FLIGHT TEST EVALUATION OF THE OH - 58C MAIN ROTOR BLADE EROSION TAPE

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FEBRUARY 1986

FINAL REPORT

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The US Army Aviation Engineering Flight Activity conducted a flight test evaluation of OH-58C main rotor blade erosion tapes between 9 and 23 October 1985. Polyurethane and stainless steel erosion tapes were tested. Hover and level flight performance tests and qualitative handling qualities tests were conducted to determine the effects of applying these leading edge erosion tapes to the main rotor blades of the test OH-58C. Hover and level flight performance were slightly improved by the installation of the stainless steel tape and...
slightly degraded by the installation of the polyurethane tape. No significant changes in handling qualities were noted as a result of the erosion tape installations. One shortcoming related to the difficult installation of the erosion tapes was noted.
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## DISTRIBUTION
INTRODUCTION

BACKGROUND

1. The US Army considers it advantageous to use tape on main rotor blade leading edges to protect the blade from erosion in high wear environments. Two types of tape have been considered for this use: stainless steel and polyurethane. The OH-58C currently has no erosion strip on the main rotor blade leading edge. The US Army Aviation Systems Command (AVSCOM) tasked the US Army Aviation Engineering Flight Activity (USAAEFA) to conduct a flight test evaluation of erosion tape for the OH-58C main rotor blade (ref 1, app A). The USAAEFA forwarded a test plan to AVSCOM (ref 2), which was subsequently approved (ref 3).

TEST OBJECTIVE

2. The objective of this evaluation was to conduct quantitative performance tests and qualitative handling qualities tests to determine the effect of two different main rotor blade leading edge erosion tapes on the OH-58C helicopter.

DESCRIPTION

3. The test aircraft, JOH-58C US Army S/N 70-15349, was a modified OH-58C, configured for the Light Combat Helicopter (LCH) mission. The OH-58C is built by Bell Helicopter Textron, Inc. (BHTI). The OH-58C has a single two-bladed, semi-rigid, teetering-type main rotor and a single two-bladed, delta-hinged, semi-rigid teetering-type tail rotor. Maximum gross weight is 3200 pounds. The aircraft is powered by an Allison T63-A-720 engine with an uninstalled intermediate power rating (30 minutes) of 420 shaft horsepower (shp) at standard sea level conditions, which was derated to 317 shp by the main transmission. A detailed description of the OH-58C is contained in the operator's manual (ref 4, app A). Major modifications to the OH-58C for the LCH mission included:

a. SFENA Stability Augmentation System
b. Fuel range extenders (590 lb total)
c. Two-position landing gear
d. Folding vertical tail fin
e. Bell 206L-3 tail rotor and drive system (improved tail rotor)

f. Hydraulic boost for the tail rotor

A detailed description of the JOH-58C is included in appendix B and reference 5, appendix A. The erosion tape was either stainless steel (Hughes Helicopter Part No. 87-369D21104) or polyurethane (NSN 9330-00-169-6407) on the leading edge of the outboard 4 ft of both main rotor blades. A detailed description of the erosion tape and tape installation procedure is contained in the test request (ref 1) and appendix B.

TEST SCOPE

4. A limited performance and handling qualities evaluation was conducted at Bakersfield (elevation 488 ft), and Edwards AFB (elevation 2302 ft), California. Tests were conducted between 9 and 23 October 1985, consisting of 14 productive test hours in 22 flights. Testing was accomplished within the constraints of the operator's manual (ref 4, app A) and the airworthiness releases for the erosion tapes (ref 6) and the JOH-58C (ref 7). Handling qualities were evaluated using MIL-H-8501A (ref 8) as a guide. Test conditions are presented in table 1.

TEST METHODOLOGY

6. Flight test data were recorded on magnetic tape by an on-board instrumentation package (app C). Established flight test techniques were used (refs 9 and 10, app A). Test methods and data analysis are briefly discussed in appendix D. Pilot comments were recorded on cockpit data cards and a cockpit voice recorder.
<table>
<thead>
<tr>
<th>Type of Test</th>
<th>Erosion Tape Configuration</th>
<th>Gross Weight (lb)</th>
<th>Longitudinal Center of Gravity (FS)</th>
<th>Density Altitude (ft)</th>
<th>Trim True Airspeed (kts)</th>
<th>Referred Rotor Speed (rpm)</th>
<th>Thrust Coefficient (x10^4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hover</td>
<td>No Tape</td>
<td>2760 to 3050</td>
<td>110.0 to 111.7</td>
<td>-70</td>
<td>Zero</td>
<td>359 to 357</td>
<td>28.9 to 33.4</td>
</tr>
<tr>
<td>Performance1</td>
<td>Polyurethane Tape</td>
<td>2740 to 3160</td>
<td>110.3 to 112.4</td>
<td>-300</td>
<td>Zero</td>
<td>350 to 358</td>
<td>28.7 to 34.0</td>
</tr>
<tr>
<td></td>
<td>Stainless Steel Tape</td>
<td>2750 to 3180</td>
<td>110.1 to 112.9</td>
<td>-500</td>
<td>Zero</td>
<td>351 to 359</td>
<td>28.4 to 34.3</td>
</tr>
<tr>
<td>Level Flight</td>
<td>No Tape</td>
<td>2910 to 3110</td>
<td>109.2 to 110.6</td>
<td>3810 to 11,240</td>
<td>34 to 104</td>
<td>353.1 to 353.7</td>
<td>34.20, 37.23, 42.49, 46.86</td>
</tr>
<tr>
<td>Performance</td>
<td>Polyurethane Tape</td>
<td>2880 to 3130</td>
<td>109.3 to 110.5</td>
<td>4400 to 11,170</td>
<td>33 to 103</td>
<td>353.0 to 353.8</td>
<td>34.15, 37.43, 42.51, 46.79</td>
</tr>
<tr>
<td></td>
<td>Stainless Steel Tape</td>
<td>2900 to 3130</td>
<td>109.3 to 110.7</td>
<td>4310 to 11,710</td>
<td>32 to 105</td>
<td>353.3 to 353.9</td>
<td>34.08, 37.26, 42.38, 46.76</td>
</tr>
<tr>
<td>Handling</td>
<td>No Tape</td>
<td>2940 to 3190</td>
<td>110.0 to 111.6</td>
<td>-300 to 1500</td>
<td>0 to 100</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Qualities2</td>
<td>Polyurethane Tape</td>
<td>2900 to 3200</td>
<td>109.8 to 111.7</td>
<td>-300 to 1500</td>
<td>0 to 100</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Stainless Steel Tape</td>
<td>3100 to 3200</td>
<td>109.6 to 110.0</td>
<td>2800 to 4500</td>
<td>0 to 100</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

NOTES:

1 Free flight hover at 50 ft above ground level.
2 Mission tasks: takeoff, landing, turns, climbs, engine failures and maneuvering flight.
RESULTS AND DISCUSSION

GENERAL

7. Hover and level flight performance testing was conducted to determine the effects of applying leading edge erosion tapes to the main rotor blades of the test JOH-58C. Hover and level flight performance were slightly improved by the installation of the stainless steel erosion tape and slightly degraded by the installation of the polyurethane erosion tape. No significant changes in the handling qualities of the JOH-58C were noted as a result of the erosion tape installations. One shortcoming identified was the difficult installation of the erosion tapes.

PERFORMANCE

Hover Performance

8. Out-of-ground effect (OGE) hover performance capability of the JOH-58C was evaluated by determining engine power required to hover at a 50 foot skid height. Testing was accomplished using the free flight hover method. Tests were conducted initially with no tape on the blades to determine a baseline. Testing was then conducted with only polyurethane tape and repeated with only stainless steel tape applied to the leading edge of the main rotor blades. Nondimensional hover performance for blades without tape is shown in figure 1, appendix E; for blades with polyurethane tape in figure 2; and for blades with stainless steel tape in figure 3.

9. The OGE hover performance of the JOH-58C without tape on the main rotor blades was essentially the same as the standard OH-58C as reported in reference 11, appendix A. Hover performance of the JOH-58C was slightly improved by installation of the stainless steel erosion tape and slightly degraded by installation of the polyurethane erosion tape. Power required for OGE hover at maximum gross weight (3200 lb) on a sea-level standard day increased approximately 4.0 shp with the polyurethane tape applied to the main rotor blades and decreased approximately 1.0 shp with the stainless steel tape applied.

Level Flight Performance

10. Level flight performance testing was conducted without tape on the main rotor blades, with only polyurethane erosion tape applied to the blades, and with only stainless steel erosion tape applied to the blades. Tests were conducted to determine changes in power required as a function of airspeed, gross weight, and density altitude. The constant referred gross weight and
rotor speed method was used. Data were obtained in zero sideslip stabilized level flight at incremental airspeeds ranging from 33 to 105 knots true airspeed. Results of these tests are presented nondimensionally in figures 4 and 5 and dimensionally in figures 6 through 17, appendix E.

11. The level flight performance of the JOH-58C was slightly improved by the installation of stainless steel erosion tape and slightly degraded by the installation of the polyurethane erosion tape. Power required for all conditions tested increased approximately 1.5 shp with the polyurethane tape applied to the main rotor blades and decreased approximately 3.0 shp with the stainless steel tape applied.

HANDLING QUALITIES

12. Handling qualities of the JOH-58C with each erosion tape installed were evaluated qualitatively in conjunction with the performance tests. Areas investigated were hover, takeoff, climb, level turns, descents, gust response, simulated sudden engine failures, stabilized autorotation and maneuvering flight. The handling qualities of the JOH-58C with either erosion tape installed were essentially unchanged from the standard JOH-58C.

RELIABILITY AND MAINTAINABILITY

13. Throughout testing, the reliability and maintainability characteristics of the erosion tape installation were observed and evaluated. No specific tests were conducted to verify long-term reliability and/or maintainability characteristics of the erosion tapes due to the short duration (calendar and flight hour) of the program. Installation of the erosion tapes was accomplished without removing the blades from the aircraft. Application instructions for the polyurethane tape stated the tape could be lifted to release entrapped air bubbles and then reaffixed to the blade. The polyurethane tape could be lifted, as per the instructions, but could not be reaffixed to the blade. Stainless steel application was difficult due to the large area of tape required. Application had to be precisely done with little margin for error. If application was correctly done, there was still a requirement to meticulously smooth the many small air bubbles and rivulets which appeared under the surface. These were time-consuming tasks with both types of tape which, if not done properly the first time, required removal of all tape and a return to the start of the entire process. With both types of tape, there was slight debonding (less than
one inch) of tape ends after one or two flights. Neither tape showed a tendency for further debonding during the remaining flights. Polyurethane tape showed slight pitting after one or two flights. Pitting increased only slightly after several flights. Stainless steel tape showed a progressive erosion after each flight, with up to moderate pitting occurring within one inch of the leading edge. Pitting will probably lead to a slight degradation of performance and will require frequent changes of the erosion tape. Difficulty in applying the tapes will lead to increased maintenance hours and lower availability of aircraft. The difficult and time-consuming installation of either erosion tape is a shortcoming.
CONCLUSIONS

GENERAL

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

a. Hover and level flight performance were slightly improved by the installation of the stainless steel tape and slightly degraded by the installation of the polyurethane tape.

b. Handling qualities were essentially unchanged with either tape installed.

c. One shortcoming was identified.

SHORTCOMING

15. The following shortcoming was identified: difficult and time-consuming installation of either erosion tape (para 13).
APPENDIX A. REFERENCES


APPENDIX B. DESCRIPTION

GENERAL

1. The test aircraft was a JOH-58C helicopter, US Army S/N 70-15349, a modification of the OH-58C. The OH-58C is built by Bell Helicopter Textron, Inc. (BHTI). The OH-58C has a single two-bladed, semi-rigid, teetering-type main rotor and a single two-bladed, delta-hinged, semi-rigid, teetering-type tail rotor. A detailed description of the OH-58C is contained in the operator's manual (ref 4, app A). The major modification for the JOH-58C configuration was addition of the three-axis stability augmentation system (SAS) by the SAS manufacturer, SFENA Corporation. Other modifications for this test included the BHTI 206L-3 tail rotor with accompanying drive shafting and gearbox and a shortened main rotor blade. External configuration was that described in reference 5, appendix A, with the Direct Vision Optics, Forward Looking Infrared System and High Frequency Antenna removed. A detailed description of the JOH-58C is contained in USAAEFA Project No. 85-03 (ref 5). The test aircraft is shown in photo 1.

WEIGHT AND BALANCE

2. The helicopter configured with all modifications and instrumentation was weighed with no fuel and with full fuel prior to any testing. The weight and longitudinal center of gravity (cg) are presented below:

<table>
<thead>
<tr>
<th>Weight (lb) /cg (fs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No fuel</td>
</tr>
<tr>
<td>Full fuel</td>
</tr>
<tr>
<td>2438/116.05</td>
</tr>
<tr>
<td>2964/116.52</td>
</tr>
</tbody>
</table>

CONTROL RIGGING

3. A complete flight control rigging check was performed by SFENA Corporation and witnessed by US Army Aviation Engineering Flight Activity (USAAEFA) quality control personnel prior to USAAEFA Project No. 85-03 and used for this test. All flight control rigging was within tolerance in accordance with reference 12, appendix A. Data for the tail rotor rigging check are presented below:

<table>
<thead>
<tr>
<th>Direction</th>
<th>Blade Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>206L-3 tail rotor</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>22° 30'</td>
</tr>
<tr>
<td>Right</td>
<td>-7° 30'</td>
</tr>
</tbody>
</table>
ROTOR SYSTEM

Tail Rotor

4. The 206L-3 tail rotor (improved tail rotor) incorporates the same airfoil section as the standard OH-58C tail rotor. The diameter is increased by 3 inches. Maximum pitch angle values for the 206L-3 tail rotor are shown in paragraph 3. A hydraulically-boosted tail rotor system was flown for this test.

Tail Rotor Drive Shaft and Gearbox

5. The tail rotor drive shafting and gearbox were changed to the 206L-3 configuration. The drive shaft is a seven-piece shaft. Each piece in the shaft is identical and has a larger diameter than the one-piece standard drive shaft. The tail rotor gearbox continuous rating is increased from 65 to 85 shaft horsepower.

Main Rotor

6. In order to maintain main rotor to tail rotor clearance, each main rotor tip cap was shortened by 1.5 inches.

Stability Augmentation System

7. The OH-58C had a limited authority, three-axis SAS. The SAS used rate gyroscopes to provide rate damping in each axis. Rate integration was used to provide attitude retention. Force trim was provided in the pitch and roll axes. An altitude hold feature was also provided in cruise flight. A detailed SAS description is included in reference 5, appendix A.

EROSION TAPE

Polyurethane Tape

8. The polyurethane tape was NSN 9330-00-169-6407 (plastic, strip, pressure sensitive), identified in the OH-58C maintenance manual (Item 120A, table 1-2, ref 12, app A). The tape was 6.0 inches wide by 0.014 inches thick. A strip of tape 48 inches long was applied to the outboard leading edge of each main rotor blade. The tape was applied inboard from the junction of the blade tip cap as shown in figure 1. Prior to application, blades were cleaned with scotchbrite pads and/or naptha. Since the tape was pressure sensitive, it was pressed into place and then smoothed with a roller or spatula. Detailed installation instructions are included in the test request (ref 1).
NOTES

1. Tape to extend outboard to the junction of the blade/tip cap.

2. Erosion tape installed with equal widths above and below the leading edge. Tape width is 6.0 inches (polyurethane) or 6.5 inches (stainless steel).

Figure 1. Erosion Tape Installation
Stainless Steel Tape

9. The stainless steel tape was Hughes Helicopter part no. 87-369021104. The tape was 6.5 inches wide by 0.0027 inches thick. A strip of tape 48 inches long was applied to the leading edge of each main rotor blade. Installation location was the same as for the polyurethane tape (fig. 1). Prior to application, blades were cleaned with 400 grit abrasion paper and solvent. The blade was then heated (not to exceed 120°F) and tape was applied and hand smoothed. Detailed installation instructions are included in the test request (ref 1, app A).
APPENDIX C. INSTRUMENTATION

1. The test instrumentation system was designed, calibrated, installed, and maintained by the US Army Aviation Engineering Flight Activity. Digital and analog data were obtained from calibrated instrumentation and were recorded on magnetic tape and/or displayed in the cockpit. The instrumentation system consisted of various transducers, signal conditioning units, a ten-bit pulse code modulation encoder, and an Ampex AR 700 tape recorder. Time correlation was accomplished with an onboard-recorded and -displayed Inter-Range Instrumentation Group B format time of day. Various specialized test indicators displayed data to the pilot and engineer continuously during the flight. A boom with a swiveling pitot-static tube, sideslip vane, and angle-of-attack vane was mounted on the nose of the aircraft. Photos 1 through 4 show the instrumentation installation. The boom airspeed system calibration in level flight is shown in figure 1. The engine torquemeter calibration is shown in figure 2.

2. The following parameters were displayed on calibrated instruments in the cockpit:

- Airspeed (boom)
- Airspeed (ship's system)
- Altitude (boom)
- Altitude (ship's system)
- Outside air temperature
- Rotor speed
- Engine torque
- Turbine outlet temperature
- Fuel flow rate
- Fuel used (totalizer)
- Normal acceleration (center of gravity)
- Angle-of-sideslip
- Time of day
- Record counter

3. The following parameters were recorded on magnetic tape:

- Time code
- Run number
- Airspeed (boom)
- Airspeed (ship)
- Altitude (boom)
- Altitude (ship)
- Outside air temperature
- Main rotor speed
- Angle-of-sideslip
- Angle-of-attack
- Engine torque
Turbine outlet temperature
Gas producer speed
Power turbine output shaft speed
Fuel flow rate
Fuel used
Control positions
   Longitudinal
   Lateral
   Directional
   Collective
Aircraft attitudes and rates
   Pitch
   Roll
   Yaw
SAS actuator positions
   Left hand cyclic
   Right hand cyclic
   Directional
Aircraft vertical acceleration (center of gravity)
Photo 2. Airspeed Boom (Attached to Underside of Aircraft)
BOOM SYSTEM AIRSPEED CALIBRATION IN LEVEL FLIGHT

JOH-58C USA S/N 70-35348

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GROSS WEIGHT (LB)</td>
<td>LONGITUDINAL DENSITY</td>
<td>OAT</td>
<td>ROTOR SPEED (DEG C)</td>
<td>(RPM)</td>
</tr>
<tr>
<td>2990</td>
<td>108.2 (MID)</td>
<td>6480</td>
<td>7.5</td>
<td>353</td>
</tr>
</tbody>
</table>

NOTE: TRAILING BOMB METHOD

CORRECTION TO BE ADDED (KNOTS)

LINE OF ZERO ERROR

CALIBRATED AIRSPEED (KNOTS)

INDICATOR AIRSPEED (KNOTS)

NOT FOR HANDBOOK USE
FIGURE 2
ENGINE TORQUEMETER CALIBRATION
ALLISON ENGINE MODEL T63-A-720 S/N 404458

SYMBOL       POWER TURBINE SPEED
○           34290 RPM
□           33280 RPM

TORQUE PRESSURE (PSI)

REVERSIBLE TORQUE (FT-LB)
APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

PERFORMANCE

1. The helicopter performance test data were generalized by use of nondimensional coefficients. Effects of compressibility and blade stall were not separated and defined. The following nondimensional coefficients were used to generalize the hover and level flight test results obtained during this flight test program.

   a. Coefficient of power (Cp):

   \[
   C_p = \frac{\text{SHP (550)}}{\rho A(\Omega R)^3}
   \]  

   b. Coefficient of thrust (CT):

   \[
   C_T = \frac{\text{Thrust}}{\rho A(\Omega R)^2}
   \]  

   c. Advance ratio (v):

   \[
   v = \frac{1.6878 \, V_T}{\Omega R}
   \]  

   d. Advancing tip Mach number (M_tip):

   \[
   M_{tip} = \frac{1.6878 \, V_T + (\Omega R)}{\rho A(\Omega R)^2}
   \]

Where:

- SHP = Engine output shaft horsepower
- 550 = Conversion factor (ft-lb/sec/shp)
- \( \rho \) = Air density (slugs/ft\(^3\)) = \( \sigma \times 0.002376881 \)
- \( \sigma \) = Density ratio = 8/9
- \( A \) = Main rotor disc area (ft\(^2\)) = 966.52
- \( \Omega \) = Main rotor angular velocity (radian/sec) = 37.07 (at 354 rpm)
- \( R \) = Main rotor radius (ft) = 17.54
- Thrust = Gross weight (lb)
Conversion factor (ft/sec/knot)

\[ V_T = \text{True airspeed (knot)} \]

\[ a = \text{Speed of sound (ft/sec) = 1116.45 \sqrt{T}} \]

\[ \delta = \frac{H_p}{145442} \]

\[ H_p = \text{Pressure altitude (ft)} \]

For a rotor speed of 354 rpm, the following constants were used:

\[ \omega = 650.21 \text{ ft/sec} \]

\[ A(\omega) = 408618602.6 \text{ ft}^4/\text{sec}^2 \]

\[ A(\omega)^3 = 2.6568790 \times 10^{11} \text{ ft}^3/\text{sec}^3 \]

**Shaft Horsepower Required**

2. The engine output shaft torque was determined from the engine manufacturer's torque system. The relationship of measured torque pressure to engine output shaft torque (ft-lb) as determined in the engine test cell calibration is shown in figure 2, appendix C. This output shp was determined from the engine output shaft torque and rotational speed by the following equation:

\[ \text{SHP} = \frac{2\pi \times N_p \times Q}{33,000} \]

Where:

\[ N_p = \text{Engine output shaft rotational speed (rpm)} \]

\[ Q = \text{Engine output shaft torque (ft-lb)} \]

\[ 33,000 = \text{Conversion factor (ft-lb/min/shp)} \]

**Hover Performance**

3. Hover performance data were obtained at 50-foot skid height by the free flight hover technique. All hover tests were conducted in winds of less than 3 knots. Atmospheric pressure, temperature, and wind velocity were recorded from a ground weather station. Free flight hover tests consisted of stabilizing the helicopter at a desired height with reference to a premeasured weighted cord.
hung from the aircraft. Ballast was incrementally removed from the aircraft until the minimum gross weight was obtained. All hover data were reduced to nondimensional parameters of $C_p$ and $C_T$ (equations 1 and 2, respectively).  

**Level Flight Performance and Specific Range**

4. Level flight performance data were reduced using equations 1, 2 and 3. Each speed power was flown at a predetermined constant $C_T$ by maintaining constant referred gross weight ($W/\delta$) and referred rotor speed ($N/\sqrt{\delta}$). A constant $W/\delta$ was maintained by increasing pressure altitude (decreasing ambient pressure ratio ($\delta$)) as the aircraft gross weight decreased due to fuel burnoff. Rotor speed was also varied to maintain a constant $N/\sqrt{\delta}$ as the ambient air temperature varied.

5. Test day (measured) level flight power was corrected to standard day conditions (average for the flight) by assuming that the test day dimensionless parameters $C_p$, $C_T$, and $\mu_t$ are identical to $C_{p_s}$, $C_{T_s}$, and $\mu_{t_s}$, respectively.

From equations 1 and 3, the following relationship can be derived:

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

$$V_{T_s} = \frac{V_{T_t}}{\mu_{t_s}} \frac{\mu_{t_s}}{\mu_t}$$

6. Test specific range was calculated using level flight performance data and the measured fuel flow.

$$\text{SR} = \frac{V_T}{W_f}$$

Where:

- **SR** = Specific range (nautical air miles per pound of fuel)
- $V_T$ = True airspeed (knot)
- $W_f$ = Fuel flow (lb/hr)
HANDLING QUALITIES

7. Handling qualities data were qualitatively evaluated using standard test methods as described in reference 9, appendix A. The definition of shortcoming used during this test is as follows: an imperfection or malfunction occurring during the life cycle of equipment which must be reported and which should be corrected to increase efficiency and to render the equipment completely serviceable. It will not cause an immediate breakdown, jeopardize safe operation, or materially reduce the usability of the material or end product.

AIRSPEED CALIBRATION

8. The boom and ship's pitot-static systems were calibrated by using the trailing bomb method to determine the airspeed position error. Calibrated airspeed ($V_{cal}$) was obtained by correcting indicated airspeed ($V_i$) using instrument ($\Delta V_{ic}$) and position ($\Delta V_{pc}$) error corrections.

$$V_{cal} = V_i + \Delta V_{ic} + \Delta V_{pc}$$

9. True airspeed ($V_t$) was calculated from the calibrated airspeed and density ratio.

$$V_t = \frac{V_{cal}}{\sqrt{\sigma}}$$

WEIGHT AND BALANCE

10. Prior to testing, the aircraft gross weight and center of gravity (cg) location were determined by using calibrated scales. The aircraft was weighed without fuel and with instrumentation on board. The aircraft weight with no fuel was 2438 pounds, with a longitudinal cg location at fuselage station 116.05.
APPENDIX E. TEST DATA

INDEX

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<th>Figure Number</th>
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<td>1 through 3</td>
</tr>
<tr>
<td>Level Flight Performance</td>
<td>4 through 17</td>
</tr>
</tbody>
</table>
FIGURE 1
NONDIMENSIONAL HOVERING PERFORMANCE
JOH-58C USA S/N 70-15349
SKID HEIGHT = 50 FEET

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>Rotor Speed (RPM)</th>
<th>Density Symbol</th>
<th>Altitude (FT)</th>
<th>OAT (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>○</td>
<td>353-354</td>
<td>○</td>
<td>-70</td>
<td>10.5</td>
</tr>
<tr>
<td>□</td>
<td>350</td>
<td>□</td>
<td>-70</td>
<td>10.5</td>
</tr>
<tr>
<td>△</td>
<td>346-347</td>
<td>△</td>
<td>-70</td>
<td>10.5</td>
</tr>
</tbody>
</table>

NOTES:
1. FREE FLIGHT HOVER TECHNIQUE
2. WINDS LESS THAN 3 KNOTS
3. VERTICAL HEIGHT FROM BOTTOM OF SKID TO CENTER OF ROTOR HUB = 9.3 FEET
4. NO TAPE ON BLADES

THRUST COEFFICIENT, C_T x 10^4 = \frac{GW}{\rho A (hR)^2} x 10^5
**FIGURE 2**
**NONDIMENSIONAL HOVERING PERFORMANCE**
**JOH-5BC USA S/N 70-15349**
**SKID HEIGHT = 50 FEET**

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>ROTOR DENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(RPM)</td>
</tr>
<tr>
<td>○</td>
<td>353-354</td>
</tr>
<tr>
<td>□</td>
<td>349-350</td>
</tr>
<tr>
<td>△</td>
<td>346-347</td>
</tr>
</tbody>
</table>

**NOTES:**
1. FREE FLIGHT HOVER TECHNIQUE
2. WINDS LESS THAN 3 KNOTS
3. VERTICAL HEIGHT FROM BOTTOM OF SKID TO CENTER OF ROTOR HUB = 9.3 FEET
4. POLYURETHANE TAPE INSTALLED ON MAIN ROTOR BLADES
FIGURE 3
NONDIMENSIONAL HOVERING PERFORMANCE
JOH-5BC USA S/N 7D-15349
SKID HEIGHT = 50 FEET

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>ROTOR SPEED</th>
<th>DENSITY ALTITUDE</th>
<th>DAT (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>◆</td>
<td>343-358</td>
<td>-500</td>
<td>7.5</td>
</tr>
<tr>
<td>◆</td>
<td>349-360</td>
<td>-500</td>
<td>7.5</td>
</tr>
<tr>
<td>△</td>
<td>346-347</td>
<td>-500</td>
<td>7.5</td>
</tr>
</tbody>
</table>

NOTES: 1. FREE FLIGHT HOVER TECHNIQUE
2. WINDS LESS THAN 3 KNOTS
3. VERTICAL HEIGHT FROM BOTTOM OF SKID TO CENTER OF ROTOR HUB = 9.3 FEET
4. STAINLESS STEEL TAPE INSTALLED ON MAIN ROTOR BLADES

POWER COEFFICIENT: $C_p = \frac{2SHP \times 10^3}{\rho \times V^2}$

THRUST COEFFICIENT: $C_T = \frac{10^4 \times 20^2}{\rho \times (SR)^2}$
FIGURE 5
NOMINAL LEVEL FLIGHT PERFORMANCE
JULY 9569 USA 5/6-19549

NOTES:
1. NO TAPE ON BLADES
2. ZERO SIDSLIP
3. AVG. LATERAL/ROLL C/A = PS 199:8 (MID)
4. AVG. V/H = 395:5
5. CURVES DERIVED FROM FIGURES 5 THROUGH 9
FIGURE 6
LEVEL FLIGHT PERFORMANCE
JUH-58C USA S/N 70-15349

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG AVG LOCATION (FS) (BL)</th>
<th>AVG DENSITY (FT)</th>
<th>AVG OAT (DEG C)</th>
<th>AVG REFERRED ROTOR SPEED (RPM)</th>
<th>AVG CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2910</td>
<td>110.6 (AFT) 0.1 MID</td>
<td>3810</td>
<td>11.0</td>
<td>353.1</td>
<td>0.003420</td>
</tr>
</tbody>
</table>

NOTES:
1. ZERO SIDESLIP
2. NO TAPE ON BLADES

CURVE DERIVED FROM ALLISON 763-A-720 ENGINE SPECIFICATION 876 WITH INSTALLATION LOSSES

CURVE DERIVED FROM FIGURES 4 AND 5
FIGURE 7
LEVEL FLIGHT PERFORMANCE
JOH-58C  USA S/N 70-15349

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LOCATION (LONG LAT)</td>
<td>LOCATION (LONG LAT)</td>
<td>LOCATION (LONG LAT)</td>
</tr>
<tr>
<td>DECS (FT) DEG C (DEG C)</td>
<td>DECS (FT) DEG C (DEG C)</td>
<td>DECS (FT) DEG C (DEG C)</td>
</tr>
<tr>
<td>ROTOR SPEED (RPM)</td>
<td>ROTOR SPEED (RPM)</td>
<td>ROTOR SPEED (RPM)</td>
</tr>
<tr>
<td>CT</td>
<td>CT</td>
<td>CT</td>
</tr>
<tr>
<td>2990 109.2(MID) 0.1 MID</td>
<td>5480 7.5</td>
<td>353.9 0.003723</td>
</tr>
</tbody>
</table>

NOTES: 1. ZERO SIDESLIP.
2. NO TAPE ON BLADES

CURVE DERIVED FROM ALLISON T63-A-720 ENGINE SPECIFICATION 876 WITH INSTALLATION LOSSES

CURVE DERIVED FROM FIGURES 4 AND 5
Figure 8
Level Flight Performance
JOH-58C USA S/N 70-15349

<table>
<thead>
<tr>
<th>Gross Weight (LB)</th>
<th>Avg CG Location (FS)</th>
<th>Avg Density OAT (FT)</th>
<th>Avg Altitude (FT)</th>
<th>Avg Rotor Speed (RPM)</th>
<th>Avg C_T</th>
</tr>
</thead>
<tbody>
<tr>
<td>3100</td>
<td>109.6 (MID)</td>
<td>0.7</td>
<td>8380</td>
<td>353.7</td>
<td>0.004249</td>
</tr>
</tbody>
</table>

Notes:
1. Zero sideslip
2. No tape on blades


Engine shaft horsepower required vs. true airspeed (knots)
Specific range (Naut. Air miles/lb fuel)
Advancing tip Mach number
FIGURE 9
LEVEL FLIGHT PERFORMANCE
JOH-58C USA S/N 70-15349

<table>
<thead>
<tr>
<th>AVG</th>
<th>AVG CG</th>
<th>AVG DENSITY</th>
<th>AVG OAT</th>
<th>AVG REFERRED</th>
<th>AVG CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRDSS</td>
<td>LOCATION</td>
<td>WEIGHT (LB)</td>
<td>LONG (FS)</td>
<td>LAT (BL)</td>
<td>ALTITUDE (FT)</td>
</tr>
<tr>
<td>3110</td>
<td>109.7(MID)</td>
<td>0.1 MID</td>
<td>11,240</td>
<td>5.5</td>
<td>353.1</td>
</tr>
</tbody>
</table>

NOTES:
1. ZERO SIDESLIP
2. NO TAPE ON BLADES

CURVE DERIVED FROM ALLISON T63-A-720 ENGINE SPECIFICATION 876 WITH INSTALLATION LOSSES

CURVE DERIVED FROM FIGURES 4 AND 5
<table>
<thead>
<tr>
<th>WEIGHT (LB)</th>
<th>LOCATION</th>
<th>DENSITY (QAT)</th>
<th>ALTITUDE (FT)</th>
<th>ROTOR SPEED (DEG E)</th>
<th>RPM</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2880</td>
<td>110.5(AFT)</td>
<td>0.7</td>
<td>4400</td>
<td>12.5</td>
<td>353.7</td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**
1. ZERO SIDESLIP
2. POLYURETHANE TAPE APPLIED TO MAIN ROTOR BLADE

**CURVE DERIVED FROM ALLISON T63-A-720 ENGINE SPECIFICATION**

**T63 WITH INSTALLATION LOSSES**

**TUNE AIRSPEED (KNOTS)**

**SPECIFIC RAME (UNIT, AUT MILES/MB FUEL)**
## Figure 11: Level Flight Performance

<table>
<thead>
<tr>
<th>GROSS WEIGHT (LB)</th>
<th>AVG C6</th>
<th>AVG LOCATION (FS)</th>
<th>DENSITY (FT3)</th>
<th>AVG Density Altitude (FT)</th>
<th>AVG QAT (DEG C)</th>
<th>AVG ROTOR SPEED (RPM)</th>
<th>AVG DERIVED CT</th>
<th>AVG DERIVED CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3010</td>
<td></td>
<td>109.3 (NID)</td>
<td>6200</td>
<td>16.0</td>
<td>353.0</td>
<td>0.003743</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Notes:
1. Zero sideslip
2. Polyurethane tape applied to main rotor blades

**Curve derived from Allison T63-A-720 engine specification 876 with installation losses**

**Curve derived from Figures 4 and 5**

**PEPS 63HP = +1.5 SHP**
## FIGURE 12
LEVEL FLIGHT PERFORMANCE
JOH-58C USA 5/N 70-15349

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG CG LOCATION (FS)</th>
<th>AVG DENSITY (LAT) (BL)</th>
<th>AVG ALTITUDE (FT)</th>
<th>AVG OAT (DEG. C)</th>
<th>AVG ROTOR SPEED (RPM)</th>
<th>AVG GT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3100</td>
<td>109.5 (MID)</td>
<td>0.1 (MID)</td>
<td>859°</td>
<td>7.5</td>
<td>353.8</td>
<td>0.004251</td>
</tr>
</tbody>
</table>

**NOTES:**
1. ZERO SIDESLIP.
2. POLYURETHANE TAPE APPLIED TO MAIN ROTOR BLADES.

CURVE DERIVED FROM ALLISON T66-A-720 ENGINE SPECIFICATION 876 WITH INSTALLATION LOSSES.

CURVE DERIVED FROM FIGURES 4 AND 5.
PLUS 4SHP = +7.5 SHP.

**TRUE AIRSPEED (KNOTS)**
### TABLE

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (lbs)</th>
<th>AVG CG LOCATION (FS)</th>
<th>AVG DENSITY (sl)</th>
<th>AVG ALTITUDE (FT)</th>
<th>AVG OAT (DEG C)</th>
<th>AVG ROTOR SPEED (RPM)</th>
<th>AVG ( q_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>3130</td>
<td>109.5 (Mid)</td>
<td>0.1 (Mid)</td>
<td>11,170</td>
<td>6.5</td>
<td>353.5</td>
<td>0.004679</td>
</tr>
</tbody>
</table>

### NOTES:
1. Zero sideslip
2. Polyurethane tape applied to main rotor blades.

### CURVES

- Curve derived from Allison T68-A-720 engine specification 876 with installation losses.
- Curve derived from figures A and 9 plus 2500 + 45.3 RPM.

### GRAPHS

- Graphs showing specific range and true airspeed.
**Figure 14**

**Level Flight Performance**

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (Lb)</th>
<th>AVG CG LOCATION (FS)</th>
<th>AVG DENSITY (g/L)</th>
<th>AVG OAT (DEG C)</th>
<th>REFERRED Rotor Speed (RPM)</th>
<th>AVG CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2900</td>
<td>110.7(AFT)</td>
<td>0.1(MID)</td>
<td>4310</td>
<td>14.0</td>
<td>353.9</td>
</tr>
</tbody>
</table>

**Notes:**

1. Zero sideslip
2. Stainless steel tape applied to main rotor blades

**Curve Derived from:**

T63-A-720 engine specification 876 with installation losses

**True Airspeed (Knots)**
FIGURE 15
LEVEL FLIGHT PERFORMANCE
JOH-58C USA S/N 7D-15349

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GROSS WEIGHT (LB)</td>
<td>LOCATION (FS)</td>
<td>LONG (BL)</td>
<td>LAT</td>
<td>ALTITUDE (FT)</td>
<td>QAT</td>
</tr>
<tr>
<td>3000</td>
<td>109.3(MID)</td>
<td>0.1 MID</td>
<td>6220</td>
<td>15.0</td>
<td>353.7</td>
</tr>
</tbody>
</table>

NOTES:
1. ZERO SIDESLIP.
2. STAINLESS STEEL TAPE APPLIED TO MAIN ROTOR BLADES.

CURVE DERIVED FROM ALLISON T63-A-720 ENGINE SPECIFICATION 876 WITH INSTALLATION LOSSES.

CURVE DERIVED FROM FIGURES 5 AND 6.
PLUS ASHP = -3.0 SHP
### LEVEL FLIGHT PERFORMANCE
**JOH-58C USA S/N 70-15349**

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG CG LOCATION (LS)</th>
<th>AVG DENSITY (FT)</th>
<th>AVG QAT (DEG C)</th>
<th>AVG REFERRED CT. (RPM)</th>
<th>AVG Rotor Speed (R.P.M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3130</td>
<td>109.6 (MID)</td>
<td>0.1</td>
<td>8660</td>
<td>11.5</td>
<td>353.9</td>
</tr>
</tbody>
</table>

**NOTES:**
1. ZERO SIDESLIP
2. STAINLESS STEEL TAPE APPLIED TO MAIN ROTOR BLADES

CURVE DERIVED FROM ALLISON T63-A-720 ENGINE SPECIFICATION 876 WITH INSTALLATION LOSSES.
## FIGURE 17
LEVEL FLIGHT PERFORMANCE
JOH-58C, USA S/N 70-15349

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | AVG DENSITY | AVG QAT | AVG ALTITUDE (FT) | AVG ROTOR SPEED (RPM) | CT | AVG | AVG /
|----------------------|-----------------|-------------|---------|------------------|-----------------------|----|-----|-----
| 3130                 | 109.6 (MID)     | 0.1 (MID)   | 11,170  | 7.0              | 353.3                 | 0.06467 | 0.04 |

### NOTES:
1. ZERO SIDESLIP.
2. STAINLESS STEEL TAPE APPLIED TO MAIN ROTOR BLADES.

**CURVE DERIVED FROM ALLISON T63-A-720 ENGINE SPECIFICATION 876 WITH INSTALLATION LOSSES**

**SPECFIC RANGE (NIGHT AIR MILES/LB FUEL)**
DISTRIBUTION

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US Army Cost and Economic Analysis Center (CACC-AM) 1

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NASA/Ames Research Center (SAVRT-R, SAVRT-M (Library))

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Aviation Applied Technology Directorate (SAVRT-TY-DRD SAVRT-TY-TSC (Tech Library))
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Aeroflightdynamics Directorate (SAVRT-AF-D)

US Army Aviation Research and Technology Activity (AVSCOM) 1
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Defense Technical Information Center (FDAC) 2

US Military Academy, Department of Mechanics 1
(Aero Group Director)

ASD/AFXT, ASD/ENF 2

US Army Aviation Development Test Activity (STEBG-CT) 2
Assistant Technical Director for Projects, Code: CT-24
(Mr. Joseph Dunn) 2

6520 Test Group (ENML) 1

Commander, Naval Air Systems Command (AIR 5115B, AIR 5301) 3

Defense Intelligence Agency (DIA-DT-2D) 1

US Army Aviation Systems Command (AMSAV-EIO) 4