1. REFERENCES. See enclosure 1.

2. BACKGROUND. Several recent instances of tail-boom buckling have occurred after an autorotational touchdown in the OH-58A helicopter. These occurrences prompted the US Army Aviation Systems Command (AVSCOM) Light Observation Helicopter (LOH) Project Manager to enter into a product improvement program (PIP) with Bell Helicopter Company (BHC) to define the problem and recommend a solution. This PIP task included computer studies, a shake test, and flight testing of a structurally instrumented OH-58A helicopter. The results of the PIP task, to date, indicate that the tail-boom buckling resulted from a resonant condition between the main rotor and the natural frequencies of the fore and aft pylon mode and the tail boom. This resonant frequency, 5 hertz, was likely to occur at high blade angles (100-percent collective) and low rotor speed (150 rpm) and was associated with large main rotor flapping excursions. Three solutions were considered: (1) change the natural frequencies of the fore and aft pylon mode and/or tail boom, (2) damp the pylon movement, and (3) eliminate the excessive blade flapping. The BHC chose the third solution by electing to restrict the maximum collective control travel which would, in turn, eliminate excessive flapping at low rotor speeds. The BHC testing showed that there was no degradation of helicopter performance as the result of the installation of an 80-percent collective pitch restriction device. Additional quantitative and qualitative data were desired by AVSCOM to ensure that performance degradation did not exist within the total OH-58A flight envelope. Accordingly, the US Army Aviation Systems Test Activity (USASTA) was directed (ref 1, incs 1) to conduct a 3-day test program at the BHC flight test facility in Arlington, Texas. Additional testing at a high-altitude test site near Bishop, California, was directed by AVSCOM (ref 2).
3. TEST OBJECTIVE. The objective of this test program was to determine if the 80-percent collective pitch restriction on the OH-58A helicopter imposed a performance degradation of the autorotational landing performance (height-velocity (H-V)) flight envelope, and to demonstrate that this restriction reduced tail-boom loads to an acceptable level when performing autorotational landings at critical conditions.

4. DESCRIPTION. A standard production model OH-58A helicopter, modified only by the installation of structural loads instrumentation, was used during the portion of the test program conducted at the BHC facility. An OH-58A helicopter instrumented by USAASTA was used for the high-altitude flight test. Structural loads instrumentation was not included on this aircraft. The 80-percent collective restriction device was installed on both aircraft. A detailed description of the test aircraft is contained in reference 3, inclosure 1.

5. SCOPE OF TEST. Flight tests were conducted by a USAASTA test team at the BHC facility in Arlington, Texas. All maintenance support and data reduction services were provided by BHC during the portion of the test program performed at the BHC flight test facility. Tests were also conducted at a high-altitude test site near Bishop, California. During the high-altitude test, all logistics support and data processing were accomplished by USAASTA. A total of 6 hours of productive flight test time was required to complete these tests. The test conditions are shown in table 1.

<table>
<thead>
<tr>
<th>Test Site</th>
<th>Gross Weight (lb)</th>
<th>Density Altitude (ft)</th>
<th>Gross-Weight/Density Ratio</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BHC²</td>
<td>2,990</td>
<td>-340</td>
<td>2,960</td>
<td>+7</td>
</tr>
<tr>
<td></td>
<td>2,970</td>
<td>-700</td>
<td>2,910</td>
<td>+7</td>
</tr>
<tr>
<td>Bishop³</td>
<td>2,450</td>
<td>2,130</td>
<td>2,650</td>
<td>-4</td>
</tr>
<tr>
<td></td>
<td>2,640</td>
<td>3,370</td>
<td>2,920</td>
<td>+2</td>
</tr>
<tr>
<td></td>
<td>2,840</td>
<td>2,620</td>
<td>3,070</td>
<td>-5</td>
</tr>
<tr>
<td>Coyote Flats³</td>
<td>2,540</td>
<td>9,670</td>
<td>3,400</td>
<td>-2</td>
</tr>
</tbody>
</table>

1. Wind speed: 4 to 7 knots.
2. Center of gravity: FS 109.7.
3. Center of gravity: FS 107.0.
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6. METHODS OF TEST. The flight test methods described in reference 4, inclusions 1, were utilized throughout the test program. At the BHC flight test facility, a ground-operated phototheodolite grid camera and an airborne oscillograph were used. At the high-altitude test sites, a Fairchild Flight Analyzer and an oscillograph were used to record data.

7. CHRONOLOGY. The chronology of the testing 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>22 November</td>
<td>1971</td>
</tr>
<tr>
<td>Flight tests initiated (BHC)</td>
<td>22 November</td>
<td>1971</td>
</tr>
<tr>
<td>Flight tests completed (BHC)</td>
<td>24 November</td>
<td>1971</td>
</tr>
<tr>
<td>Additional requirements received</td>
<td>3 December</td>
<td>1971</td>
</tr>
<tr>
<td>High-altitude tests initiated</td>
<td>6 December</td>
<td>1971</td>
</tr>
<tr>
<td>High-altitude tests completed</td>
<td>17 December</td>
<td>1971</td>
</tr>
<tr>
<td>Preliminary message report dispatched</td>
<td>21 December</td>
<td>1971</td>
</tr>
<tr>
<td>Project Manager debriefed</td>
<td>28 December</td>
<td>1971</td>
</tr>
</tbody>
</table>

8. RESULTS AND DISCUSSION. a. General. Test results show that the reduction of collective control travel did not eliminate the excitation of the tail-boom resonance. It did, however, extend the touchdown airspeed envelope within which tail-boom resonance does not occur. The unacceptable tail-boom resonance characteristic is a deficiency, correction of which is mandatory. The autorotational landing performance of the OH-58A helicopter was degraded with the 80-percent collective control travel restriction at density altitudes greater than 5,000 feet.

   b. Tail-Boom Resonance. A time history of an autorotational landing is presented in figure 1, inclusions 2. Shown in these data are the conditions under which tail-boom resonance was encountered during tests at the BHC flight test facility. The horizontal touchdown velocity at the time of the occurrence of the tail-boom resonance was estimated to be 40 knots. This airspeed was in excess of touchdown speeds which are normally used during flight operations. The structural loads experienced during this incident were not severe enough to cause failure of the tail boom; however, a 6-inch crack developed in the fiberglass fairing just forward of the tail-boom attaching point. As evidenced by the flight test data, the 80-percent restriction of collective control travel did not eliminate the excitation of tail-boom resonance. It did, however, extend the touchdown airspeed envelope within which tail-boom resonance did not occur. Immediate action should be initiated to eliminate the tail-boom resonance deficiency. As an interim measure to reduce the incidences of tail-boom resonance during autorotational landings, flight test techniques developed during USAASTA Project No. 69-16 (ref 4, incl 1) should be employed. Use of these techniques results in touchdown with rotor speed remaining in excess of 200 rpm. To demonstrate these techniques, a USAASTA test team should be sent to the Continental Army Command (CONUS) training sites. The following "WARNING" should be incorporated in the OH-58A operator's manual:
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WARNING

Touchdown autorotations with rotor speed below 200 rpm may result in tail-boom resonance.

c. Autototational Landing Performance

(1) Qualitative test results indicate that the reduction of collective control travel had little or no effect on the H-V characteristics of the OH-58A under the conditions tested at the BHC facility. The test conditions are shown in Table 1. Figure 2, inclusion 2, shows a typical H-V maneuver and denotes actual conditions at entry and termination of the maneuver. As shown in this figure, the rotor speed at ground contact is in excess of 250 rpm.

(2) Incorporated in figure 3, inclusion 2, are data collected during recent high-altitude tests with the collective control restricted to 80 percent of full travel. These recent data indicate that the H-V characteristics of the OH-58A are degraded at density altitudes greater than 5,000 feet. Also shown in figure 3 are the near maximum performance and the recommended operational curves generated during USAASTA's previous H-V test program, Project No. 69-16 (ref 4, incls 1). The techniques utilized during the recent test program were the same as those developed during the conduct of Project No. 69-16.

(3) Time histories of selected data points shown in figure 3, inclusion 2, are presented in figures 4 through 13. These time histories denote the test data generated with the collective control travel restricted to 80 percent of full travel. Figures 7, 8, and 10 show that maximum available collective control was used to complete the maneuver. Qualitative pilot comments indicate that additional collective would have been used were it available.

(4) Figures 14 and 15, inclusion 2, are additional data specifically requested by AVSCOM. These figures show data points collected for the recommended operational curve which resulted from Project No. 69-16 testing along with the maximum pitch rates and attitudes utilized. These data are presented to facilitate determination of consistency of pilot technique.

9. CONCLUSIONS

a. General. The following conclusions were reached upon completion of the autorotational evaluation of the OH-58A helicopter:

(1) The 80-percent collective control restriction did not eliminate the excitation of tail-boom resonance (para 8b).

(2) The 80-percent collective control restriction extended the touchdown airspeed envelope within which tail-boom resonance did not occur (para 8b).

(3) The use of autorotational landing techniques developed during USAASTA Project No. 69-16 results in touchdown with rotor speed remaining in excess of 200 rpm (para 8b).
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(4) The autorotational landing performance characteristics (H-V) of the OH-58A helicopter are degraded at density altitude in excess of 5,000 feet (para 8c(2)).

b. Deficiency Affecting Flight Safety. Correction of the unacceptable tail-boom resonance characteristic is mandatory (para 8b).

10. RECOMMENDATIONS. The following recommendations are made:

a. The deficiency, correction of which is mandatory, should be corrected as soon as possible.

b. A USASTA team should be sent to the CONUS training sites to instruct standardization instructor pilots in the autorotational landing techniques developed during the conduct of Project No. 69-16.

c. The following "WARNING" should be incorporated in the OH-58A operator's manual:

WARNING

Touchdown autorotations with rotor speed below 200 rpm may result in tail-boom resonance.

Prepared by:

[Signature]

JOSEPH C. WATTS
Project Officer/Pilot

VERNON L. DIEKMANN
Project Engineer

Approved by:

[Signature]

DEAN E. WRIGHT
Colonel, TC
Commanding
REFERENCES


FIGURE 1
TIME HISTORY OF AUTO-ROTATIONAL LANDING
GH-58A S/N 41155

<table>
<thead>
<tr>
<th>GROSS WEIGHT</th>
<th>DENSIFF</th>
<th>CENTER OF GRAVITY</th>
<th>TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2500 LBS</td>
<td>-300</td>
<td>109.7 F.</td>
<td>7 DEG C</td>
</tr>
<tr>
<td>(M10)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE 1. DATA SUPPLIED BY BELL HELICOPTER CO.
2. AIRSPEED AT T.O. 40 KIAS (ESTIMATED)

MAX. OSC. 90 DEG C.G. VERT. = 18.3 G

MAX. OSC. C.G. VERT. = 1.7 G

NOTE 100 PERCENT = 17 DEGREES

GROUND CONTACT

CONTROL POSITIONS:
- LONG CYCLIC - PERCENT
- SHORT CYCLIC - PERCENT
- COLLECTIVE - PERCENT
- ROLL - PERCENT

TIME - SECONDS
0 1 2 3 4 5 6 7 8
Figure 2
Height Velocity Time History
CH-59A S/N 4155

Entry Airspeed Height Gross Center of Density Collective GAD Speed Free-Air
Ktas Feet Lbs F.S. Feet Percent Knots Deg C
45 80 2250 109.7 -700 67 10 7

Note 1: Data supplied by Bell Helicopter Co.
FIGURE 3
HEIGHT VELOCITY PROFILES
MAXIMUM PERFORMANCE CURVES
AND
RECOMMENDED OPERATIONAL CURVE

NOTE
1. CURVES EXTRACTED FROM FINAL REPORT USAFTR-PAD-1 NO. 69-16.
2. OPEN SYMBOLS INDICATE DATA POINTS WHERE MORE THAN 75 PERCENT
OF FULL COLLECTIVE FLIGHT WAS USED (FROM NO. 69-16)
3. SHAPED SYMBOLS - COLLECTIVE FLIGHT LIMIT LIMITED TO
80 PERCENT
4. FLAGGED SYMBOLS - 80 PERCENT STOP CONTACTED
DURING MANEUVER
5. NUMBERED SYMBOLS INDICATE TIME HISTORY FIGURE NUMBERS.

- RECOMMENDED OPERATIONAL CURVE
  2450 LB - S.L. TO 10,750 FT HD
  2950 LB - S.L. TO 1600 FT HD
  2950 LB - S.L. HD

- MAXIMUM PERFORMANCE CURVE
  $G_W = 2950\,\text{LB}$
  $H_O = 1500, 750\,\text{FT}$
### Figure 5

**Height Velocity Time History**

<table>
<thead>
<tr>
<th>Entry Altitude (KIAS)</th>
<th>Entry Height (FT AGL)</th>
<th>Gross Weight (LB)</th>
<th>Density (LB/FT³)</th>
<th>Center of Gravity (F.S.)</th>
<th>Free-Air Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>250</td>
<td>2640</td>
<td>3370</td>
<td>107.0 (FAD)</td>
<td>2</td>
</tr>
</tbody>
</table>

![Graph showing various parameters over time](https://example.com/graph.png)
<table>
<thead>
<tr>
<th>Entry Airspeed</th>
<th>Entry Height</th>
<th>Gross Weight</th>
<th>Density</th>
<th>Center of Gravity</th>
<th>Sigma</th>
<th>Free Air Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>320</td>
<td>2540</td>
<td>9670</td>
<td>107.0</td>
<td>-3</td>
<td>3400</td>
</tr>
</tbody>
</table>

**Figure 8**

**Height, Velocity, Time History**

- **True Airspeed**: Knots
- **Pitch Attitude**: Deg
- **Collective Control**: Percent
- **RPM**:

- **Throttle Chop**
- **Touch Down**

**Time**: Seconds
FIGURE 11
HEIGHT VELOCITY TIME HISTORY
DH-58A  S/N 68-16706

<table>
<thead>
<tr>
<th>ENTRY</th>
<th>ATTAP</th>
<th>GRAY</th>
<th>DENSITY</th>
<th>CENTER OF GRAVITY</th>
<th>FREE AIR</th>
<th>TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>KIAS</td>
<td>HEIGHT</td>
<td>WT</td>
<td>FEET</td>
<td>WEIGHT</td>
<td>S.G.</td>
<td>DEG C</td>
</tr>
<tr>
<td>32</td>
<td>190</td>
<td>2400</td>
<td>6110</td>
<td>107.0</td>
<td>2940</td>
<td>24</td>
</tr>
</tbody>
</table>

NOTE: DATA FROM USAF RTA PRJ. 69-16
<table>
<thead>
<tr>
<th>ENTRY AIRSPEED (KIAS)</th>
<th>ENTRY HEIGHT (FT)</th>
<th>GROSS WEIGHT (LB)</th>
<th>DENSITY (SL)</th>
<th>ALTITUDE (FEET)</th>
<th>CENTER OF GRAVITY (F.S.)</th>
<th>FREE AIR TEMPERATURE (DEG C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>190</td>
<td>2490</td>
<td>6110</td>
<td>107.0</td>
<td>2940</td>
<td>24</td>
</tr>
</tbody>
</table>

NOTE: DATA FROM USARSTA PROJ. 69-16

**FIGURE 11**

HEIGHT VELOCITY TIME HISTORY

DH-58C  S/N 68-16706

- **THROTTLE CHOP**
- **TOUCH DOWN**

TIME SECONDS: 0 4 8 12 16 20

- **ROTOR SPEED (RPM):**
- **COLLECTIVE CONTROL POSITION (DEG):**
- **PITCH ATTITUDE (DEG):**
- **TIME AIRSPEED (KNOTS):**
- **FREE ARA TEMPERATURE (DEG C):**
FIGURE 12
HEIGHT VELOCITY TIME HISTORY
OH-58A S/N 66-16706

<table>
<thead>
<tr>
<th>ENTRY AIRSPEED</th>
<th>ENTRY HEIGHT</th>
<th>GROSS WEIGHT</th>
<th>DENSITY</th>
<th>CENTER OF GRAVITY</th>
<th>FREE AIR TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>70</td>
<td>2440</td>
<td>1300</td>
<td>107.0</td>
<td>2540</td>
</tr>
</tbody>
</table>

NOTE: DATA FROM USNASTA PROJ. 69-16
FIGURE 14
RECOMMENDED OPERATIONAL HEIGHT VELOCITY PROFILE
OH-6A/1  S/N 68-16706

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>GROSS WEIGHT (LB)</th>
<th>ALTITUDE (FT)</th>
<th>CENTER OF GRAVITY (F.S.)</th>
<th>FREE AIR</th>
<th>TEMPERATURE (DEG C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
<td>2600</td>
<td>4800</td>
<td>107.0 (PHD)</td>
<td>3200</td>
<td>10</td>
</tr>
<tr>
<td>○</td>
<td>2600</td>
<td>4500</td>
<td>107.0 (PHD)</td>
<td>3200</td>
<td>8</td>
</tr>
<tr>
<td>△</td>
<td>2460</td>
<td>1100</td>
<td>107.0 (PHD)</td>
<td>3400</td>
<td>8</td>
</tr>
</tbody>
</table>

NOTE: 1. BASED ON SIMULATION OF PITCH ATTITUDES AND PITCH RATES UTILIZED BY OPERATIONAL AVIATION AVIATORS.
2. 2 SECOND DELAY FROM THROTTLE CROP TO COLLECTIVE REDUCTION.
3. 3500 LB-2 FT TO 10,000 FT 10
    3900 LB-5 FT TO 16,000 FT 10
4. DATA FROM USAFITA PROJ. 69-16

<table>
<thead>
<tr>
<th>ENTRY INDICATED AIRSPEED (KNOTS)</th>
<th>0</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>80</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHO (HEIGHT (A.G.L.)) - FEET</td>
<td>700</td>
<td>600</td>
<td>500</td>
<td>400</td>
<td>300</td>
<td>200</td>
</tr>
</tbody>
</table>

Diagram showing recommended operational height and velocity profile with data points marked by symbols.
FIGURE 15
MAXIMUM PITCH ATTITUDES AND RATES DURING PUSHOVER
OPERATIONAL AND MAXIMUM PERFORMANCE CURVE POINTS

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>GROSS WEIGHT</th>
<th>DENSITY</th>
<th>CENTER OF GRAVITY</th>
<th>SIGMA</th>
<th>FREE AIR</th>
<th>TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
<td>2450</td>
<td>6400</td>
<td>107.01°F/°C</td>
<td>300</td>
<td>30°C</td>
<td></td>
</tr>
<tr>
<td>□</td>
<td>2450</td>
<td>5900</td>
<td>107.01°F/°C</td>
<td>350</td>
<td>15°F</td>
<td></td>
</tr>
<tr>
<td>□</td>
<td>2450</td>
<td>11100</td>
<td>107.01°F/°C</td>
<td>3040</td>
<td>6°F</td>
<td></td>
</tr>
</tbody>
</table>

NOTE 1. BASIC SYMBOLS DENOTE MAXIMUM PERFORMANCE CURVE POINTS
2. SHADED SYMBOLS DENOTE OPERATIONAL CURVE POINTS
3. DATA FROM USAF STA PROJ. 69-16