FLIGHT TEST EVALUATION OF THE OH-5C MAIN ROTOR BLADE EROSION TAPE (U) ARMY AVIATION ENGINEERING ACTIVITY EDWARDS AFB CA J R MARTIN ET AL. FED 86 F 3/1
FLIGHT TEST EVALUATION OF THE OH-58C MAIN ROTOR BLADE EROSION TAPE

JOHN R. MARTIN
MAJ, AV
PROJECT OFFICER/PILOT

RALPH WORATSCHEK
PROJECT ENGINEER

FREDERICK W. STELLAR
MAJ, AV
PROJECT PILOT

MATTHEW GRAHAM
PROJECT ENGINEER

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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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. BHTI 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. 87-36921104) 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 1. Test Conditions

<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 (x10⁴)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hover Performance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Tape</td>
<td></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>Polyurethane Tape</td>
<td></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>Stainless Steel Tape</td>
<td></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><strong>Level Flight Performance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Tape</td>
<td></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>Polyurethane Tape</td>
<td></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>Stainless Steel Tape</td>
<td></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><strong>Handling Qualities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Tape</td>
<td></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>Polyurethane Tape</td>
<td></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>Stainless Steel Tape</td>
<td></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.
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 reattached 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)</th>
<th>cg (fs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No fuel</td>
<td>2438/116.05</td>
</tr>
<tr>
<td>Full fuel</td>
<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>Left: 22° 30', Right: -7° 30'</td>
</tr>
</tbody>
</table>
ROTORSYSTEM

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 torque meter 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)
Photo 3. Voice and Pulse Code Modulation Recorders Installed in
Passenger Compartment
BOOM SYSTEM AIRSPEED CALIBRATION IN LEVEL FLIGHT
JOH-56C USA 5/N 70-16548

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG LONGITUDINAL CG LOCATION (FS)</th>
<th>AVG DENSITY (FT)</th>
<th>AVG QAT (DEG C)</th>
<th>AVG ROTOR SPEED (RPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2990</td>
<td>109.2 (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 ZER0 ERROR

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
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 \((C_p)\):

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

   \(\rho\) = Air density (slugs/ft\(^3\)) = \sigma \times 0.002376881

   \(\sigma\) = Density ratio = 8/0

   \(\Lambda\) = 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)

   \[
   \text{Thrust} = \frac{1.6878 \cdot V_T}{\Omega R}
   \]

   \[
   C_T = \frac{\text{Thrust}}{\rho \Lambda \Omega R^2}
   \]

   \[
   \mu = \frac{1.6878 \cdot V_T}{\Omega R}
   \]

   \[
   M_{tip} = \frac{1.6878 \cdot V_T + (\Omega R)}{\Lambda}
   \]

   \[
   \text{SHP} = \text{Engine output shaft horsepower}
   \]

   \[
   550 = \text{Conversion factor (ft-lb/sec/shp)}
   \]

   \[
   \rho = \text{Air density (slug/ft}^3\text{)} = \sigma \times 0.002376881
   \]

   \[
   \sigma = \text{Density ratio} = 8/0
   \]

   \[
   \Lambda = \text{Main rotor disc area (ft}^2\text{)} = 966.52
   \]

   \[
   \Omega = \text{Main rotor angular velocity (radian/sec)} = 37.07 \text{ (at 354 rpm)}
   \]

   \[
   R = \text{Main rotor radius (ft)} = 17.54
   \]

   \[
   \text{Thrust} = \text{Gross weight (lb)}
   \]
1.6878 Conversion factor (ft/sec/knot)

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

\[ a = \text{Speed of sound (ft/sec)} = 1116.45 \sqrt{\frac{T}{T + 273.15}} \]

\[ T = \text{Ambient air temperature (°C)} \]

\[ \delta = \left(1 - \frac{H_p}{145442}\right)^{5.25585} \]

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

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

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

\[ A(\omega_r)^2 = 40861860.6 \text{ ft}^4/\text{sec}^2 \]

\[ A(\omega_r)^3 = 2.6568790 \times 10^{11} \text{ ft}^5/\text{sec}^3 \]

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:

\[ \text{SHP} = \frac{2\pi \times N_p \times Q}{33,000} \]  (5)

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:

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

$$V_T^s = V_T^t \left( \frac{\mu_s}{\mu_t} \right)$$

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

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

Where:

- $\text{SR} =$ Specific range (nautical air miles per pound of fuel)
- $V_T =$ True airspeed (knot)
- $W_f =$ Fuel flow (lb/hr)

25
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 \( \Delta V_i \) and position \( \Delta V_p \) error corrections.

\[
V_{cal} = V_i + \Delta V_i + \Delta V_p
\]  

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 (FT)</th>
<th>OAT (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>○</td>
<td>353-354</td>
<td>-70</td>
<td>10.5</td>
</tr>
<tr>
<td>□</td>
<td>350</td>
<td>-70</td>
<td>10.5</td>
</tr>
<tr>
<td>△</td>
<td>346-347</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 10^6 = \frac{GW}{P A (\rho R)^2} X 10^6
### Figure 2
Non-dimensional Hovering Performance

**JOH-58C USA S/N 70-15349**

**Skid Height = 50 Feet**

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>Rotor Density Symbol</th>
<th>Speed (RPM)</th>
<th>Altitude (FT)</th>
<th>OAT (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>◯</td>
<td>353-354</td>
<td>-300</td>
<td>9.0</td>
<td></td>
</tr>
<tr>
<td>□</td>
<td>349-350</td>
<td>-300</td>
<td>9.0</td>
<td></td>
</tr>
<tr>
<td>△</td>
<td>346-347</td>
<td>-300</td>
<td>9.0</td>
<td></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 70-15349**

**Skid Height = 50 Feet**

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>ROTOR SPEED (RPM)</th>
<th>DENSITY ALTITUDE (FT)</th>
<th>DENSITY ALTITUDE (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>343-358</td>
<td>-500</td>
<td>7.5</td>
</tr>
<tr>
<td>G</td>
<td>349-360</td>
<td>-500</td>
<td>7.5</td>
</tr>
<tr>
<td>A</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:**
\[ C_T \times 10^5 = \frac{SHP \times 550}{\rho(T)(AR)^{0.5}} \times 10^5 \]

**Thrust Coefficient:**
\[ C_T \times 10^4 = \frac{\rho(T)(AR)^{0.5}}{SHP} \times 10^4 \]
<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG CG LOCATION (FS)</th>
<th>AVG DENSITY (AT) (FT)</th>
<th>AVG OAT (DEG C)</th>
<th>AVG REFERRED ROTOR SPEED (RPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2910</td>
<td>110.6 (AFT)</td>
<td>3810</td>
<td>11.0</td>
<td>353.1</td>
</tr>
</tbody>
</table>

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

**CURVE DERIVED FROM ALLISON 163-A-720 ENGINE SPECIFICATION 876 WITH INSTALLATION LOSSES**
### FIGURE 7
LEVEL FLIGHT PERFORMANCE
JHO-58C USA S/N 70-15349

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG CG LOCATION</th>
<th>AVG DENSITY (QAT)</th>
<th>AVG QAT</th>
<th>AVG REFERRED ROTOR SPEED (RPN)</th>
<th>C_T</th>
</tr>
</thead>
<tbody>
<tr>
<td>2990</td>
<td>109.2 (MID)</td>
<td>0.1 MID</td>
<td>5480</td>
<td>7.5</td>
<td>353.9</td>
</tr>
</tbody>
</table>

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

**CURVE DERIVED FROM ALLISON T63-A-720 ENGINE SPECIFICATION G.2-7 WITH INSTALLATION LOSSES**

**DATA**
- **SPECIFIC RANGE (NAUT. AIR MILES/LB FUEL)**: 0.7, 0.6, 0.5, 0.4, 0.3, 0.2
- **ENGINE SHaFT HOREPOWER REQUIRED**: 340, 300, 260, 220, 180, 140, 100
- **TRUE AIRSPEED (KNOTS)**: 0, 20, 40, 60, 80, 100, 120

**DIAGRAM**
- Plot showing specific range and advancing tip Mach number vs. engine shaft horsepower required.
- Curve derived from figures 4 and 5.
FIGURE 8
LEVEL FLIGHT PERFORMANCE
JMH-58C USA S/N 70-15349

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG AVG CG LOCATION LONG LAT (FS) (BL)</th>
<th>AVG DENSITY OAT (FT) (DEG C)</th>
<th>AVG REFERRED ROTOR SPEED RPM</th>
<th>AVG AVG AVG</th>
</tr>
</thead>
<tbody>
<tr>
<td>3100</td>
<td>109.6 (MID)</td>
<td>0.1 MID</td>
<td>8380</td>
<td>6.0</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 9
LEVEL FLIGHT PERFORMANCE
JOH-58C USA S/N 70-15349

<table>
<thead>
<tr>
<th>AVG GRID SS</th>
<th>AVG CG LOCATION</th>
<th>AVG DENSITY</th>
<th>AVG OAT</th>
<th>AVG REFERRED ROTOR SPEED</th>
<th>AVG C T</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEIGHT (LB)</td>
<td>LONG (FS) LAT (BL)</td>
<td>ALTITUDE (FT)</td>
<td>OAT (DEG C)</td>
<td></td>
<td></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
### Figure 10

**LEVEL FLIGHT PERFORMANCE**

**JOH-58C USA S/N 70-15349**

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG LOCATION</th>
<th>DENSITY (QAT)</th>
<th>AVG ALTITUDE (FT)</th>
<th>AVG ROTOR SPEED (RPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2880</td>
<td>110.5 (AFT)</td>
<td>0.1 MID</td>
<td>4400</td>
<td>12.5</td>
</tr>
</tbody>
</table>

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

**CURVE DERIVED FROM ALLISON T65-A-720 ENGINE SPECIFICATION 876 WITH INSTALLATION LOSSES**

**CURVE DERIVED FROM FIGURES 2 AND 3**

**PLANE ASHP = 41.8 SHP**

---

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**Figure 12**

**Level Flight Performance**

**HOH-58C USA 57N 70-15349**

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG CG LOCATION (FS)</th>
<th>AVG DENSITY (LBS/FT³)</th>
<th>AVG OAT (DEG C)</th>
<th>AVG REFERRED ROTOR SPEED (RPM)</th>
<th>AVG G\textsubscript{T}</th>
</tr>
</thead>
<tbody>
<tr>
<td>3100</td>
<td>109.5 (MID)</td>
<td>0.1 MID</td>
<td>8590</td>
<td>7.5</td>
<td>353.8</td>
</tr>
</tbody>
</table>

**Notes:**

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

---

**Curve Derived from Allison T6B-A-720 Engine Specification 876 With Installation Losses**

- **Advancing Tip Mach Number**
- **True Airspeed (Knots)**

---

**Horsepower Required**

- **Specific Range (Nautical Miles/LB Fuel)**

---

**Engine Output**

- **Plus 4 SHP = 47.5 SHP**
FIGURE 13
LEVEL FLIGHT PERFORMANCE
JMD-59E USA 5/67-70-15349

<table>
<thead>
<tr>
<th>AVG</th>
<th>AVG CS</th>
<th>AVG DENSITY</th>
<th>AVG OAT</th>
<th>AVG REFERRED</th>
<th>AVG Q,</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROSS WEIGHT (lb)</td>
<td>LONG CG LOCATION (ft)</td>
<td>LATITUDE (ft)</td>
<td>ALTITUDE (deg C)</td>
<td>ROTOR SPEED (RPM)</td>
<td></td>
</tr>
<tr>
<td>3130</td>
<td>109.5 (MID)</td>
<td>0.1 (MID)</td>
<td>11,170</td>
<td>6.5</td>
<td>353.3</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 
0.5 HP + 41.3 MPH

TRUE AIRSPEED (KNOTS)
**Figure 14**

**Level Flight Performance**

**JOH-58C USA S/N 70-13349**

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG CG LOCATION (FS)</th>
<th>AVG LONG LAT (BL)</th>
<th>AVG ALTITUDE (FT)</th>
<th>AVG DENSITY (ENG CF)</th>
<th>AVG OAT (DEG C)</th>
<th>AVG ROTOR SPEED (RPM)</th>
<th>AVG REFFERED KT</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>
<td>0.003408</td>
<td></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**
<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG CG LOCATION (FS)</th>
<th>AVG DENSITY</th>
<th>AVG ALTITUDE (FT)</th>
<th>AVG QAT (DEG C)</th>
<th>AVG ROTOR SPEED (RPM)</th>
<th>AVG CT</th>
</tr>
</thead>
<tbody>
<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>
<td>0.003726</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 16
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 (FT)</th>
<th>AVG OAT (DEG C)</th>
<th>AVG REFERRED ROTOR SPEED (RPM)</th>
<th>AVG C_T</th>
</tr>
</thead>
<tbody>
<tr>
<td>3130</td>
<td>109.6 (MID)</td>
<td>0.1 MID</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


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