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**AUTHORITY**
USAAVSCOM ltr, 12 Nov 1973

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EVALUATION OF THE OH-58A HELICOPTER WITH AN ALLISON 250-C20 ENGINE

FINAL REPORT

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UNITED STATES ARMY AVIATION SYSTEMS TEST ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523
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UNITED STATES ARMY AVIATION SYSTEMS TEST ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523
FOREWORD

Technical assistance was provided by the engine manufacturer, Detroit Diesel Allison Division of General Motors.
ABSTRACT

The United States Army Aviation Systems Test Activity conducted a limited performance and handling qualities evaluation of the Bell Helicopter Company model OH-58A helicopter with an Allison 250-C20 engine installed. The evaluation was conducted at Edwards Air Force Base, and Bishop, California, during the period 22 September 1971 to 7 January 1972. Twenty-five flights, 21.2 productive test hours, were required for the evaluation. Test results obtained with the Allison 250-C20 engine were compared with those previously obtained with the standard T63-A-700 engine. The primary performance improvement noted was an increase in out-of-ground-effect hover ceiling at a 3000-pound gross weight to 10,000 feet from 4600 feet. The long-range cruise airspeed was increased to 111 knots true airspeed from 104 knots true airspeed at a 5000-foot density altitude and a 3000-pound gross weight. The increased engine power did not significantly increase the service ceiling over the basic OH-58A at identical gross weights. One shortcoming, insufficient left directional control at 35 knots true airspeed in right sideward flight, was noted. Within the scope of the test, the performance of the OH-58A helicopter with the Allison 250-C20 engine was improved over the basic OH-58A helicopter. Handling qualities were essentially unchanged.
# TABLE OF CONTENTS

## INTRODUCTION

<table>
<thead>
<tr>
<th>Background</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Objectives</td>
<td>1</td>
</tr>
<tr>
<td>Description</td>
<td>1</td>
</tr>
<tr>
<td>Scope of Test</td>
<td>1</td>
</tr>
<tr>
<td>Methods of Test</td>
<td>3</td>
</tr>
<tr>
<td>Chronology</td>
<td>3</td>
</tr>
</tbody>
</table>

## RESULTS AND DISCUSSION

<table>
<thead>
<tr>
<th>General</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>4</td>
</tr>
<tr>
<td>General</td>
<td>4</td>
</tr>
<tr>
<td>Hover Performance</td>
<td>4</td>
</tr>
<tr>
<td>Level Flight Performance</td>
<td>5</td>
</tr>
<tr>
<td>Climb Performance</td>
<td>5</td>
</tr>
<tr>
<td>Handling Qualities</td>
<td>7</td>
</tr>
<tr>
<td>General</td>
<td>7</td>
</tr>
<tr>
<td>Sideward Flight Characteristics</td>
<td>7</td>
</tr>
<tr>
<td>Control Positions in Trimmed Forward Flight</td>
<td>7</td>
</tr>
<tr>
<td>Collective-Fixed Static Longitudinal Stability</td>
<td>8</td>
</tr>
<tr>
<td>Autorotational Characteristics</td>
<td>8</td>
</tr>
<tr>
<td>Miscellaneous Tests</td>
<td>10</td>
</tr>
<tr>
<td>Engine Characteristics</td>
<td>10</td>
</tr>
<tr>
<td>Engine Governing Characteristics</td>
<td>10</td>
</tr>
</tbody>
</table>

## CONCLUSIONS

<table>
<thead>
<tr>
<th>General</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12</td>
</tr>
<tr>
<td>Shortcoming Affecting Mission Accomplishment</td>
<td>12</td>
</tr>
<tr>
<td>Specification Compliance</td>
<td>12</td>
</tr>
</tbody>
</table>

## RECOMMENDATIONS                     | Page |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13</td>
</tr>
</tbody>
</table>
APPENDIXES

A. References ......................................................................................................................... 14
B. Safety-of-Flight Release ....................................................................................................... 15
C. Test Instrumentation ............................................................................................................ 22
D. Test Data ............................................................................................................................. 23

DISTRIBUTION
INTRODUCTION

BACKGROUND

1. The 250-C20 gas turbine engine is a growth version of the T63-A-700 engine manufactured by the Detroit Diesel Allison Division of General Motors Corporation. Engineering flight tests of the Bell Helicopter Company model OH-58A helicopter with the T63-A-700 engine were previously conducted by the United States Army Aviation Systems Test Activity (USAASTA) (refs 1 and 2, app A). The United States Army Aviation Systems Command (AVSCOM) directed USAASTA to conduct an evaluation of the OH-58A helicopter with the 250-C20 engine installed (refs 3 and 4).

TEST OBJECTIVE

2. The objective of this test was to evaluate the performance and handling qualities of the OH-58A helicopter with an Allison 250-C20 engine installed.

DESCRIPTION

3. The OH-58A is a single-main-rotor, turbine-powered, light observation helicopter, manufactured by Bell Helicopter Company, Fort Worth, Texas. The main rotor is a two-bladed, semirigid, teetering type; and the tail rotor is a two-bladed, semirigid, delta-three hinge type. The cockpit configuration is two place (pilot and copilot/observer), and the cargo compartment has provisions for seating two passengers. Dual flight controls are provided with cyclic and collective controls boosted, and the tail rotor controls unboosted. The main landing gear is a fixed, energy-absorbing, skid type. For this testing, the helicopter was powered by an Allison 250-C20 free gas turbine engine with a military rated power of 400 shaft horsepower (slip) derated to the transmission power limit of 270 slp (maximum continuous) with a takeoff power limit of 317 slp (5 minutes). A detailed description of the OH-58A helicopter is contained in the operator's manual (ref 5, app A).

SCOPE OF TEST

4. Flight testing of the OH-58A helicopter with the 250-C20 engine installed was conducted at Edwards Air Force Base, and Bishop, California, during the period 22 September 1971 through 7 January 1972 by USAASTA personnel. Twenty-five test flights consisting of 21.2 productive hours were conducted under the conditions listed in table 1.
Table 1. Test Conditions.¹

<table>
<thead>
<tr>
<th>Test</th>
<th>Calibrated Airspeed (kt)</th>
<th>Gross Weight (lb)</th>
<th>Density Altitude (ft)</th>
<th>Average Outside Air Temperature (°C)</th>
<th>Average Center of Gravity (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hover performance²</td>
<td>Zero</td>
<td>2463 to 3209</td>
<td>10,300 to 11,700</td>
<td>5</td>
<td>108.0 (fwd)</td>
</tr>
<tr>
<td>Level flight performance</td>
<td>20 to 93</td>
<td>3150 to 3200</td>
<td>8,350 to 14,170</td>
<td>-6.74 to -1.34</td>
<td>107.1 (fwd)</td>
</tr>
<tr>
<td>Climb performance</td>
<td>38 to 50 (takeoff)</td>
<td>3213</td>
<td>1,200 to 16,800</td>
<td>NA</td>
<td>107.0 (fwd)</td>
</tr>
<tr>
<td>Sideward flight</td>
<td>Zero to 35</td>
<td>2460 to 2785</td>
<td>9,920 to 11,340</td>
<td>1.9 to 13.6</td>
<td>109.0 (mid)</td>
</tr>
<tr>
<td>Trim control positions</td>
<td>32 to 103</td>
<td>3115 to 3200</td>
<td>7,750 to 14,420</td>
<td>-6.7 to 2.0</td>
<td>107.1 (fwd) 111.4 (aft)</td>
</tr>
<tr>
<td>Static longitudinal stability</td>
<td>61, 80, 102</td>
<td>3115</td>
<td>7,750</td>
<td>2.0</td>
<td>111.4 (aft)</td>
</tr>
<tr>
<td>Autorotational entry characteristics</td>
<td>Zero to 117</td>
<td>2570 to 3215</td>
<td>6,000</td>
<td>19</td>
<td>106.8 (fwd)</td>
</tr>
<tr>
<td>Engine governing characteristics</td>
<td>80 to 3140</td>
<td>7,000</td>
<td>12</td>
<td>107.0 (fwd)</td>
<td></td>
</tr>
</tbody>
</table>

¹Rotor speed: 354 rpm.
²Out of ground effect (50-foot skid height).
³In ground effect (4-foot skid height).
³Knots true airspeed.
5. Test results were compared to those previously reported for the OH-58A helicopter with the T63-A-700 engine (refs 1 and 2, app A). Flight limitations contained in the operator's manual (ref 5) and the safety-of-flight release (app B) were observed during the test.

**METHODS OF TEST**

6. Flight test methods used are briefly described in the Results and Discussion section of this report. Performance data were manually recorded from cockpit instrumentation. All performance data are based on specification engine performance (ref 6, app A) adjusted for T63-A-700 installation losses (ref 1). Flying qualities data were recorded by an oscillograph located in the cargo/passenger compartment. A detailed list of test instrumentation is contained in appendix C.

**CHRONOLOGY**

7. The chronology of the OH-58A helicopter with Allison 250-C20 engine evaluation is as follows:

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test directive received</td>
<td>24 June</td>
<td>1971</td>
</tr>
<tr>
<td>Allison 250-C20 engine installed</td>
<td>16 September</td>
<td>1971</td>
</tr>
<tr>
<td>Flight tests started</td>
<td>22 September</td>
<td>1971</td>
</tr>
<tr>
<td>Flight tests completed</td>
<td>7 January</td>
<td>1972</td>
</tr>
</tbody>
</table>
RESULTS AND DISCUSSION

GENERAL

8. A limited performance and handling qualities evaluation of the OH-58A helicopter with an Allison 250-C20 engine installed was conducted by the United States Army Aviation Systems Test Activity personnel. Performance testing included hover, level flight, and climb performance. Handling qualities were evaluated during sideward flight, forward flight, and autorotational entries. Primary performance improvement over the standard T63-A-700 engine was an increase in out-of-ground-effect hover ceiling to 10,000 feet from 4600 feet. The specific range was essentially unchanged, but there was an increase of the long-range cruise airspeed to 111 knots true airspeed from 104 knots true airspeed at a 5000-foot density altitude and a 3000-pound gross weight. The climb capability of the aircraft was not limited by engine power available. Instead, an apparent maximum rotor thrust limit which occurred at a 6800-foot density altitude, a 3150-pound gross weight, and a thrust coefficient of 0.00531 prevented climbing to higher altitudes. One shortcoming, insufficient left directional control at 35 knots true airspeed in right sideward flight, was noted. Within the scope of the test, the performance of the OH-58A helicopter with the Allison 250-C20 engine was improved over the basic OH-58A helicopter, while handling qualities were essentially unchanged.

PERFORMANCE

9. Performance testing of the OH-58A helicopter with the Allison 250-C20 engine was conducted at a hover, in level flight, and in climbs. Performance test results were compared to results obtained with the previously tested T63-A-700 engine. The out-of-ground-effect (OGE) hover ceiling was increased to 10,000 feet from 4600 feet. The specific range was essentially unchanged, but there was an increase of the long-range cruise airspeed to 111 KTAS from 104 KTAS at a 5000-foot density altitude and a 3000-pound gross weight. A service ceiling of 16,800 feet at a 3200-pound gross weight was obtained during climb testing. Within the scope of the test, the performance characteristics of the OH-58A helicopter with the Allison 250-C20 engine are improved over the basic OH-58A helicopter.

Hover Performance

10. Hover performance tests were conducted at skid heights of 4 feet in ground effect (IGE), and 50 feet OGE under the conditions shown in table 1. The free-flight hover method was used to determine hover performance. Skid height was measured by visual reference to a measured weighted cord attached to the right skid. Incremental amounts of ballast were added to the helicopter until either the engine temperature or transmission power limit was reached. Test results are presented in figures 1 and 2, appendix D.
II. A comparison of the standard-day hover performance with the 250-C20 and T63-A-700 engine is presented as figure A. The OH-58A with the 250-C20 engine installed had an increase in OGE hover ceiling to 10,000 feet from 4600 feet at a gross weight of 3000 pounds. The increased hover performance of the OH-58A with the 250-C20 engine enhances its operational capability. Within the scope of the test, the hover performance of the OH-58A helicopter with the 250-C20 engine is improved over the basic OH-58A helicopter.

**Level Flight Performance**

12. Level flight performance tests were conducted to determine power required and associated fuel flow as a function of airspeed. In addition, specific range, long-range cruise airspeed, and maximum airspeed in level flight were determined. Test conditions are presented in table 1. Data were obtained in stabilized coordinated level flight using the referred gross weight method of test. Test results are presented in figures 3 through 6, appendix D. Level flight range summaries are presented as figures 7 through 9. For altitudes at sea level, 5000, and 10,000 feet, long-range cruise airspeed increased for the 250-C20 engine. There was essentially no change in the specific range. Within the scope of this test, the level flight performance of the OH-58A helicopter with the 250-C20 engine is improved over the basic OH-58A helicopter.

**Climb Performance**

13. Continuous climbs were conducted from a 1200-foot density altitude to the service ceiling under the conditions listed in table 1. The climb airspeeds used were determined from previous climb tests (ref 1, app A). Test results are presented in figure 10, appendix D.

14. An abrupt reduction in the rate of climb accompanied by intense airframe vibrations was noted above a density altitude of 16,000 feet. Attempts to increase the rate of climb at the service ceiling of 16,800 feet by varying airspeed from the scheduled 34 knots indicated airspeed (KIAS) had no effect except that vibrations increased markedly at higher airspeed followed by immediate altitude losses. At slower airspeeds the vibrations decreased, but again the helicopter lost altitude. The sharp decrease in rate of climb and the vibrations encountered are attributed to an apparent rotor thrust limit which occurred at a 16,800-foot density altitude, a 3150-pound gross weight, and a $C_T$ of 0.00531. Despite an increase in power available with the 250-C20 engine, the service ceiling is not significantly increased over the basic OH-58A at identical gross weights.
FIGURE A
STANDARD DAY HOVER PERFORMANCE
MODEL 350-C20 AND T63-A-700 ENGINES
OH-58 HELICOPTER
5540 MAX ROTOR RPM

NOTES:
1. SOLID LINES DENOTE 250-C20 ENGINE PERFORMANCE
2. DASHED LINES DENOTE T63-A-700 ENGINE PERFORMANCE
3. HOVER POWER AVAILABLE OBTAINED FROM FIGS 1 AND 2, APPENDIX D
4. SPECIFICATION POWER AVAILABLE OBTAINED FROM FIG 19, APPENDIX D

PRESSURE ALTITUDE ~ FT

GROSS WEIGHT ~ LB
HANDLING QUALITIES

General

15. A limited handling qualities evaluation of the OH-58A helicopter with the Allison 250-C20 engine was conducted under day visual-flight-rules conditions. Sideward flight, forward flight, and autorotational entries were conducted, and the results were compared to those obtained with the standard T63-A-700 engine. One shortcoming, insufficient left pedal at 35 knots true airspeed in right sideward flight, was noted. Within the scope of this test, the handling qualities of the OH-58A helicopter with the Allison 250-C20 engine were essentially unchanged from the basic OH-58A helicopter.

Sideward Flight Characteristics

16. Sideward flight characteristics were evaluated at the conditions shown in table 1. Wind azimuths at 45, 90, and 135 degrees relative to the nose of the helicopter were used. These azimuths were considered critical due to previous data contained in reference 2, appendix A. Test results are presented in figure 11, appendix D.

17. Previous right sideward flight test at a C_T of 0.00343 resulted in a left pedal margin of 5 percent at 35 KTAS (ref 2, app A). Results of tests with the 250-C20 engine showed that at 35 KTAS, the directional control margin rapidly diminished with increased C_T's. In 35-KTAS right sideward flight at a C_T of 0.00392, the directional control margin was reduced to less than 2 percent. Although aircraft control could be maintained, there was not sufficient left directional control to counteract a lateral gust disturbance. However, at 30 KTAS, at least a 12-percent directional control margin remained. Directional control in 35-KTAS right sideward flight failed to meet the requirements of paragraph 3.3.4 of MIL-H-8501A. Insufficient left directional control in 35-KTAS right sideward flight is a shortcoming.

Control Positions in Trimmed Forward Flight

18. Control positions in trimmed forward flight were evaluated from 32 to 103 knots calibrated airspeed under the conditions shown in table 1. Test results are presented in figures 12 and 13, appendix D. For all test conditions, increasing forward longitudinal control movement was required for increased trim speed. The variation in longitudinal control position between autorotations and maximum-power climbs was approximately 1.2 inches.

19. Directional and lateral control positions varied less than 1 inch for a given configuration throughout the airspeed range tested. No significant variation in directional or lateral control positions was noted when transitioning from a maximum-power climb to an autorotation. The requirements of paragraphs 3.2.10.2 and 3.3.17 of MIL-H-8501A (ref 7, app A) were met. Within the scope of the
test, the control position characteristics of the OH-58A helicopter with the 250-C20 engine are essentially unchanged from the basic OH-58A helicopter.

**Collective-Fixed Static Longitudinal Stability**

20. Collective-fixed static longitudinal stability was evaluated under the conditions listed in table 1. The tests were conducted by initially trimming the helicopter at the desired airspeed and then stabilizing at slower and faster airspeeds while holding constant collective pitch. Test results are presented in figure 14, appendix D.

21. For the configurations tested, the aircraft possessed static longitudinal stability as evidenced by forward longitudinal control displacement for increased airspeed, and aft longitudinal control displacement for decreased airspeed from trim. Within the scope of the test, the collective-fixed static longitudinal stability of the OH-58A helicopter with the 250-C20 engine is essentially unchanged from the basic OH-58A helicopter.

**Autorotational Characteristics**

22. The response of the helicopter to simulated sudden engine failures was evaluated under the conditions shown in table 1. The aircraft was trimmed in balanced flight and with the controls fixed, the throttle was rapidly retarded to the flight-idle position (throttle chop). Recoveries were initiated at a minimum rotor speed of 304 rpm, a maximum pitch attitude of 30 degrees, or a maximum roll attitude of 45 degrees. Test results are presented in figures 15 and 16, appendix D. A true sudden engine failure could not be simulated by rapidly closing the throttle since the fuel control limited the engine deceleration. An engine torque decay time constant (time to 63 percent of initial value) of 1.1 second was measured for the 250-C20 engine, compared to a time constant of 0.6 second for the T63-A-700 engine. As a result of the larger engine torque decay time constant, the rate of rotor decay and aircraft reactions were not as great as those previously tested with the T63-A-700 engine (figs. 15 and 16). To determine the rate of rotor decay for a sudden engine failure, an analytical method was used with a time constant of zero. By assuming that the power coefficients (Cp's) before and after the throttle chop are equal, the following equation for rate of rotor decay can be derived:
\[ \frac{d\Omega}{dt} = \frac{-I \Omega^2}{Q_o} \sqrt{t^2 + \left(\frac{2I \Omega \omega}{Q_o}\right)(t) + \left(\frac{I \Omega \omega}{Q_o}\right)^2} \]

Where:
- \( \frac{d\Omega}{dt} \) = rate of rotor decay
- \( I \) = main rotor inertia
- \( t \) = time after engine failure
- \( \Omega_0 \) = initial main rotor speed
- \( Q_0 \) = initial main rotor torque

This equation was solved for \( \frac{d\Omega}{dt} \) at the following:
- \( t = 1 \) second
- \( I = 607 \) slug/ft²
- \( \Omega_0 = 354 \) rev/min
- \( Q_0 = \) from 1881 ft-lb to 4703 ft-lb

The results of this analysis show that a main rotor decay rate of 50 rpm per second (rpm/sec) would be encountered, compared to a measured main rotor decay rate of 23 rpm/sec (figs. 15 and 16). This decay rate would not allow a 2-second delay before lowering the collective, as specified in paragraph 3.5.5 of MIL-H-8501A for a minimum transient rotor speed of 304 rpm. No attempt was made to calculate the magnitude of the aircraft reactions for a sudden engine failure; however, they would be greater than those measured.

23. The reaction of the helicopter following the throttle chop was a slight nose-up pitch during the first second followed by a substantial nose-down pitching motion. In addition, a left roll and left yaw were observed in all instances. The roll rate increased with increasing forward airspeed, while the yaw rate decreased as airspeed was increased. Control effectiveness during the recovery phase was adequate to avoid unsafe rates, attitudes, or airspeeds. The aircraft responses to sudden engine failure with the 250-C20 engine were similar to those previously observed with the basic OH-58A helicopter.
MISCELLANEOUS TESTS

Engine Characteristics

24. Engine characteristics of the 250-C20 engine to include fuel flow and power available were determined from the engine manufacturer's specifications (ref 6, app A). A comparison of the power available for the 250-C20 and the T63-A-700 engine is presented in figure 17, appendix D. Engine fuel-flow data for the 250-C20 engine are presented in figure 18. Inlet and exhaust losses were determined from data previously obtained with the T63-A-700 engine (ref 1, app A).

Engine Governing Characteristics

25. Static and dynamic droop characteristics of the 250-C20 engine governor were evaluated under the conditions listed in table 1. Static tests were conducted by trimming the helicopter at 103-percent power turbine speed (N2), and incrementally lowering and raising the collective. Dynamic characteristics were evaluated by rapidly moving the collective between maximum-power and minimum-power settings. Test results are presented in table 2 and figure B.

Table 2. Dynamic Droop Characteristics in Level Flight at 80 KCAS.¹

<table>
<thead>
<tr>
<th>Test Condition</th>
<th>Steady-State Engine Torque (psi)²</th>
<th>Steady-State Rotor Speed (rpm)</th>
<th>Transient Rotor Speed (rpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trim to down collective</td>
<td>63 to 354</td>
<td>361</td>
<td>367 (max)</td>
</tr>
<tr>
<td>Trim to up collective</td>
<td>21 to 361</td>
<td>353</td>
<td>345 (min)</td>
</tr>
</tbody>
</table>

¹OH-58 helicopter with Allison 250-C20 engine.
²Pounds per square inch.

26. Rotor speed during the engine governing systems tests did not exceed the output shaft speed limit. A 12-rpm underspeed occurred during full-up collective positioning, but was not considered a critical factor. Within the scope of this test, the engine governing characteristics of the 250-C20 engine are satisfactory for Army use.
**Figure B**

**Static Droop Characteristics**

**Model 250-C20 Engine**

**OH-58 USA TH-55D**

**Notes:**
1. Solid points denote trim conditions at 80 KIAS.
3. Avg. gross weight 340 lb, Avg. density altitude 7000 ft, Avg. outside air temperature 12.0°C.

--

**Graph:**

- Engine torque vs. RPM
- Rotor speed vs. RPM

---

- 5-minute torque limit
- Maximum continuous torque limit

---

**Axes:**

- X-axis: Rotor speed (RPM)
- Y-axis: Engine torque (lbf)

---

**Legend:**

- Different symbols represent various data points and limits.
CONCLUSIONS

GENERAL

27. The following conclusions were reached upon completion of testing.
   
a. Within the scope of this test, the performance of the OH-58A helicopter with the Allison 250-C20 engine was improved over the basic OH-58A helicopter, while handling qualities were essentially unchanged (para 8).
   
b. The out-of-ground-effect hover ceiling at a 3000-pound gross weight was increased to 10,000 feet from 4600 feet (para 11).
   
c. The long-range cruise airspeed was increased to 111 knots calibrated airspeed from 104 knots calibrated airspeed (para 12).
   
d. The increased engine power did not significantly increase the service ceiling over the basic OH-58A at identical gross weights (para 14).
   
e. One shortcoming was noted.

SHORTCOMING AFFECTING MISSION ACCOMPLISHMENT

28. Insufficient left directional control at 35 KTAS in right sideward flight is a shortcoming, correction of which is desirable (para 17).

SPECIFICATION COMPLIANCE

29. Within the scope of this test, the OH-58A helicopter with the 250-C20 engine failed to meet paragraph 3.3.4 of military specification MIL-H-8501A, in that insufficient left directional control was available during 35-KTAS right sideward flight (para 17).

30. A sudden engine failure at maximum torque would not meet paragraph 3.5.5 of military specification MIL-H-8501A, in that collective delay would be less than 1 second (para 22).
RECOMMENDATIONS

31. The shortcoming, correction of which is desirable, should be corrected as soon as possible.

32. The test results should be incorporated in the operator’s manual if the OH-58A helicopter with the 250-C20 engine is released for operational use.
APPENDIX A. REFERENCES


APPENDIX B. SAFETY-OF-FIGHT RELEASE
1. This letter constitutes a safety of flight release, in accordance with AMCR 70-33, for USAASTA to conduct USAAVSCOM/USASTA Project No. 71-24, Evaluation of the Allison 250-C20 Engine in the OH-58A Helicopter.

2. The flight envelope and operating limitations for conduct of Project No. 71-24 shall be in accordance with the TM55-1520-228-10, OH-58A Operators Manual, except as noted below:

   a. Instrument Markings

   (1) Engine Oil Pressure Module

      Double green arc       115 - 130 psig
      Single green arc       90 - 115 psig
      Yellow arc             50 - 90 psig
      Red line at            50 psig

   (2) Torquemeter

      Red line at            74.3 psig - max
      Yellow arc             63.0 - 74.3 psig - 5 min. oper
      Green arc              0 - 63.0 psig - continuous oper

   (3) Gas Produce Tach

      Green arc             60% - 104%
      Red line at            104% - max

NOTE:

Transient Limit 105% (max of 15 sec)
SUBJECT: Safety of Flight Release for USAAVSOCOM/USAASA
Project No. 71-24

(4) Turbine Outlet Temperature

Red line at 793°C - max (30 min. limit below 40°C
0.A.T. and 5 min. limit above
40°C 0.A.T.)

Yellow arc 737°C - 793°C - starting and transient

Green arc 330°C - 737°C continuous oper.

NOTE:

Transient limit 793°C to 843°C during power transients
(6 sec. max)

Maximum for starting 793°C to 927°C (10 sec. max)

b. Center of Gravity Limitations - The maximum center of gravity limitations are shown in figure 1 (Incl 1).

c. Weight Limitations - 3200 pounds maximum gross weight.

d. Vertical Load Factor at the c.g. - The maximum load factor versus gross weight is shown in figure 2 (Incl 2).

e. Airframe and engine torque and output shaft (N2) speed limits are shown in figure 3 (Incl 3).

f. Fatigue lives are the same as the standard OH-58A except for the pylon support link which has a 4800 hour retirement life for the test configuration.

g. Ambient operating temperatures shall be limited to 100°F due to engine compartment cooling.

h. Special Instructions

(1) Engine starting procedure shall be the same as that for the standard OH-58A.

(2) During low power descents N2 speeds up to 106% are authorized; as are transient N2 speeds down to 98% upon power application for the purpose of evaluating engine governing characteristics.
3. This safety of flight release applies to the OH-58A/C20 resulting from the incorporation of the BHC retro-fit kit (P/N 206HA-108-1) and the Allison C20 engine in accordance with the retro-fit kit instructions.

4. Aircraft Logbook Entry:

   a. In accordance with the provisions of TM 38-750, the following entries will be made on the DA Form 2408-13 and will be perpetuated on each form during the period of the test, or until superseded by another safety of flight release, or until the reason for limitation is removed, or until the appropriate -10 and 10CL manuals are revised to reflect the limitations as normal procedure.

      (1) Block 17, "Test Aircraft - Operate within limitations prescribed in the inclosed SOFR, (date)".

      (2) The above entry will be preceded by the entry of a circled red X within block 16, and block 7 adjusted when appropriate.

   b. An exact copy of this SOFR will be inserted into the aircraft logbook.

FOR THE COMMANDER:

[Signature]

ROBERT F. FORSYTH
LTC, TC
Actg Chief, Flt Std & Qual Div
Directorate for RD&E

Copy furnished:
Commanding General
US Army Materiel Command
ATTN: AMCRD-FQ
AMCSF-A
FIGURE 2
LIMIT LOAD FACTOR VS GROSS WEIGHT

LIMIT LOAD FACTOR ~ Nf

GROSS WEIGHT ~ LBS.
Figure 3
Airframe and Engine Torque
and Output Shaft Speed Limits

- Max Transient Torque Limit 10 Sec - Eng.
- Max Allow. Torque Limit 30 Min - Eng.
- Max Continuous Torque Limit - Eng.
- Max Allow. Torque Lim. 5 Min. Airframe
- Max Continuous Torque Lim. Airframe
- 15 Sec. Max. (Airframe Only)

Torquemeter Pressure - PSI

% Output Shaft Speed
APPENDIX C. TEST INSTRUMENTATION

The instrumentation installed for this test is listed below:

<table>
<thead>
<tr>
<th>Pilot and Engineer Panel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airspeed (boom system)</td>
</tr>
<tr>
<td>Altitude (boom system)</td>
</tr>
<tr>
<td>Free air temperature</td>
</tr>
<tr>
<td>Rotor speed</td>
</tr>
<tr>
<td>Engine torque pressure</td>
</tr>
<tr>
<td>Longitudinal control position</td>
</tr>
<tr>
<td>Lateral control position</td>
</tr>
<tr>
<td>Directional control position</td>
</tr>
<tr>
<td>Collective control position</td>
</tr>
<tr>
<td>Fuel-used indicator</td>
</tr>
<tr>
<td>Oscillograph correlation counter</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Oscillograph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throttle position</td>
</tr>
<tr>
<td>Rotor speed</td>
</tr>
<tr>
<td>Engine torque pressure</td>
</tr>
<tr>
<td>Collective control position</td>
</tr>
<tr>
<td>Directional control position</td>
</tr>
<tr>
<td>Yaw attitude</td>
</tr>
<tr>
<td>Yaw rate</td>
</tr>
<tr>
<td>Lateral control position</td>
</tr>
<tr>
<td>Roll attitude</td>
</tr>
<tr>
<td>Roll rate</td>
</tr>
<tr>
<td>Longitudinal control position</td>
</tr>
<tr>
<td>Pitch attitude</td>
</tr>
<tr>
<td>Pitch rate</td>
</tr>
<tr>
<td>Engineer event</td>
</tr>
</tbody>
</table>
# APPENDIX D. TEST DATA

## INDEX

<table>
<thead>
<tr>
<th>Figure</th>
<th>Figure Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hovering Performance</td>
<td>1 and 2</td>
</tr>
<tr>
<td>Level Flight Performance</td>
<td>3 through 9</td>
</tr>
<tr>
<td>Climb Performance</td>
<td>10</td>
</tr>
<tr>
<td>Sideward Flight Characteristics</td>
<td>11</td>
</tr>
<tr>
<td>Trim Control Position Characteristics</td>
<td>12 and 13</td>
</tr>
<tr>
<td>Static Longitudinal Stability</td>
<td>14</td>
</tr>
<tr>
<td>Autorotational Entry Characteristics</td>
<td>15 and 16</td>
</tr>
<tr>
<td>Engine Performance</td>
<td>17 and 18</td>
</tr>
</tbody>
</table>
FIGURE 2
Nondimensional Hovering Performance
OH-58 USA 5N 66-16705
250-C-20 ENGINE AND T63-R-700 ENGINE
SEA LEVEL HEIGHT 4 - 50 FEET
SYMBOL ENGINE
O T63-R-700 317 SHP
O 250-C-20 400 SHP

POWER COEFFICIENT (CP) x 10^4

THRUST COEFFICIENT (Ct) x 10^4
Figure 3

LEVEL FLIGHT PERFORMANCE

OH-58   USAF VV6-16705 and VV6-16709
CLEAN CONFIGURATION - DOORS OPEN
CO: 11.1% (148)
MODEL 51D-2 ENGINE

ENGINE POWER COEFFICIENT - C_E, 1

NOTES:
1. DASHED PORTIONS DECLINE
2. AIRWORTHINESS AND FLIGHT CHARACTERISTICS TEST
4. DATA POINTS DERIVED FROM PIGS 4 THROUGH 6.

THRUST COEFFICIENT = C_T X 10^6
Figure 5
LEVEL FLIGHT PERFORMANCE
ON SST USA SLD-14-05
MODEL 250-C30 ENGINES

AVG. DENSITY AUG. ALTITUDE AVG. GRID. WGT. AVG. LONG. ROTOR SPEED AVG. CY. Day AVG. CONFIGURATION
FT. LB. IN. RPM.

SPECIFIC RANGE SP. RPMPP

ADVANCE R.G. NUMBER A. INVMPP

ENGINE OUTPUT SHP

MILITARY RATED POWER AVAILABLE
NORMAL RATED POWER AVAILABLE
LONG RANGE CRUISE SPEED

NOTE CURVE DERIVED FROM FIG. 5

TRUE AIRSPEED KNOTS
<table>
<thead>
<tr>
<th>Altitude (FEET)</th>
<th>True Airspeed (KNOTS)</th>
<th>Engine Output (SHP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>140</td>
<td>140</td>
<td>140</td>
</tr>
</tbody>
</table>

Note: Curve derived from Fig A.
Figure 7
Level Flight Range Summary
CH-54 USAW 5/65-16708
Standard Day
Dry Level

Long Co

Motor Speed

RPM

Notes:
1. Data derived from Figs 3 and 1-B
2. Solid lines denote 750-1500 engine
3. Dashed lines denote 7-63-A-100 engine, obtained from
Fig. 28: Final Report (Performance), USAARF Project 64-30
4. Clean all doors on configuration

- Long Range Cruise Airspeed
- Long Range Cruise Range

Gross Weight - Lb

0.5
0.6
0.7

- Ktas

2000
2400
2800
3200
FIGURE 8
LEVEL FLIGHT RANGE SUMMARY
ON-R.B. USA F-86/1610G
STANDARD DAY
3000 FEET

NOTES:
1. DATA DERIVED FROM FLCA SAND-US
2. DASHED LINES DENOTE 125-320 ENGINE
3. DASHED LINES INCLUDE 72-HR. 1200 ENGINE (DERIVED FROM 12-HR. 1200 ENGINE)
4. FINAL REPORT (PERFORMANCE)
5. USAF ASRA, PROJECT 64-90
6. LEFT ALL ROCKS ON CONE S. L. LOCATION

SPECIFIC RANGE AT LONG-RANGE CRUISE, MPH

LONG RANGE CRUISE, MPH

GROSS WEIGHT, LB

2000 2400 2800 3200
Figure 4
LEVEL FLIGHT RANGE SUMMARY
OH-58 USA WGB-1870G
STANDARD DAY
10000 FEET

LONG COG
n/m
107.1 (FH-D)

ROTOR SPEED
n/RPM
354

NOTES:
1. DATA DERIVED FROM FIGS 3 AND 4
2. SOLID LINES DELIOTE 250-CEO ENGINE
3. DASHED LINES DENOTE 250-CEO ENGINE OBTAINED FROM FIG. 28, FINAL REPORT (PERFORMANCE), USA ASTA, PROJECT GB-20
4. CLEAN, ALL DOORS ON CONFIGURATION
FIGURE 11
RIGHT SIDEWARD FLIGHT
ON-185 USA FABRICATION
MODEL 250 CE ENGINE

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>AVG DENSITY</th>
<th>ALTITUDE</th>
<th>AVG. TEMP.</th>
<th>ALTITUDE</th>
<th>AVG. ALT.</th>
<th>ENGINE</th>
<th>ROCKER</th>
<th>AVG. G</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>1.340</td>
<td>2200</td>
<td>17.0</td>
<td>168.6</td>
<td>554</td>
<td>25.1</td>
<td>0.0034</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>4.320</td>
<td>2500</td>
<td>15.0</td>
<td>169.4</td>
<td>554</td>
<td>25.1</td>
<td>0.0034</td>
<td></td>
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<tr>
<td>a</td>
<td>10.240</td>
<td>2700</td>
<td>13.0</td>
<td>169.4</td>
<td>554</td>
<td>25.1</td>
<td>0.0034</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: TOTAL DIRECTIONAL CONTROL TRAVEL IS 5.68 INCHES

RELATIVE WIND FROM 45° TO THE RIGHT OF THE NOSE

RELATIVE WIND FROM 90° TO THE RIGHT OF THE NOSE

RELATIVE WIND FROM 135° TO THE RIGHT OF THE NOSE
Figure 12

Control Positions in Trim Level Flight
CH-3RA USA NAVY SH-3H
Model 256C, C-12E Engines

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>AVG CLB</th>
<th>AVG DENSITY ALTITUDE</th>
<th>MAX RPM</th>
<th>AVER LONG</th>
<th>AVG ACH</th>
<th>AVG DAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3150</td>
<td>8350</td>
<td>105</td>
<td>1.07</td>
<td>0.0405</td>
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<tr>
<td>0</td>
<td>3150</td>
<td>7750</td>
<td>105</td>
<td>1.07</td>
<td>0.0039</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Longitudinal Control Position

Directional Control Position

Lateral Control Position

Collective Stick Position

Percent from Full Down

Percent from Full Forward

NOTE: TOTAL CONTROL DISPLACEMENT

DIRECTIONAL = 6.84 IN.
LATERAL = 10.30 IN.
COLLECTIVE = 10.15 IN.
LONGITUDINAL = 12.00 IN.

Calibrated Airspeed = Knots

35
<table>
<thead>
<tr>
<th>Symbol</th>
<th>AVG. GROSS</th>
<th>AVG. DENSITY</th>
<th>Rotor Speed</th>
<th>AVG. LONG.</th>
<th>AVG. C.G.</th>
<th>AVG. CAY</th>
<th>~ °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENG</td>
<td>1000</td>
<td>12000</td>
<td>354</td>
<td>107.0 (Fwd)</td>
<td>0.00495</td>
<td>-1.3</td>
<td></td>
</tr>
<tr>
<td>3200</td>
<td>14420</td>
<td>554</td>
<td>107.2 (Fwd)</td>
<td>0.00495</td>
<td>-6.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 13**

Control Positions in Trim Level Flight

**CH-54A** USA 56-16754

**Model 250-C26 Engine**

Notes: Total Control Displacement

- Directional: +6.56 in
- Lateral: +0.5 in
- Collective: ±0.5 in
- Longitudinal: ±2.0 in

Calibrated Airspeed: Knots
**Figure 14**

**Static Longitudinal Collective Fixed Stability**

**Model 250 - C-20 Engine**

<table>
<thead>
<tr>
<th>AVG DENSITY</th>
<th>AVG WEIGHT</th>
<th>AVG LONG</th>
<th>Rotor Speed</th>
<th>AVG</th>
<th>AVG OIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>~ ft</td>
<td>~ lb</td>
<td>~ in.</td>
<td>~ RPM</td>
<td>~ C</td>
<td>~ C</td>
</tr>
<tr>
<td>7750</td>
<td>315</td>
<td>114 (AFT)</td>
<td>354</td>
<td>0.009</td>
<td>2.0</td>
</tr>
</tbody>
</table>

**Notes:**
1. Total control displacement:
   - Directional: 6.86 in.
   - Lateral: 10.30 in.
   - Collective: 10.15 in.
   - Longitudinal: 12.00 in.

2. Shaded symbols denote trim points.
Figure 14
AUTOROTATIONAL ENTRY CHARACTERISTICS
OH-58A USA 966-16706

<table>
<thead>
<tr>
<th>A.V.G.</th>
<th>A.V.G.</th>
<th>A.V.G.</th>
<th>ENTRY ROTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRWT</td>
<td>ALTITUDE</td>
<td>CG</td>
<td>SPEED</td>
</tr>
<tr>
<td>116</td>
<td>6000</td>
<td>108.6 (F.W.D)</td>
<td>154</td>
</tr>
</tbody>
</table>

Calculated rate of rotor decay at one second after engine failure at time constant 2400 sec.

Rate of rotor decay at one second after throttle chop at time constant 1.006 sec.

Rate of rotor decay at one second after throttle chop at time constant 1.411 sec.

250-C2D ENGINE

Engine torque ~ percent
Note: Symbols denote data for 250-C2D engine only.

Pitch, roll, yaw attitude at one second after throttle chop

Calibrated airspeed ~ knots

A YAW
O ROLL
O PITCH

39
FIGURE 17
SHAFT HORSEPOWER AVAILABLE COMPARISON
MODEL 250-1-250 AND T34-A-100 ENGINES
ON-SEA

NOTES:
1. SOLID LINES DENOTE MODEL 250-1-250 ENGINE TAKEOFF RATED POWER @ 1580 R.P.M.
2. DASHED LINES DENOTE MODEL T34-A-100 ENGINE TAKEOFF RATED POWER @ 1580 R.P.M.
4. AIRSPEED = 250 K
5. ICETO AIRJETTED AND ANTI-ICE OFF
6. INLET PRESSURE AND EXHAUST PRESSURE LOSS RATIOS OBTAINED FROM FIG. 30 AND
   FINAL REPORT (PERFORMANCE)
   NAVSTA, PROJ CT-66-35
   HORSEPOWER EXTRACTION = 28 SHP
7. INLET TEMPERATURE RISE OBTAINED FROM
   FINAL REPORT (PERFORMANCE)
   NAVSTA, PROJ CT-66-35

PRESSURE ALTITUDE ~ FEET

ENGINE OUTPUT ~ SHP

MAIN ROTOR ~ 240
Towering ~ 320
Towering ~ 400

FIGURE 18
SPECIFICATION: FUEL FLOW
ALLISON 260-C, CROSSING ENGINE
STANDARD DRY
OH-21A

Notes:
2. Static conditions
3. Zero bleed, airframe off
4. Power extracted equals 2.05 HP
6. Exhaust Pressure Loss Ratios determined from Fig. G1, Final Report on Performance J5A, ASTA, Project 68-50

Engine Output x 100

Fuel Flow x 100

400 360 320 280 240 200 160 120 80 40 0

40 80 120 160 200 240 280 320 360 400

41
**UNCLASSIFIED**

**EVALUATION OF THE OH-58A HELICOPTER WITH AN ALLISON 250-C20 ENGINE**

**ABSTRACT**

The United States Army Aviation Systems Test Activity conducted a limited performance and handling qualities evaluation of the Bell Helicopter Company model OH-58A helicopter with an Allison 250-C20 engine installed. The evaluation was conducted at Edwards Air Force Base, and Bishop, California, during the period 22 September 1971 to 7 January 1972. Twenty-five flights, 21.2 productive test hours, were required for the evaluation. Test results obtained with the Allison 250-C20 engine were compared with those previously obtained with the standard T63-A-700 engine. The primary performance improvement noted was an increase in out-of-ground-effect hover ceiling at a 3000-pound gross weight to 10,000 feet from 4600 feet. The long-range cruise airspeed was increased to 111 knots true airspeed from 104 knots true airspeed at a 5000-foot density altitude and a 3000-pound gross weight. The increased engine power did not significantly increase the service ceiling over the basic OH-58A at identical gross weights. One shortcoming, insufficient left directional control at 35 knots true airspeed in right sideward flight, was noted. Within the scope of the test, the performance of the OH-58A helicopter with the Allison 250-C20 engine was improved over the basic OH-58A helicopter. Handling qualities were essentially unchanged.
<table>
<thead>
<tr>
<th>KEY WORDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited performance and handling qualities evaluation</td>
</tr>
<tr>
<td>Bell Helicopter Company model OH-58A helicopter</td>
</tr>
<tr>
<td>Allison 250-C20 engine</td>
</tr>
<tr>
<td>Increase in out-of-ground-effect hover ceiling</td>
</tr>
<tr>
<td>Long-range cruise airspeed increased</td>
</tr>
<tr>
<td>Insufficient left directional control</td>
</tr>
<tr>
<td>Performance was improved</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LINK A</th>
<th>LINK B</th>
<th>LINK C</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROLE</td>
<td>WT</td>
<td>ROLE</td>
</tr>
<tr>
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</tbody>
</table>