}$

$V_T = \text{True airspeed (kt)}$

$a = \text{Speed of sound (ft/sec)}$

$1.6878 = \text{Conversion factor (ft/sec/kt)}$

Calibrated airspeed was obtained by correcting indicated airspeed for position error using Figure 2, Appendix C. True airspeed was calculated using calibrated airspeed ($V_{CAL}$) and density ratio ($\sigma$) as follows:

$$V_T = V_{CAL}/\sqrt{\sigma} \quad \text{(D-5)}$$

Where:

$$\sigma = \rho / 0.0023769$$

4. Engine output shaft torque was determined from the engine manufacturer's differential torque pressure system. The relationship of measured differential torque pressure (psi) to engine output shaft torque (in lb) is illustrated in Figure 2, Appendix C. The output SHP was determined from the engine output shaft torque and rotational speed by the following equation:

$$\text{SHP} = 20.38362 \times N_R \times Q \times 1.586663 \times 10^{-5} \quad \text{(D-6)}$$

Where:

$N_R = \text{Rotor shaft rotational speed (RPM)}$

$20.38362 = \text{Gear ratio of transmission}$

$1.586663 \times 10^{-5} = \text{Conversion factor (SHP/RPM/in lb)}$

$\text{SHP} = \text{Shaft horsepower}$

$Q = \text{Engine output shaft torque (in lb)}$
5. By rearranging equation 2 as follows:

\[ C_T = \frac{GW/\delta}{\rho_o \pi R (\frac{\pi R}{30})^2 \left(\frac{N}{\sqrt{\delta}}\right)^3} \]

It can be seen that \( C_T \) will be constant if \( GW/\delta \) and \( N/\sqrt{\delta} \) are constant. During these tests, the target \( GW/\delta \) was different for each flight, but the target \( N/\sqrt{\delta} \) was 324 RPM for all flights. The reason for maintaining constant \( N/\sqrt{\delta} \) was to minimize the difference in compressibility effects between flights.

6. Test-day level flight power was corrected to standard-day conditions by assuming the test-day dimensionless parameters \( C_p \), \( C_T \), \( \mu \), and \( r \) are independent of atmospheric conditions. Consequently, the standard-day dimensionless parameters \( C_p \), \( C_T \), \( \mu \), and \( r \) are identical to \( C_p \), \( C_T \), \( \mu \), and \( r \), respectively. From the definition of equation 1, the following relationship can be derived:

\[ \text{SHP}_s = \text{SHP}_t \left( \frac{\rho_s}{\rho_t} \right) \left( \frac{\Omega_s}{\Omega_t} \right)^3 \]

Where:

- \( \text{SHP} \) = Engine output shaft horsepower
- \( \mu \) = Air density
- \( t \) = Test day
- \( s \) = Standard day
- \( \Omega \) = Main rotor angular velocity (rad/sec)

ENGINE AND TRANSMISSION COOLING CHARACTERISTICS

7. Engine and transmission temperatures were recorded during ground run, climb, level flight, descent, and prior to engine shutdown. Temperatures were recorded on all flights at these conditions. The maximum temperature at each condition is presented in Table 2 and corrected to 125°F with the following equation:

\[ T_{\text{correction}} = T_{\text{max}} + (125\,^\circ\text{F} - \text{OAT}) \]
**APPENDIX E. TEST DATA**

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<th>Figure Number</th>
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<td>Control Positions in Trimmed Forward Flight</td>
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<td>Static Longitudinal Stability</td>
<td>5 and 6</td>
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<td>-----</td>
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<td>GROSS</td>
<td>LONG</td>
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<tr>
<td>(LB)</td>
<td>(PS)</td>
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<tr>
<td>8560</td>
<td>194.2(FWD)</td>
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NOTES:
1. ZERO SIDESLIP
2. REFERRED ROTOR SPEED, \( n/\sqrt{c} \equiv 321.8 \) RPM
3. SUBSTITUTE STRAIGHT EXHAUST PIPE INSTALLED.

**Figure 2**

LEVEL FLIGHT PERFORMANCE
LE-35 [USA 76-22554]
LYCOMING ENGINE MODEL TS3-L-703 S/N 131432

FAIRED CURVE DERIVED FROM 1-954 THROUGH 6 OF
REF. 10, APP. A
### Figure 3: Control Positions in Trained Forward Flight

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</table>

*Substitute Straight Exhaust Pipe Installed*

- **Total Directional Control Travel = 5.5 Inches**

- **Total Lateral Control Travel = 8.7 Inches**

- **Total Longitudinal Control Travel = 10.2 Inches**

**Calibrated Airspeed (Knobs)**
TOTAL DIRECTIONAL CONTROL TRAVEL = 5.5 INCHES

TOTAL LATERAL CONTROL TRAVEL = 6.7 INCHES

TOTAL LONGITUDINAL CONTROL TRAVEL = 10.2 INCHES
Figure 5

Objective: Reduce Noise Intensity

Table 1: Noise Intensity Reduction

<table>
<thead>
<tr>
<th>Condition</th>
<th>Original</th>
<th>After Reduction</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>85 dB</td>
<td>75 dB</td>
<td>10%</td>
</tr>
<tr>
<td>Test 2</td>
<td>90 dB</td>
<td>80 dB</td>
<td>11%</td>
</tr>
<tr>
<td>Test 3</td>
<td>95 dB</td>
<td>85 dB</td>
<td>10%</td>
</tr>
</tbody>
</table>

Summary:
- Single Thermal Muffler: 10% noise reduction
- Substitute Straight Exhaust Pipe: 11% noise reduction

- Total Reduction: Control Travel = 5.5 inches
- Total Exhaust Control Travel = 8.7 inches
- Total Instrument Control Travel = 10.2 inches
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