PRELIMINARY AIRWORTHINESS EVALUATION OF
THE UH-60A EQUIPPED WITH THE XM-139
VOLCANO MINE DISPENSING SYSTEM

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Preliminary Airworthiness Evaluation of the UH-60A Equipped with the XM-139 VOLCANO Mine Dispensing System. Unclassified

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A Preliminary Airworthiness Evaluation of the UH-60A helicopter (S/N 84-23953) with the XM-139 VOLCANO system installed was conducted by the U.S. Army Aviation Engineering Flight Activity. The test was conducted at the Sikorsky Flight Test Facility at West Palm Beach, Florida (elevation 28 feet). Tests totaling 22.4 hours of productive flight time were conducted between 21 January and 27 February 1987. Tests were conducted to determine handling qualities and performance of the UH-60A in the VOLCANO system configuration at an average mission gross weight of 20,500 pounds and a longitudinal center of gravity at fuselage station 351.0. The handling qualities of the UH-60A with the VOLCANO system installed were similar to the normal utility UH-60A. Three shortcomings were noted in this configuration: (1) the increased frequency and magnitude of "tail shake" with the VOLCANO installed; (2) the position error for the ship's airspeed system was increased by approximately 2 knots at low speed (45 knots calibrated airspeed (KCAS)) and approximately 8 knots at higher speeds (120 KCAS) due to the installation of the VOLCANO mine dispensing system; and (3) Stability Augmentation System...
System (SAS) OFF dynamic response, not attributed to the VOLCANO installation, was aperiodic and divergent. The UH-60A helicopter with VOLCANO failed to meet two requirements of the Prime Item Development Specification; however, these noncompliances were not significant. Recommendations were made to incorporate data into the applicable portion of the VOLCANO operator’s manual and to conduct additional testing.
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INTRODUCTION

BACKGROUND

1. The U.S. Army is investigating the potential of the UH-60A Black Hawk helicopter for carrying the XM-139 VOLCANO mine dispensing system. The airborne dispensing system, designed to launch a mix of anti-tank and anti-personnel mines, was developed by the U.S. Army Aviation Research, Development and Engineering Center in conjunction with the Program Manager for Mines, Countermines, and Demolition. The development effort was initiated in response to a requirement of the High Technology Light Division for a helicopter mine dispensing system. The prime development contractor for the XM-139 VOLCANO system is Honeywell, Inc. The U.S. Army Armament, Munitions, and Chemical Command has been tasked with system production and has in turn requested support from the U.S. Army Aviation Systems Command (AVSCOM) for qualification of the airborne system. On 14 November 1986, AVSCOM tasked the U.S. Army Aviation Engineering Flight Activity (ARPA) (ref 1, app A) to plan, conduct and report on a Preliminary Airworthiness Evaluation (PAE) of the UH-60A with the XM-139 VOLCANO mine dispensing system installed.

TEST OBJECTIVE

2. The objective of this evaluation was to conduct a limited handling qualities and performance evaluation of the UH-60A helicopter with the XM-139 VOLCANO system installed. Data will be used by AVSCOM to determine the airworthiness of the VOLCANO installation and the associated limitations to the UH-60A flight envelope.

DESCRIPTION

3. The UH-60A is a twin-engine, single main rotor configured helicopter with a fixed wheel-type landing gear. The main and tail rotors are both four-bladed with a capability of manual main rotor blade and tail pylon folding. A moveable horizontal stabilator is located on the lower portion of the tail rotor pylon. A more detailed description of the UH-60A helicopter is contained in the operator's manual (ref 2). The test helicopter, UH-60A Black Hawk, U.S. Army S/N 84-23933, equipped with fixed provision mounting points, was configured with the VOLCANO mine dispensing system (photo 1). The VOLCANO system evaluated consisted of four launching racks loaded with 160 slug (inert) mine canisters, the aircraft mounting kit hardware, and fully operational rack jettison mechanisms. The Dispenser Control Unit was not installed for this evaluation. The VOLCANO system
Photo 1. UH-60A Test Aircraft S/N 84-23953 with XM-139 VOLCANO Mine Dispenser System Installed
was mounted on the sides of the aircraft fuselage outboard of the sliding doors. A more detailed description of the VOLCANO mine dispensing system is included in references 3 and 4, and in appendix B.

TEST SCOPE

4. The PAX was performed by ARPA personnel at the Sikorsky Flight Test Facility at West Palm Beach, Florida (elevation 28 feet). Tests totaling 22.4 hours of productive flight time were conducted between 31 January and 7 February 1987. The contractor provided all maintenance and logistical support of the test aircraft and test instrumentation and provided data reduction support. Tests were conducted to determine handling qualities and performance of the UH-60A in the VOLCANO system configuration at an average mission gross weight of 20,500 pounds and a longitudinal center of gravity at fuselage station 351.0. Results were compared to the requirements of MIL-H-8501A (ref 5, app A). Flight restrictions and operating limitations observed throughout the evaluation are contained in the operator's manual (ref 2) and the airworthiness release issued by AVSCOM (ref 6). Testing was conducted in accordance with the approved test plan (ref 7) at the conditions shown in tables 1 and 2.

TEST METHODOLOGY

5. The flight test data were recorded by hand from test instrumentation displayed in the cockpit, by on-board magnetic tape recording equipment and via telemetry to Sikorsky's Real-Time Acquisition and Processing of Inflight Data system. A detailed listing of test instrumentation is contained in appendix C. Flight test techniques and data reduction procedures are described in appendix D.
Table 1. Level Flight Performance Test Conditions

<table>
<thead>
<tr>
<th>Average Gross Weight (1b)</th>
<th>Average Thrust Coefficient (x10^4)</th>
<th>Average Longitudinal Center of Gravity (FS)^2</th>
<th>Average Density Altitude (ft)</th>
<th>Airspeed Range (KTAS)^3</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>17,720</td>
<td>79.66</td>
<td>350.4</td>
<td>7,930</td>
<td>49 to 160</td>
<td>Normal</td>
</tr>
<tr>
<td>17,840</td>
<td>90.22</td>
<td>350.9</td>
<td>10,870</td>
<td>51 to 151</td>
<td>Utility</td>
</tr>
<tr>
<td>17,820</td>
<td>100.40</td>
<td>350.9</td>
<td>13,290</td>
<td>53 to 133</td>
<td></td>
</tr>
<tr>
<td>20,450</td>
<td>79.85</td>
<td>350.7</td>
<td>3,010</td>
<td>44 to 124</td>
<td></td>
</tr>
<tr>
<td>20,500</td>
<td>89.98</td>
<td>350.7</td>
<td>6,260</td>
<td>46 to 124</td>
<td>VOLCANO</td>
</tr>
<tr>
<td>20,650</td>
<td>99.96</td>
<td>350.7</td>
<td>9,330</td>
<td>49 to 111</td>
<td>Installed</td>
</tr>
</tbody>
</table>

NOTE:
1Tests conducted with doors and windows closed, SAS ON, PRA centered and locked, and engine bleed air systems OFF. Main rotor speed of 25R referred rpm, approximate mid lateral center of gravity location.
2FS: Fuselage station.
3KTAS: Knots true airspeed.
Table 2. Handling Qualities Test Conditions

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>Average Gross Weight (lb)</th>
<th>Average Longitudinal Center of Gravity (Pb)</th>
<th>Average Density Altitude (ft)</th>
<th>Trim Calibrated Airspeed (kt)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Positions in trimmed forward flight</td>
<td>17,790</td>
<td>350.7</td>
<td>7,930 to 13,290</td>
<td>42 to 143</td>
<td>Normal utility configuration (no VOLCANO)</td>
</tr>
<tr>
<td>Static Longitudinal Stability</td>
<td>20,530</td>
<td>350.9</td>
<td>3,010 to 9,330</td>
<td>42 to 122</td>
<td>VOLCANO installed</td>
</tr>
<tr>
<td>Static Lateral-Directional Stability</td>
<td>20,690</td>
<td>351.4</td>
<td>4490</td>
<td>81 and 118</td>
<td>Level flight</td>
</tr>
<tr>
<td>Maneuvering Stability</td>
<td>20,680</td>
<td>351.3</td>
<td>5000</td>
<td>82</td>
<td>IRP climb and 1000 fpm descent</td>
</tr>
<tr>
<td>Dynamic Stability</td>
<td>20,500</td>
<td>350.6</td>
<td>5120</td>
<td>81 and 120</td>
<td>Level flight</td>
</tr>
<tr>
<td>Controllability in Hover</td>
<td>20,560</td>
<td>350.1</td>
<td>-160</td>
<td>0</td>
<td>Wheel height 50 feet</td>
</tr>
<tr>
<td>Low Speed Flight</td>
<td>20,490</td>
<td>350.9</td>
<td>290</td>
<td>0 to 40 (KTAS)</td>
<td>Autonomous: 0°, 90°, 180°, 270°, 315°. Wheel height 50 feet</td>
</tr>
<tr>
<td>Simulated Single-Engine Failures</td>
<td>20,310</td>
<td>350.0</td>
<td>5140</td>
<td>82 to 117</td>
<td>Level flight</td>
</tr>
<tr>
<td></td>
<td>20,170</td>
<td>349.6</td>
<td>5260</td>
<td>85</td>
<td>TRP climb</td>
</tr>
</tbody>
</table>

NOTES:
1. Test conducted with VOLCANO installed and AFCS ON unless otherwise indicated, PBA centered and locked. Rotor speed of 258 rpm, and mid lateral center of gravity location.
2. PB: Fuselage station.
3. Test conducted in bell-centered flight.
4. In conjunction with level flight performance, trim and FFS OFF.
5. TRP: Intermediate rated power.
6. fpm: Feet per minute
8. PPS: Flight Path Stabilization.
9. KTAS: Knots true airspeed.
RESULTS AND DISCUSSION

GENERAL

6. A Preliminary Airworthiness Evaluation (PAP) of the performance and handling qualities of the UH-60A with the XM-139 VOLCANO mine dispensing system installed was conducted at the Sikorsky Aircraft Development Flight Test Center at West Palm Beach, Florida. The handling qualities of the UH-60A with the VOLCANO system installed were similar to the normal utility UH-60A. Three shortcomings were noted in this configuration: (1) the increased frequency and magnitude of "tail shake" with the VOLCANO installed; (2) the position error for the ship's airspeed system was increased by approximately 2 knots at low speed (45 knots calibrated airspeed (KCAS)) and approximately 8 knots at higher speeds (120 KCAS) due to the installation of the VOLCANO mine dispensing system; and (3) Stability Augmentation System (SAS) OFF dynamic response, not attributed to the VOLCANO installation, was aperiodic and divergent. The UH-60A helicopter with VOLCANO failed to meet two requirements of the Prime Item Development Specification (PIDS) (ref 8, app A), however, these noncompliances were not significant. Recommendations were made to incorporate data into the applicable portion of the VOLCANO operator's manual and to conduct additional testing.

LEVEL FLIGHT PERFORMANCE

7. Limited performance flight testing was conducted on the UH-60A helicopter to determine the performance differences between the UH-60A helicopter with the fixed provision fairings installed (normal utility) and the UH-60A configured with the VOLCANO system. Level flight performance tests were conducted at the conditions listed in table 1 to determine power required at various airspeeds. Each test was flown in ball-centered flight. Nondimensional level flight test results in the normal utility configuration are presented in figures 1 through 3, appendix F. Dimensional level flight test results are presented in figures 4 through 6. The VOLCANO configuration test results are presented in figures 7 through 9. With the VOLCANO installed on the UH-60A helicopter, change in equivalent flat plate area ($A_f$) varied as a function of thrust coefficient ($C_T$) and airspeed from approximately 42 sq ft at a $C_T$ of 0.008 to approximately 55 sq ft at a $C_T$ of 0.010 as described in paragraph 10, appendix D. A pitch attitude difference, caused by the VOLCANO installation, was noted. At 40 KCAS, the normal utility aircraft and the UH-60A with VOLCANO exhibited the same pitch attitude. However, at 80 KCAS, the UH-60A with VOLCANO exhibited a 2° increase nose down pitch attitude when compared to the normal utility aircraft. This pitch attitude difference increased to 3° at
The following CAUTION should be incorporated into the operator's manual.

CAUTION

Prior to installation of the VOLCANO system, ensure that modified input modules (P/N 7035108001-046) have been installed in the aircraft. The increased nose-down pitch attitudes during level flight when the VOLCANO system is installed may result in oil foaming and inadequate lubrication without the required gearbox modification.

HANDLING QUALITIES

General

8. A limited handling qualities evaluation of the UH-60A configured with the VOLCANO mine dispensing system was conducted to determine any changes caused by the VOLCANO installation. Handling qualities of the UH-60A in the test configuration were qualitatively evaluated and found to be similar to the normal utility configured UH-60A. During a 40 knots indicated airspeed (KIAS) collective-fixed turn at 45 degrees angle-of-bank, the airspeed indication would abruptly decrease to zero. Airspeed could not be increased by application of forward cyclic in the turn. This condition of zero airspeed turn, which was not VOLCANO related, was perceived by the pilot as similar to a fixed-wing aircraft in a spin. Also not caused by the VOLCANO installation, the SAS OFF dynamic stability was aperiodic and divergent. With the VOLCANO installed, the aircraft exhibited an increased frequency and magnitude of "tail shake".

Control Positions in Trimmed Forward Flight

9. Control positions in trimmed, ball-centered, forward flight were obtained in conjunction with level flight performance testing at the conditions in table 2. Figures 10 through 15, appendix R, present the results of these tests. The variation of longitudinal control position with airspeed during trimmed level flight generally required increasing forward cyclic control with increasing airspeed. The control positions in trimmed forward flight are similar to the normal UH-60A and are satisfactory.
Static Longitudinal Stability

10. The static longitudinal stability characteristics were evaluated at the conditions presented in table 2. The helicopter was stabilized in ball-centered flight at the desired trim airspeed and flight condition. The collective control was held fixed while airspeed was varied incrementally approximately ±20 knots about trim. Test results are shown in figures 16 through 18. The static longitudinal stability, as indicated by the variation of longitudinal cyclic control position with airspeed, was positive (0.025 in/kt) (forward longitudinal cyclic control position to maintain increased airspeed) at 81 KCAS, but neutral at maximum airspeed in level flight at intermediate rated power (IRP) \( V_H \) (118 KCAS). Control force cues of longitudinal cyclic control displacement about trim were weak, but sufficient for airspeed control within ± 2 knots during normal mission maneuvering. The static longitudinal stability characteristics were essentially the same during climbs, descents, and level flight and were similar to the normal utility UH-60A. The static longitudinal stability characteristics are satisfactory, but did not meet the requirements of MIL-H-8501A in that the static longitudinal stability was neutral at \( V_H \).

Static Lateral-Directional Stability

11. The static lateral-directional stability characteristics were evaluated at the conditions presented in table 2. The helicopter was stabilized in ball-centered flight at the desired trim airspeed and flight condition. The collective control was held fixed and sideslip angle was varied incrementally (left and right) while maintaining constant airspeed and ground track. Test results are shown in figures 19 through 21. Apparent static directional stability, as indicated by the variation of directional control position with sideslip angle, was positive (left pedal for right sideslip angles) and essentially linear. Dihedral effect, as indicated by the variation of lateral cyclic control position with sideslip angle, was positive (right cyclic control for right sideslip angles) and essentially linear. The sideforce characteristics, as indicated by the variation of bank angle with sideslip, were positive (right bank angle with right sideslip). The UH-60A exhibited pitch with sideslip coupling (variation of longitudinal control position with sideslip) and although it was noticeable to the pilots it was not considered objectionable. During the 83 KCAS climb, the left pedal stop was contacted at approximately 21 degrees right sideslip angle, 2 degrees prior to reaching the limit sideslip angle of 23 degrees right. This was not considered to be a significant finding. The static lateral-directional stability characteristics were essentially
the same during climbs, descents, and level flight. During cruise flight, the aircraft trim condition was maintained within +2 degrees of heading and bank angle, and +1/2 ball width from trim with little pilot compensation (Handling Qualities Rating Scale (HORS 2)). The static lateral-directional stability characteristics in all flight conditions are satisfactory and met the requirements of MIL-H-8301A.

**Maneuvering Stability**

12. Maneuvering stability was evaluated at the conditions presented in table 2 in left and right collective-fixed, steady-state turns, symmetrical pull-ups and pushovers. The steady-state turn tests were accomplished by initially stabilizing the helicopter in ball-centered level flight at the trim airspeed and then incrementally increasing the normal acceleration (g) by increasing the bank angle in left and right turns. Constant collective control position was maintained during the maneuvers and the pilot attempted to maintain a constant airspeed. Symmetrical pull-ups and pushovers were conducted by alternately climbing and diving the helicopter to achieve varying g while the aircraft was passing through the trim altitude at the desired airspeed. Test results are presented in figures 22 through 25.

13. The stick-fixed maneuvering stability, as indicated by the variation of longitudinal cyclic control position with g, was positive (increasing aft cyclic control with increasing g). There were no significant differences in the handling qualities characteristics between right and left turns. The variation in longitudinal control positions with g was essentially linear and the lateral cyclic control position remained essentially constant at all bank angles. The longitudinal control force cues were adequate at bank angles greater than 15 degrees. The maneuvering stability characteristics were similar to the normal utility UH-6OA and are satisfactory.

14. Maneuvering stability was evaluated at 40 KIAS in angles of bank from 15 to 45 degrees. The aircraft was stabilized at 40 KIAS and bank angle was increased in 15 degree increments. If the airspeed was allowed to decrease below 40 KIAS while stabilizing at 45 degrees angle of bank airspeed indication would abruptly decrease to zero. Increasing forward longitudinal cyclic caused the pitch attitude to decrease (nose further down), but did not increase the airspeed. This condition was perceived by the pilot as being similar to a fixed-wing aircraft in a spin. The aircraft was easily recovered by rolling out of the turn using lateral cyclic and opposite pedal. As the airspeed increased, aircraft recovery was completed by the application of aft cyclic.
A similar result occurred when this test was repeated without the VOLCANO installed. This is characteristic of the helicopter and not VOLCANO related, but has not been previously documented. The following note should be incorporated into chapter 5 of the operator's manual (ref 2, app A).

**NOTE**

While flying at 40 KIAS or below, maneuvers should be limited to less than 45° angle of bank to prevent inadvertent entry into a spin type maneuver, characterized by zero airspeed indication, in which forward cyclic results in an increased nose down pitch attitude without the expected and corresponding airspeed increase. Upon inadvertent entry into this flight condition, recovery should be effected by rolling out of the turn first, and applying aft cyclic to return to level flight.

**Dynamic Stability (Gust Response)**

15. The dynamic stability characteristics were evaluated at the conditions presented in table 2. The gust response characteristics were evaluated qualitatively in calm to light turbulence conditions as defined in the DoD Flight Information Handbook (ref 9). The helicopter response was evaluated using one-inch 0.5 second control pulses in level flight, climbs and descents at 80 KCAS, SAS ON and SAS OFF. Additional control pulses were evaluated in level flight at \(V_h\) (120 KCAS), SAS ON and SAS OFF. Representative time history data (80 KCAS) are presented in figures 26 through 39, appendix E. SAS ON dynamic response was deadbeat. SAS OFF dynamic response was aperiodic and divergent. Control pulses in other axes rapidly coupled into the longitudinal axis. During descents, the SAS OFF response rates were noticeably higher than during the other test conditions. Pilot workload during SAS OFF level flight requires continuous, small (±1/4 inch) longitudinal control inputs to maintain airspeed ±5 KIAS (HORS 3). Steady heading sideslip releases in level flight, climbs and descents were also evaluated. Pedal releases (SAS ON) at a 10 degree sideslip angle (left and right) resulted in a rapid return to within 1/2 ball-width of trim with no more than one heading overshoot of approximately 2 degrees. Long-term longitudinal dynamic stability was evaluated by observing the aircraft response after displacing the aircraft from trim airspeed approximately 10 to 15 knots and smoothly returning the longitudinal control to the trim position. With SAS ON, the aircraft immediately began to return to trim. The aircraft was flown "hands off" for extended time periods (greater than 1 minute) in
light turbulence with only small transient airspeed and altitude fluctuations noted. The SAS ON dynamic stability characteristics are satisfactory and met the specification requirements. The aperiodic divergent SAS OFF dynamic stability is a shortcoming. This is characteristic of the normal utility UH-60A and is not attributed to the VOLCANO installation.

Controllability in Hover

16. Controllability tests were conducted during hover to evaluate the control power, response, and sensitivity characteristics. Controllability was measured in terms of aircraft attitude displacement (control power), maximum angular velocities (control response), and maximum angular accelerations (control sensitivity) about an aircraft axis following a control step input of a measured size. Following the input, all controls were held fixed until a maximum rate was established or until recovery was necessary. The magnitude of inputs was varied by using an adjustable rigid control fixture on the cyclic control and the directional pedals. Real time telemetry monitoring was utilized to confirm the desired input size and shape. Controllability tests were conducted at the conditions presented in table 2.

17. Longitudinal controllability characteristics and representative time histories are presented in figures 40 through 42, appendix E. Longitudinal control power (pitch attitude change within one second following a one inch input) and longitudinal control response (maximum pitch rate per inch of control input) were similar in both the forward and aft directions. The rates and accelerations were linear with respect to control input magnitude. The longitudinal control response was predictable with no tendency to overcontrol. The longitudinal controllability characteristics are satisfactory and met the requirements of MIL-H-8501A.

18. Lateral controllability characteristics and representative time histories are presented in figures 43 through 45. The lateral control power, response, and sensitivity did not change with the direction of input. The lateral controllability characteristics are satisfactory and met the requirements of MIL-H-8501A.

19. Directional controllability characteristics and representative time histories are presented in figures 46 through 48. The control response was predictable with no tendency to overcontrol. The rates and acceleration were linear with respect to control input magnitude. The directional controllability characteristics are satisfactory and met the requirements of MIL-H-8501A.
Low Speed Flight Characteristics

20. The low speed flight characteristics were evaluated at the conditions presented in table 2. Tests were conducted at true airspeeds up to 40 knots in forward and rearward (0° and 180° relative azimuths) and sideward (090°, 270°, and 315° relative azimuths) flight at a wheel height of 30 feet (as measured by the radar altimeter). Surface winds were 5 knots or less and a ground pace vehicle was used as a speed reference. The low speed flight test data are presented in figures 49 through 51.

21. The flight control trends in rearward flight (fig. 49) were unconventional in that a nominal longitudinal cyclic position of approximately 6.4 in. was maintained between 0 and 15 knots true airspeed (KTAS). Qualitatively, longitudinal cyclic position and force cues were minimal at airspeeds less than 20 KTAS. Additionally, larger control inputs were required above 20 KTAS, however, overall control input frequency was noticeably less. The stabilator remained programmed in the full trailing edge down (40°) position throughout this portion of the evaluation and adequate control margins remained during both forward and rearward flight. The low speed flight characteristics during forward and rearward flight are similar to the normal utility UH-60A and are satisfactory.

22. The flight control trends during left and right sideward flight (fig. 50) were conventional. During left sideward flight, the lateral cyclic position cues were noticeably weaker than during right sideward flight. Stabilator programming began to occur at approximately 15 KTAS during left sideward flight, while the stabilator remained programmed in the full trailing edge down (40°) position during right sideward flight. During left sideward flight, the frequency of control inputs was very high (almost continuous) in all control axes. Adequate control margins remained throughout this evaluation. Aircraft vibrations were noticeably higher during left sideward flight (Vibration Rating Scale (VRS 6)). In addition to the typical airframe shudder, an intermittent lateral "tail shake" (as discussed in para 25) was noted. The low speed flight characteristics during left and right sideward flight are similar to the normal utility UH-60A and are satisfactory.

23. The flight control trends during sideward flight at a relative wind azimuth of 315 degrees (fig. 51) were non-linear, but were not objectionable. The non-linearities occurred as the stabilator began to program inconsistently above approximately 15 KTAS. There were adequate control margins throughout the evaluation. The "tail shake" discussed in paragraph 25 occurred at a higher frequency and greater magnitude than during the other wind azimuths.
evaluated. The low speed characteristics during sideward flight at a relative wind azimuth of 315° were similar to a normal utility UH-60A and are satisfactory.

**Simulated Single-Engine Failure**

24. Simulated single engine failures were evaluated at the conditions presented in table 2. Representative time histories of the simulated engine failures during level flight and in an IRP climb are presented in figure 52. The engine failures were simulated by pulling one engine power control lever from the flight position to the idle position and delaying pilot reaction for a minimum of 2 seconds or until the low rotor speed warning sounded. There were no differences (handling qualities or failure cues) noted between a "failed" left engine or a "failed" right engine. The simulated engine failures were detected by an audible warning tone, an RMG OUT master caution light, a difference in cockpit engine parameters, and a noticeable 2 to 4 deg left yaw. Other than the yaw excursion, no unusual attitude changes or control forces were observed during the simulated engine failures and the subsequent transition to single-engine flight. At high collective pitch settings, main rotor speed decreased rapidly, but normal operating rotor speed was easily restored by reducing the collective pitch control. The simulated single-engine failure characteristics are satisfactory.

**VIBRATION**

25. Intermittent, variable intensity lateral accelerations were noted in the cockpit with the VOLCANO installed. Sikorsky flight test personnel commonly referred to this as "tail shake". Tail shake appears to be associated with disturbed airflow across the stabilator surface which transmits a lateral "kick" into the cockpit. The frequency and magnitude of the lateral kicks increased noticeably during descents, left sideslip maneuvers, left turns and at \( V_{NH} \). Observations from the chase aircraft indicate that the entire stabilator intermittently rocks laterally a noticeable amount. Stabilator tip vibration data indicates occasional spike loads of 10 g's with nominal alternating loads of approximately 4 g's. Stabilator mount bushing wear was monitored and an increase in mount bushing wear was noted. Upon further investigation, tail shake was apparent in a normal utility UH-60A under similar flight conditions, but the frequency and magnitude were noticeably less. The excessive magnitude of the tail shake with the VOLCANO installed is a shortcoming. A detailed maintenance evaluation should be conducted to determine potential increased maintenance and supply system impacts pursuant to VOLCANO operations.
AIRSPEED CALIBRATION

26. Airspeed calibration tests were conducted to determine the position error of the UN-60A's airspeed system in both the clean (normal utility) configuration and with the VOLCANO system installed. The aircraft's pitot-static system was calibrated during level flight over a measured ground speed course and by use of a calibrated trailing bomb (finned pitot-static system). The aircraft was flown up to 122 KIAS using the trailing bomb method and up to 156 KIAS using the ground speed course. Data are presented in figures 55 and 56. The position error increased approximately 2 knots at lower speeds (45 KCAS) and approximately 8 knots at higher speeds (120 KCAS) due to the installation of the VOLCANO mine dispensing system. This large position error associated with the VOLCANO installation will result in a discrepancy between the desired mine dispensing airspeed and the actual dispensing airspeed, affecting the mine field density, and is a shortcoming. The position error data presented in figure 56, should be incorporated into the applicable VOLCANO mine dispensing system operator's manual.
CONCLUSIONS

GENERAL

27. Based on this evaluation, the following conclusions were reached about the UH-60A Black Hawk with the XM-139 VOLCANO system installed.

a. With the VOLCANO system installed on the UH-60A helicopter, change in flat plate area ($\Delta A_p$) varied as a function of coefficient of thrust ($C_T$) and airspeed from approximately 42 sq ft at a $C_T$ of 0.008 to approximately 55 sq ft at a $C_T$ of 0.010 (para 7).

b. An increased nose down pitch attitude difference, attributable to the VOLCANO installation, was noted (para 7).

c. Handling qualities of the UH-60A helicopter were not significantly changed by the installation of the XM-139 VOLCANO system (para 8).

SHORTCOMINGS

28. The following shortcomings were identified and are listed in order of importance.

a. The excessive magnitude of the tail shake with the VOLCANO installed (para 25).

b. The large airspeed system position error associated with the VOLCANO installation (para 26).

c. The aperiodic dynamic instability with the SAS OFF at 80 KCAS with and without the VOLCANO installed (para 15).

SPECIFICATION COMPLIANCE

29. The UH-60A helicopter with VOLCANO failed to meet the following requirements of the PIDS (ref 8, app A).

a. Paragraph 10.3.3.1.3 - The static longitudinal stability was neutral at $V_H$ (para 10).

b. Paragraph 10.3.3.2.1a - The SAS OFF dynamic stability, not attributed to the VOLCANO installation, was aperiodic and divergent (para 15).
RECOMMENDATIONS

30. The following recommendations are made.

a. The following NOTE should be incorporated into chapter 3 of the operator's manual (para 14).

NOTE

While flying at 40 KIAS or below, maneuvers should be limited to less than 45° angle of bank to prevent inadvertent entry into a stalls type maneuver, characterised by zero airspeed indication, in which forward cyclic results in an increased nose down pitch attitude without the expected and corresponding airspeed increase. Upon inadvertent entry into this flight condition, recovery should be effected by rolling out of the turn first and applying aft cyclic to return to level flight.

b. The following CAUTION should be incorporated into chapter 5 of the operator's manual (para 7).

CAUTION

Prior to installation of the VOLCANO system, ensure that modified input modules (P/N 70391090001-046) have been installed in the aircraft. The increased nose-down pitch attitudes during level flight when the VOLCANO system is installed may result in oil foaming and inadequate lubrication without the required gearbox modification.

c. A detailed maintenance evaluation should be conducted to determine potential increased maintenance and supply system impacts pursuant to VOLCANO operations (para 25).

d. The position error data presented in figure 56, appendix F should be incorporated into the applicable VOLCANO mine dispensing system operator's manual (para 26).
APPENDIX A. REFERENCES

1. Letter, AVSCOM, AHSAV-6, 14 November 1966, subject: Preliminary Airworthiness Evaluation (PAE) of the UH-60A/VOLCANO.


APPENDIX B. DESCRIPTION

GENERAL

1. The UH-60A (Black Hawk) is a twin turbine engine, single main rotor helicopter with nonretractable wheeled landing gear. A movable horizontal stabilizer is located on the lower portion of the tail rotor pylon. The main and tail rotor are both four-bladed with a capability of manual main rotor blade and tail pylon folding. The cross-beam tail rotor with composite blades is attached to the right side of the pylon. The tail rotor shaft is canted 20° upward from the horizontal. Primary mission gross weight is 16,260 pounds and maximum alternate gross weight is 20,250 pounds. The proposed maximum gross weight is 22,000 pounds and the VOLCANO configured helicopter design gross weight is 20,572 pounds. The UH-60A is powered by two General Electric T700-GE-700 turboshaft engines having an installed thermodynamic rating (30 minute) of 1553 shaft horsepower (shp) (power turbine speed of 20,900 revolutions per minute) each at sea level, standard-day static conditions. Installed dual-engine power is transmission limited to 2828 shp. The aircraft also has an automatic flight control system and a command instrumentation system. The test helicopter, UH-60A S/N 84-23933, was manufactured by Sikorsky Aircraft Division of United Technologies Corporation and is a production Black Hawk equipped with fixed provision mounting points. These points provide the mounting for the VOLCANO system hardware. The main differences between the test aircraft and a normal utility UH-60A are the addition of an external nose-mounted airspeed boom and special test instrumentation (app C), and the mounting of the VOLCANO system (photos 1 through 4, app F). A more complete description of the UH-60A helicopter can be found in reference 2, appendix A.

XM-139 VOLCANO MINE DISPENSER

2. The XM-139 VOLCANO weapons system with related equipment is produced by Honeywell, Inc. The VOLCANO is an automated, scatterable mine delivery system capable of launching mines from host ground and air vehicles (5 ton dump and cargo trucks and the UH-60A helicopter). The mine dispenser system is modular and consists of four major components: (1) mounting hardware kits, (2) four launcher racks, (3) 160 mine canisters, and (4) a Dispenser Control Unit (DCU). Dimensions and weights of these components are summarized in table 1 and aircraft mounting locations are shown in figure 1.
Table 1. XM-139 Component Dimensions

<table>
<thead>
<tr>
<th>Component</th>
<th>Dimensions (in.)</th>
<th>Weight (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UP-GOA Side Panel (each)</td>
<td>58.5 37.25 6.25</td>
<td>238</td>
</tr>
<tr>
<td>Launcher Rack (each)</td>
<td>25.0 79.0 9.0</td>
<td>225</td>
</tr>
<tr>
<td>XM-88 Canisters (each)</td>
<td>19 24.0 3.0 (dia)</td>
<td>32</td>
</tr>
<tr>
<td>DCU</td>
<td></td>
<td>70</td>
</tr>
</tbody>
</table>

The mounting hardware (photos 3 through 7, app F) is the only application-unique system element and allows mounting to the Black Hawk fixed provision mounting points (photos 8 and 9) without any aircraft modifications. This hardware accepts up to four launcher racks (two per side) (photos 10 and 11), with each rack holding up to 40 individual XM-87 Mine Canisters (photos 12 and 13). Each canister contains a stack of five BLU-91/A anti-tank and one BLU-92/A anti-personnel GATOR mines giving the system a total delivery capability of 960 mines. A web assembly is interlaced between the mines providing dispersion and mine arming during firing. Inert XM-88 mine canisters were used for this test. They are identical to the XM-87 canisters except for color and markings, but contain no transmitter coils and six dummy mines. A frontal and side view of the completed installation are shown in photos 14 and 15, respectively. The XM-139 DCU mounted in the cargo compartment, is programmed by the operator with the selected dispensing speed and mine self-destruct time. It is designed to control firing of one to four racks in a prescribed sequence on alternating sides of the aircraft. This DCU was not installed on the aircraft. The interface control panel (photo 16), mounted on the center instrument console, and the go-around switch, located on both pilot and copilot cyclic controls, control the arming, firing and jettison of the launcher racks. The interface control panel allows the pilot to conduct a continuity test of the jettison system. The test aircraft was equipped with the jettison, but not the firing, capability. A more complete description of the system can be found in references 3 and 4, appendix A.

MODIFICATIONS

3. Several modifications were made to the test aircraft to accommodate ballast and instrumentation, or for safety purposes. These modifications were not part of the VOLCANO modifications or a normal utility UP-60A. Four mounting provisions were used to
accomodate ballast. These are shown in photos 17 through 19, appendix F. An instrumentation package was installed in the cargo compartment and can be seen in photos 20 and 21. Sikorsky drag estimates for the external items (photos 22 through 25) totalled 3.04 square feet of equivalent flat plate area. Each item is listed below:

**Item**

- Standard size tail rotor slip ring
- Medium size main rotor slip ring with cover
- Nose boom
- Tail-mounted TM antennas
- Belly-mounted TM antenna
- Main rotor instrumentation
- Ambient air temperature sensor
- Emergency crew door handles
APPENDIX C. INSTRUMENTATION

GENERAL

1. The test instrumentation was installed, calibrated and maintained by Sikorsky Aircraft personnel. A test boom, with a swiveling pitot-static tube and angle-of-attack and sideslip vanes, was installed at the nose of the aircraft. Three telemetry antennae were installed. Two were mounted to the top left side of the tail boom and one was mounted on the belly of the aircraft just forward of the tail boom. Slip ring assemblies were installed on the main and tail rotor shafts. All other instrumentation was installed inside the test aircraft. Data were obtained from calibrated instrumentation and displayed or recorded as indicated below.

Pilot Panel

Airspeed (boom)
Altitude (boom)
Rate of climb (boom)
Rotor speed (sensitive-percent)
Engine torque* **
Turbine gas temperature* **
Power turbine speed (Np)* **
Gas producer speed (Ng)* **
Control positions
  Longitudinal
  Lateral
  Directional
  Collective
Horizontal stabilator position
Angle of sideslip

Copilot Panel

Airspeed*
Altitude*
Rotor speed*
Engine torque* **
Fuel remaining* **
Total air temperature
Instrumentation controls
Run number
Event switch

2. Data parameters recorded on board the aircraft and available for telemetry include the following:

*Ship's system
**Both engines
**Digital (PCM) Data Parameters**

- Airspeed (boom)
- Altitude (boom)
- Airspeed (ship's)
- Altitude (ship's)
- Radar altimeter (low range)
- Total air temperature
- Rotor speed
- Gas generator speed **
- Power turbine speed **
- Engine fuel flow **
- Engine fuel temperature **
- Engine output shaft torque **
- Turbine gas temperature **
- Longitudinal acceleration at the cg
- Lateral acceleration at the cg
- Normal load factor at the cg
- Stabilator position
- Control positions
  - Longitudinal
  - Lateral
  - Directional
  - Collective
- Attitude
  - Pitch
  - Roll
  - Heading
- Angular Acceleration
  - Pitch
  - Roll
  - Yaw
- SAS output position
  - Longitudinal
  - Lateral
  - Directional
- Main rotor shaft torque
- Tail rotor shaft torque
- Tail rotor impressed pitch (blade angle at 0.75 blade span)
- Angle of sideslip
- Angle of attack
- Time of day
- Run number
- Pilot event switch

**Both engines**
Analog (FM) Vibration Parameters

| Vertical pilot seat | Lateral pilot seat | Longitudinal pilot seat | Vertical copilot seat | Lateral copilot seat | Lateral pilot floor | Vertical copilot floor | Vertical pilot instrument panel | Vertical copilot instrument panel | Center of gravity vertical | Center of gravity lateral | Center of gravity longitudinal | No. 1 engine exhaust frame vertical | No. 2 engine exhaust frame horizontal | No. 1 engine front frame longitudinal | No. 2 engine front frame longitudinal | Vertical side panel left forward lower | Vertical side panel left forward upper | Vertical side panel right forward upper | Vertical side panel left aft upper | Vertical side panel right aft upper | Lateral side panel left aft lower | Lateral side panel right aft lower | Lateral side panel left forward upper | Lateral side panel right forward upper | Lateral side panel left aft upper | Lateral side panel right aft upper | Lateral side panel right forward lower | Longitudinal side panel left aft upper | Longitudinal side panel right aft upper |

**TEST BOOM AIRSPEED SYSTEM**

3. The test boom airspeed system mounted at the nose of the test aircraft provided measurements of airspeed and altitude. Sensors for angles of attack and sideslip were also mounted on the test boom (photo 22, app F). The tip of the swiveling pitot-static tube was 79.6 inches forward of the nose of the aircraft (fuselage station 97), 25.7 inches to the right of the aircraft reference buttline and 7 inches below the forward avionics bay floor, waterline 208.
## BOOM AIRSPEED CALIBRATION

**UH-60A USA S/N 8-23353**

<table>
<thead>
<tr>
<th>SYM</th>
<th>GROSS WEIGHT (LB)</th>
<th>AVG C.G. LOCATION (FL)</th>
<th>AVG DENSITY (BL)</th>
<th>AVG ALTITUDE (FEET)</th>
<th>AVG OUTSIDE AIR TEMP. (DEG C)</th>
<th>TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>15270</td>
<td>350.6</td>
<td>0.2</td>
<td>3350</td>
<td>13.5</td>
<td>TRAILING BOMB</td>
</tr>
<tr>
<td>△</td>
<td>18600</td>
<td>350.6</td>
<td>0.2</td>
<td>6200</td>
<td>17.5</td>
<td>TRAILING BOMB</td>
</tr>
<tr>
<td>□</td>
<td>17800</td>
<td>350.0</td>
<td>0.2</td>
<td>-10</td>
<td>16.0</td>
<td>GRIND SPD CRSE</td>
</tr>
</tbody>
</table>

**NOTES:**
1. NORMAL UTILITY CONFIGURATION
2. LEVEL FLIGHT
3. BALL CENTERED TRIM CONDITION
4. MAIN ROTOR SPEED = 250 RPM

**POLYNOMIAL CURVE FIT**

\[
V_{CAL} = +4.1841 + 0.9966 \times V_{IC} - 0.00080188 \times V_{IC}^2 + 0.0000031627 \times V_{IC}^3
\]
**FIGURE 2**

**BOOM AIRSPEED CALIBRATION**

**UH-60A USA S/N 84-23053**

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG C.G. LOCATION LONG (FS)</th>
<th>AVG C.G. LOCATION LAT (BL)</th>
<th>AVG DENSITY (GEO C)</th>
<th>AVG OUTSIDE AIR TEMP. (DEG C)</th>
<th>TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>20570</td>
<td>350.8</td>
<td>0.2</td>
<td>5200</td>
<td>6.5</td>
<td>TRAILING BOMB</td>
</tr>
</tbody>
</table>

**NOTES:**
1. VOLCANO CONFIGURATION
2. LEVEL FLIGHT
3. BALL CENTERED TRIM CONDITION
4. MAIN ROTOR SPEED=298 RPM

**POLYNOMIAL CURVE FIT**

\[
V_{CAL} = -3.48549 + 1.33036 \times V_{IN}
- 0.6049791 \times V_{IN}^2
+ 0.0002163 \times V_{IN}^3
\]

**NOT FOR HANDBOOK USE**
NOTES:  1. NUMBER ONE ENGINE
2. POWER TURBINE SPEED = 20,000 RPM
3. DATA OBTAINED FROM G E ENGINE PRODUCTION RATING SHEET

FIGURE 3
ENGINE TORQUEMETER CALIBRATION
UH-60A USA S/N 84-23053
1700-GE-700 S/N 306825

CORRECTION TO BE ADDED (FT-LB)

DYNAMOMETER TORQUE (FT-LB)

ENGINE TORQUEMETER (FT-LB)
NOTES:
1. NUMBER TWO ENGINE
2. POWER TURBINE SPEED = 20,000 RPM
3. DATA OBTAINED FROM G E
   ENGINE PRODUCTION RATING SHEET
4. The test boom airspeed system along with the ship's standard systems were calibrated in level flight using a calibrated trailing bomb to determine the position error. Sikorsky's ground speed course was used to determine the high speed calibration data (above 120 knots indicated airspeed). The position error of the boom airspeed system is presented in figures 1 through 2.

ENGINE CALIBRATION

5. Calibrations of the engine torque sensor systems was conducted by the engine manufacturer, General Electric. Figures 3 and 4 present the calibrations used to determine engine power.

SPECIAL EQUIPMENT

Weather Station

6. A portable weather station consisting of an anemometer, sensitive temperature gauge, relative humidity sensor and barometer, was used to record wind speed, wind direction, ambient temperature and humidity and pressure altitude at 50 feet above ground level.

Ground Pace Vehicle

7. Pace vehicle speedometers were calibrated by Sikorsky personnel. The pace vehicles were used to establish precise ground speed during the low airspeed handling qualities tests.
APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

AIRCRAFT RIGGING

1. Prior to the start of testing, a flight controls engineering rigging check was performed on the main and tail rotors by Sikorsky Aircraft and monitored by the U.S. Army Aviation Engineering Flight Activity. The stabilator control system was also checked to ensure compliance with the production stabilator schedule. The rigging data are presented in table 1.

AIRCRAFT WEIGHT AND BALANCE

2. The test aircraft was weighed in both the normal utility configuration and with the VOLCANO system installed, with full oil and all fuel drained, all ballast removed, and test instrumentation system and ballast mounting provisions installed. The initial weight of the aircraft in normal utility configuration was 12,368 pounds with a longitudinal center of gravity (cg) located at fuselage station (FS) 361.4. Installation of the XM-139 VOLCANO mine dispensing system side panels, launcher racks, and 160 full XM-88 mine canisters increased the empty weight of the aircraft by 6530 lbs to a weight of 18,898 lbs with a longitudinal cg at FS 350.8. The fuel weight for each performance test flight was determined by pre- and post-flight aircraft weighings, fuel flowmeter instrumentation, and fuel specific gravity measurements.

PERFORMANCE

General

3. Performance data were obtained using the basic methods described in Army Material Command Pamphlet, AMCP 706-204 (ref 10, app A). Level flight performance and control positions in level flight were obtained in coordinated (ball-centered) flight. Referred rotor speed was maintained constant for all performance tests at 25R rpm. Longitudinal cg was allowed to vary ±1.5 inch during each test flight, but for each data set (consisting of several flights in the same aircraft configuration at different thrust coefficient values) the average cg location was maintained constant near the proposed mission value. The data were analyzed to determine the drag differences between aircraft configurations in terms of change in equivalent flat plate area (Δ Fe).

4. Helicopter performance was generalized through the use of non-dimensional coefficients as follows using the 1968 U.S. Standard Atmosphere:
Table 1. Main and Tail Rotor Rigging Information

Main Rotor Rigging

<table>
<thead>
<tr>
<th>Flight Control Position</th>
<th>Blade Angle (deg)</th>
<th>Flight Control Position (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Long</td>
</tr>
<tr>
<td>Aft</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Block</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Block</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Block</td>
<td></td>
<td>*</td>
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<tr>
<td>Aft</td>
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<td>Left</td>
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<td>Block</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Fwd</td>
<td></td>
<td>Left</td>
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<tr>
<td>Aft</td>
<td></td>
<td>Left</td>
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<tr>
<td>Fwd</td>
<td></td>
<td>Right</td>
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<td>Fwd</td>
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<td>High</td>
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<tr>
<td>Fwd</td>
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<td>Right</td>
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<tr>
<td>Aft</td>
<td></td>
<td>Left</td>
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<tr>
<td>Aft</td>
<td></td>
<td>Right</td>
</tr>
<tr>
<td>Aft</td>
<td></td>
<td>Left</td>
</tr>
</tbody>
</table>

Tail Rotor Rigging

<table>
<thead>
<tr>
<th>Flight Control Position</th>
<th>Blade Angle (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COLLECTIVE</td>
</tr>
<tr>
<td></td>
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<td>*</td>
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<td></td>
<td>*</td>
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<td>Low</td>
<td>*</td>
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<td>High</td>
<td>Left</td>
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<tr>
<td>High</td>
<td>Right</td>
</tr>
<tr>
<td>Low</td>
<td>Right</td>
</tr>
<tr>
<td>Low</td>
<td>Left</td>
</tr>
</tbody>
</table>

NOTES:

1 Measured on the Black Blade at the cuff.
2 *270 degree reading minus 90 degree reading divided by 2.
3 *180 degree reading minus 0 degree reading divided by 2.
4 *Sum of all four readings divided by 4.
5 * Indicates appropriate control was pinned at a rigged position.
6 * Indicates a block was inserted between the aft longitudinal control stop and the cyclic control such that no limiters are contacted to determine longitudinal to collective coupling.
7 * Measured on the Blue Blade at the cuff.
a. Coefficient of Power ($C_p$):

$$C_p = \frac{SHP (350)}{\rho A (WR)^3}$$

b. Coefficient of Thrust ($C_T$):

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

c. Advance Ratio ($\mu$):

$$\mu = \frac{V_T (1.6878)}{WR}$$

Where:

- $SHP =$ Engine output shaft horsepower (both)
- $\rho =$ Ambient air density ($lb \cdot sec^2/ft^4$)
- $A =$ Main rotor disc area = 2262.03 ft$^2$
- $\omega =$ Main rotor angular velocity (radians/sec)
- $R =$ Main rotor radius = 26.833 ft
- $GW =$ Gross weight (lb)

$$V_E = \frac{V_T}{1.6878/\rho/\rho_0}$$

$1.6878 =$ Conversion factor (ft/sec/kt)

$\rho_0 =$ 0.0023769 (lb-sec$^2$/ft$^4$)

5. The engine output shaft torque was determined by use of engine torque sensors. The power turbine shaft contains a torque sensor tube that mechanically displays the total twist of the shaft. A concentric reference shaft is secured by a pin at the front end of the power turbine drive shaft and is free to rotate relative to the power turbine shaft at the rear end. The relative rotation is due to transmitted torque, and the resulting phase angle between the reference teeth on the two shafts is picked up by the torque sensor. This torque sensor was calibrated in a test cell by the engine manufacturer. The output from the engine torque sensor was recorded by the on-board data recording system.
The output SHP was determined from the engine's output shaft torque and rotational speed by the following equation.

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

(4)

Where:

\( Q \) = Engine output shaft torque (ft-lb)

\( N_p \) = Engine output shaft rotational speed (rpm)

**Level Flight Performance**

6. Each speed power data set was flown in ball-centered flight by reference to the ship's turn and slip indicators at a predetermined thrust coefficient \( (C_T) \) and referred rotor speed \( (N_R/\sqrt{\rho}) \). Both the pilot's and copilot's turn and slip indicators were checked for alignment with the aircraft positioned in a level attitude on the ground. To maintain the ratio of gross weight to pressure ratio \( (W/\rho) \) constant, altitude was increased as fuel was consumed. To maintain \( N_R/\sqrt{\rho} \) constant, rotor speed was varied as appropriate for the ambient air temperature. Corrections to power required were made for the installation of test instrumentation. The power consumption for the electrical operation of the instrumentation equipment was measured and determined to be 0.76 shp and subtracted from the power required data. The effects of the external instrumentation and nonstandard aircraft equipment were estimated by the contractor to be the equivalent of 3.04 square feet of equivalent flat plate area.

7. The non-dimensional coefficients (equations 1 through 3) can be expressed in terms of referred rotor speed as follows:

\[
C_p = \frac{\text{SHP} \times (478935.3)}{\left( \frac{N_R}{\sqrt{\rho}} \right)^3 \left( \frac{\rho_o A R}{\sqrt{\rho}} \right)}
\]  

(5)
Test-day level flight data were corrected to standard day conditions by the following equations:

\[ C_T = \frac{GW \ (91.19)}{N_R^2 \ \phi \ (\frac{P_o}{\sqrt{\gamma}})^2 (\rho_0 AR)^2} \]  

\[ \nu = \frac{V_T \ (16.12)}{(R \sqrt{\gamma}) (\frac{N_R}{\sqrt{\gamma}})} \]  

\[ \frac{SHP_s}{SHP_t} = \left( \frac{P_s}{P_t} \right) \left( \frac{N_R_s}{N_R_t} \right) \]  

\[ \frac{V_T_s}{V_T_t} = \left( \frac{N_R_s}{N_R_t} \right) \]  

Where:

Subscript \( t \) = Test day
Subscript \( s \) = Standard day

\[ \phi = \text{Pressure ratio} = \left( 1 - \frac{H_P}{145442.15} \right)^{5.255863} \]  

\[ \theta = \frac{T_A + 273.15}{288.15} \]  

\( T_A \) = Ambient air temperature (°C)
\( N_R \) = Main rotor speed (rev/min)
478935.3 = Conversion factor (ft-lb-sec²-rev³/min³-SHP)
91.19 = Conversion factor (sec²-rev²/min²)
\( \rho = \rho_0 \times \sigma \)
\[ \sigma = \delta / \theta \]

16.12 = Conversion factor (ft-rev/min-kt)

Test data corrected for instrumentation electrical power consumption and corrected to standard altitude and ambient temperature are presented in figures 4 through 9, appendix R.

8. Changes in equivalent flat plate area calculated from changes in engine power coefficient were determined using the following equation:

\[ \Delta \alpha = \frac{\Delta C_p (2A)}{\mu^3} \]  

(10)

Where:

\[ \Delta \alpha = \text{Change in equivalent flat plate area (ft}^2 \text{)} \]

The data obtained in the normal utility configuration were analyzed by use of a simulated three dimensional plot (\( C_T \) and \( \mu \) versus \( C_p \)). The reduction of this simulated three dimensional plot to a family of curves of \( C_T \) versus \( C_p \), for a constant \( \mu \) value, allows determination of the power required as a function of airspeed for any value of \( C_T \). The data obtained in both aircraft configurations were compared to determine changes in the equivalent flat plate area using equation 10.

9. Analysis of the level flight performance data in the normal utility configuration defined the basic performance curves (figs. 1 through 3. app R). Applying the \( \Delta \alpha \) technique to these curves to produce a consistent fit to the VOLCANO configuration data (figs. 7 through 9, app R) required the \( \Delta \alpha \) values to change with thrust coefficient and airspeed, as shown in figure 1. The baseline \( \Delta \alpha \) shown here as a function of \( C_T \) applies to a level aircraft pitch attitude, which occurred at 47 KCAS. Since aircraft pitch attitude varied as a function of calibrated airspeed and was consistent for all values of \( C_T \) flown (figs. 13 through 15), a percentage adjustment to the baseline \( \Delta \alpha \) values could be obtained by calculating increase in projected frontal area of the VOLCANO system resulting from pitch attitude change. This projected area variation was solely based on geometric considerations resulting by tilting a rectangle that approximated the proportional dimensions of the VOLCANO system (assumed 50 unit height and 15 unit base). The percentage of \( \Delta \alpha \) adjustment as a function of calibrated airspeed shown in figure 1 was added to the baseline \( \Delta \alpha \) using the expression:
\[ \Delta F_e = (1.0 + \text{percent } \Delta F_e \text{ increase/100.}) \times \Delta F_e_{\text{baseline}} \]  

(11)

HANDLING QUALITIES

10. Handling qualities data were evaluated using standard test methods described in Naval Air Test Center Flight Test Manual, FTM No. 101 (ref 11). A Handling Qualities Rating Scale (HQRS) (fig. 2) was used to augment pilot comments relative to aircraft handling qualities.

VIBRATIONS

11. A Vibration Rating Scale (fig. 3) was used to augment pilot comments relative to aircraft vibrations.

DEFINITION

12. Results were categorized as shortcomings in accordance with the following definition.

Shortcoming: 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.
FIGURE 1
CHANGE IN $\Delta F_v$ WITH AIRSPEED AND GROSS WEIGHT
UH-60A USA S/N 84-23953

NOTES: 1. VOLCANO CONFIGURATION
2. LEVEL FLIGHT
3. BALL CENTERED TRIM CONDITION
4. REFERRED MAIN ROTOR SPEED=258 RPM

BASELINE $\Delta F_v$ OF VOLCANO INSTALLATION OVER NORMAL UTILITY CONFIGURATION APPLIES TO LEVEL AIRCRAFT ATTITUDE. PERCENT INCREASE IN $\Delta F_v$ WITH AIRSPEED IS BASED ON GEOMETRIC CONSIDERATIONS AS PITCH ATTITUDE CHANGES AND IS VALID FOR ALL THRUST COEFFICIENTS.

Baseline $\Delta F_v$ (square ft)

Coefficient of Thrust ($C_T \times 10^4$)

Pitch Attitude (deg)

Percent $\Delta F_v$ increase

Calibrated Airspeed (knots)

Baseline value is valid for an airspeed of 47 knots.
Figure 2. Handling Qualities Rating Scale
<table>
<thead>
<tr>
<th>DEGREE OF VIBRATION</th>
<th>DESCRIPTION</th>
<th>PILOT RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>No vibration</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Slight</td>
<td>Not apparent to experienced aircrew fully occupied by their tasks, but noticeable if their attention is directed to it or if not otherwise occupied.</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>Moderate</td>
<td>Experienced aircrew are aware of the vibration but it does not affect their work, at least over a short period.</td>
<td>4, 5, 6</td>
</tr>
<tr>
<td>Severe</td>
<td>Vibration is immediately apparent to experienced aircrew even when fully occupied. Performance of primary task is affected or tasks can only be done with difficulty.</td>
<td>7, 8, 9</td>
</tr>
<tr>
<td>Intolerable</td>
<td>Sole preoccupation of aircrew is to reduce vibration level.</td>
<td>10</td>
</tr>
</tbody>
</table>

*Based on the Subjective Vibration Assessment Scale developed by the Aeroplane and Armament Experimental Establishment, Boscombe Down, England.

Figure 3. Vibration Rating Scale
## APPENDIX E. TEST DATA

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<th>Figure Number</th>
</tr>
</thead>
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<tr>
<td>Control Positions in Trimmed Forward Flight</td>
<td>10 through 15</td>
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<tr>
<td>Collective-Fixed Static Longitudinal Stability</td>
<td>16 through 18</td>
</tr>
<tr>
<td>Collective-Fixed Static Lateral-Directional Stability</td>
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<td>22 through 25</td>
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<td>26 through 39</td>
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<td>49 through 51</td>
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<td>52 through 54</td>
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<tr>
<td>Airspeed System Calibration</td>
<td>55 and 56</td>
</tr>
</tbody>
</table>
FIGURE 1
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23953

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. BALL CENTERED TRIM CONDITION
3. MID LONGITUDINAL AND LATERAL CG
4. REFERRED ROTOR SPEED = 250 RPM
5. POINTS DERIVED FROM FIGURES 4 THRU 6
FIGURE 2
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23863

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. BALL CENTERED TRIM CONDITION
3. MID LONGITUDINAL AND LATERAL CG
4. REFERRED ROTOR SPEED = 250 RPM
5. POINTS DERIVED FROM FIGURES 4 THRU 6
FIGURE 3
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-2333

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. BALL CENTERED TRIM CONDITION
3. MID LONGITUDINAL AND LATERAL CG
4. REFERRED ROTOR SPEED = 250 RPM
5. POINTS DERIVED FROM FIGURES 4 THRU 6
FIGURE 4
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23953

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG C.G. LOCATION (FS)</th>
<th>AVG LAT (BL)</th>
<th>AVG DENSITY OUTSIDE (FEET)</th>
<th>AVG AIR TEMP. (DEG C)</th>
<th>AVG ROTOR SPEED (RPM)</th>
<th>AVG COEFFICIENT OF THRUST</th>
</tr>
</thead>
<tbody>
<tr>
<td>17720</td>
<td>350.4</td>
<td>0.2</td>
<td>7930</td>
<td>13.5</td>
<td>258.5</td>
<td>0.007968</td>
</tr>
</tbody>
</table>

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. BALL CENTERED TRIM CONDITION

CURVE DERIVED FROM Figs. 1 through 3
FIGURE 5
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23053

<table>
<thead>
<tr>
<th>AVG</th>
<th>C.G. LOCATION</th>
<th>AVG</th>
<th>DENSITY</th>
<th>AVG</th>
<th>REFERRED</th>
<th>AVG</th>
<th>COEFFICIENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROSS WEIGHT (LB)</td>
<td>C.G. LOCATION (FS)</td>
<td>GROSS LOCATION (BL)</td>
<td>ALTITUDE (FEET)</td>
<td>AIR TEMP. (DEG C)</td>
<td>ROTOR SPEED (RPM)</td>
<td>COEFFICIENT OF THRUST</td>
<td></td>
</tr>
<tr>
<td>17840</td>
<td>350.9</td>
<td>0.2</td>
<td>10870</td>
<td>8.5</td>
<td>257.6</td>
<td>0.009022</td>
<td></td>
</tr>
</tbody>
</table>

NOTES:
1. NORMAL UTILITY CONFIGURATION
2. BALL CENTERED TRIM CONDITION

SPECIFIC RANGE (M.I.T., AIR MILES/UB. FUEL)

ENGINE SHAFT HORSEPOWER

CURVE DERIVED FROM FIGS. 1 THROUGH 3

TRUE AIRSPEED (KNOTS)
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 64-23953

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG C.G. LOCATION LONG (FT)</th>
<th>AVG DENSITY (A.T.)</th>
<th>AVG ALTITUDE (FEET)</th>
<th>AVG OUTSIDE AIR TEMP. (DEG C)</th>
<th>AVG REFERRED ROTOR SPEED (RPM)</th>
<th>AVG COEFFICIENT OF THRUST</th>
</tr>
</thead>
<tbody>
<tr>
<td>17820</td>
<td>350.9</td>
<td>0.2</td>
<td>13250</td>
<td>0.5</td>
<td>257.2</td>
<td>0.010040</td>
</tr>
</tbody>
</table>

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. BALL CENTERED TRIM CONDITION
FIGURE 7
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23893

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG C.G. LOCATION (FS)</th>
<th>AVG DENSITY (BL) LATITUDE (FEET)</th>
<th>AVG OUTSIDE AIR TEMP. (DEG C)</th>
<th>AVG REFERRED ROTOR SPEED (RPM)</th>
<th>AVG COEFFICIENT OF THRUST</th>
</tr>
</thead>
<tbody>
<tr>
<td>20450</td>
<td>350.7</td>
<td>0.2</td>
<td>3010</td>
<td>12.0</td>
<td>258.2</td>
</tr>
</tbody>
</table>

NOTES:
1. VOLCANO CONFIGURATION
2. BALL CENTERED TRIM CONDITION

CURVE DERIVED FROM DASHED LINE
WITH AFE OBTAINED FROM FIG. 1 APP. D

DASHED LINE DERIVED FROM FIGS. 1 THRU 3
FIGURE 8
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23953

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG C.G. LOCATION LONG (FS)</th>
<th>AVG C.G. LOCATION LAT (BL)</th>
<th>AVG DENSITY (FEET)</th>
<th>AVG OUTSIDE AIR TEMP. (DEG C)</th>
<th>AVG REFERRED ROTOR SPEED (RPM)</th>
<th>AVG COEFFICIENT OF THRUST</th>
</tr>
</thead>
<tbody>
<tr>
<td>20500</td>
<td>350.7</td>
<td>0.2</td>
<td>6260</td>
<td>7.5</td>
<td>257.9</td>
<td>0.008988</td>
</tr>
</tbody>
</table>

NOTES:
1. VOLCANO CONFIGURATION
2. BALL CENTERED TRIM CONDITION

CURVE DERIVED FROM DASHED LINE
WITH ΔFO OBTAINED
FROM FIG. 1 APP. D

DASHED LINE DERIVED FROM FIGS. 1 THRU 3
FIGURE 9
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23953

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG C.G. LOCATION (FS)</th>
<th>AVG DENSITY (REF) (LBS/FT^3)</th>
<th>AVG OUTSIDE AIR TEMPERATURE (DEG C)</th>
<th>AVG REFERRED ROTOR SPEED (RPM)</th>
<th>AVG COEFFICIENT OF THRUST</th>
</tr>
</thead>
<tbody>
<tr>
<td>20650</td>
<td>351.2</td>
<td>0.2</td>
<td>9330</td>
<td>6.0</td>
<td>258.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.009996</td>
</tr>
</tbody>
</table>

NOTES:
1. VOLCANO CONFIGURATION
2. BALL CENTERED TRIM CONDITION

- SPECIFIC RANGE (MILES/HR: FUEL)
- TRUE AIRSPEED (KNOTS)
- ENGINE SHIP HORSEPOWER
- SIDESLIP ANGLE (DEG)

CURVE DERIVED FROM DASHED LINE WITH AFE OBTAINED FROM FIG. 1 APP. D
DASHED LINE DERIVED FROM FIGS. 1 THRU 3
FIGURE 10
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GROSS</td>
<td>SPEED</td>
<td>LONG</td>
<td>SPEED</td>
<td>LAT</td>
<td>ALTITUDE</td>
<td>OAT</td>
</tr>
<tr>
<td>(Lb)</td>
<td>(KTS)</td>
<td>(FT)</td>
<td>(FT)</td>
<td>(FT)</td>
<td>(Deg F)</td>
<td>(RPM)</td>
</tr>
<tr>
<td>17720 350.4 0.3 7930 13.5 258</td>
<td>.007906</td>
<td>NORMAL</td>
<td>UTILITY</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Sublave Pressure (psig)**
- **Sidewall Pressure (psig)**
- **Angle of Attack (Deg.)**
- **Pitch Attitude (Deg.)**
- **Collective Control Position (In.)**

**Total Collective Control Travel = 9.8 Inches**

**Total Directional Control Travel = 5.6 Inches**

**Total Lateral Control Travel = 9.7 Inches**

**Total Longitudinal Control Travel = 10.2 Inches**

---

**Figure Description:**
- The chart illustrates various control positions in trimmed forward flight.
- The data includes average values for various parameters such as gross weight, speed, and altitude.
- The chart shows trends for sublave pressure, sidewall pressure, angle of attack, and pitch attitude.
- The collective control position is measured in inches and its total travel is indicated.
- Other control positions such as directional and lateral are also shown with respective travel measurements.

---

**Calibrated Airspeed (Knots):**

<table>
<thead>
<tr>
<th>Knots</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>60</td>
</tr>
<tr>
<td>80</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>120</td>
</tr>
<tr>
<td>140</td>
</tr>
<tr>
<td>160</td>
</tr>
</tbody>
</table>

---

**Legend:**
- AVG: Average
- LONG: Longitudinal
- LAT: Lateral
- ALTITUDE: Altitude
- OAT: Outside Air Temperature
- ROTOR: Rotor Speed
- THROTTLE: Throttle Coefficient
- CONFIGURATION: Aircraft Configuration
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPART</td>
<td>LOCATION</td>
<td>LATITUDE</td>
<td>ALTITUDE</td>
<td>QTY</td>
<td>DENSITY</td>
</tr>
<tr>
<td>17840</td>
<td>350.91</td>
<td>0.32</td>
<td>10670</td>
<td>0.5</td>
<td>285</td>
</tr>
</tbody>
</table>

- NORMAL UTILITY

**Figure 11**

- **Total Collective Control Travel:** 0.8 inches
- **Total Directional Control Travel:** 5.6 inches
- **Total Lateral Control Travel:** 0.7 inches
- **Total Longitudinal Control Travel:** 10.3 inches

**Data Points:**
- COLLECTIVE ATTITUDE (IN.
- PITCH ATTITUDE (IN.
- YAW ATTITUDE (IN.
- TOTAL COLLECTIVE CONTROL TRAVEL = 0.8 INCHES
- TOTAL DIRECTIONAL CONTROL TRAVEL = 5.6 INCHES
- TOTAL LATERAL CONTROL TRAVEL = 0.7 INCHES
- TOTAL LONGITUDINAL CONTROL TRAVEL = 10.3 INCHES

**Calibrated Airspeed (KNOTS):**

- 20
- 40
- 60
- 80
- 100
- 120
- 140
- 160

**Figure Details:**
- Normal Utility
- Trimmed Forward Flight
- Control Positions

**Legend:**
- AVERAGE DEPART (FT)
- COLLECTIVE ATTITUDE (IN.
- PITCH ATTITUDE (IN.
- YAW ATTITUDE (IN.
- TOTAL COLLECTIVE CONTROL TRAVEL = 0.8 INCHES
- TOTAL DIRECTIONAL CONTROL TRAVEL = 5.6 INCHES
- TOTAL LATERAL CONTROL TRAVEL = 0.7 INCHES
- TOTAL LONGITUDINAL CONTROL TRAVEL = 10.3 INCHES

**Note:**
- Data and graphs related to control positions in trimmed forward flight.
- Utilitarian and technical data presented in a structured format.

**Technical Observations:**
- Analysis of control positions under various flight conditions.
- Quantitative measurement of control travel.
- Integration of graphical representation for clear understanding.

**Conclusion:**
- Comprehensive study of control positions for efficient flight operations.
- Importance of precise control in aircraft management.

**Further Reading:**
- Aircraft flight dynamics
- Control systems engineering
- Flight testing methodologies
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

FIGURE 12

UH-60A USA S/N 84-32983

<table>
<thead>
<tr>
<th>AVG WEIGHT (LD)</th>
<th>AVG LOCATION (PS)</th>
<th>AVG DEPTH (DL)</th>
<th>AVG ALTITUDE (FT)</th>
<th>AVG DAY</th>
<th>AVG SPOOL (RPM)</th>
<th>AVG THRUST</th>
<th>AIRCRAFT CONFIGURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>17620</td>
<td>390.9MID</td>
<td>0.36T</td>
<td>13200</td>
<td>0.5</td>
<td>251</td>
<td>.010040</td>
<td>NORMAL UTILITY</td>
</tr>
</tbody>
</table>

TOTAL COLLECTIVE CONTROL TRAVEL = 9.8 INCHES

TOTAL DIRECTIONAL CONTROL TRAVEL = 9.0 INCHES

TOTAL LATERAL CONTROL TRAVEL = 9.7 INCHES

TOTAL LONGITUDINAL CONTROL TRAVEL = 10.2 INCHES
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

<table>
<thead>
<tr>
<th>UH-60A USA S/N 84-23563</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVG GEARS DETENT (LB)</td>
</tr>
<tr>
<td>32000</td>
</tr>
<tr>
<td>350.7 FT</td>
</tr>
<tr>
<td>0.3 FT</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>0.3</td>
</tr>
<tr>
<td>VOLCRO</td>
</tr>
</tbody>
</table>

**Figure 13**

- **Total Collective Control Travel**: 10.6 inches
- **Total Directional Control Travel**: 6.6 inches
- **Total Lateral Control Travel**: 6.7 inches
- **Total Longitudinal Control Travel**: 10.2 inches
**CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT**

<table>
<thead>
<tr>
<th>Aircraft Configuration</th>
<th>Trimmed Condition</th>
<th>Average Collective Travel</th>
<th>Average Directional Travel</th>
<th>Average Lateral Travel</th>
<th>Average Longitudinal Travel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>9.8 inches</td>
<td>5.6 inches</td>
<td>9.7 inches</td>
<td>16.2 inches</td>
</tr>
</tbody>
</table>

**Graphs**

- **Control Position**
- **Slew Up, Down (cm)**
- **Angle of Attack (deg)**
- **Pitch Attitude (deg)**
- **Total Collective Control Travel**
- **Total Directional Control Travel**
- **Total Lateral Control Travel**
- **Total Longitudinal Control Travel**

**Legend**
- **LONG**: Longitudinal
- **LAT**: Lateral
- **ALT**: Altitude
- **AVG DCT**: Average Collective
- **AVG DS**: Average Directional
- **AVG LAT**: Average Lateral
- **AVG LSG**: Average Longitudinal
- **AVG SPEED**: Average Speed
- **AVG FUEL**: Average Fuel
- **AVG THR**: Average Thrust
- **AVG C/D**: Average Coeff.

**Legend for Graphs**
- **FL**: Forward
- **FL**: Forward
- **FL**: Forward
- **FL**: Forward
- **FL**: Forward
- **FL**: Forward
- **FL**: Forward
- **FL**: Forward
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

Figure 18

Control Positions in Trimmed Forward Flight

Average Weight (lbs)
Average Longitudinal Deflection (in)
Average Lateral Deflection (in)
Average Altitude (ft)
Average Density (slugs/ft³)
Average Gyr (g)
Average Rotor Speed (RPM)
Average Thrust Coefficient
Aircraft Configuration

<table>
<thead>
<tr>
<th>Average Weight (lbs)</th>
<th>Average Longitudinal Deflection (in)</th>
<th>Average Lateral Deflection (in)</th>
<th>Average Altitude (ft)</th>
<th>Average Density (slugs/ft³)</th>
<th>Average Gyr (g)</th>
<th>Average Rotor Speed (RPM)</th>
<th>Average Thrust Coefficient</th>
<th>Aircraft Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>281.2</td>
<td>0.201</td>
<td>0.336</td>
<td>0.0</td>
<td>254</td>
<td>0.0008</td>
<td>VOLCANO</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calibrated Airspeed (Knots)

Total Collective Control Travel = 8.6 Inches

Total Directional Control Travel = 5.6 Inches

Total Lateral Control Travel = 0.7 Inches

Total Longitudinal Control Travel = 10.2 Inches
FIGURE 16
COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY
UH-60A USA S/N 84-23953

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG CG LOCATION (FS)</th>
<th>AVG DENSITY LAT (BL)</th>
<th>AVG OAT (FT)</th>
<th>AVG ROTOR SPEED (DEG C)</th>
<th>AVG CALIBRATED SPEED (RPM)</th>
<th>AVG AIRSPEED (KTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
<td>20830</td>
<td>351.8 MID</td>
<td>0.3 LT</td>
<td>5000</td>
<td>14.0</td>
<td>258</td>
<td>81</td>
</tr>
<tr>
<td>○</td>
<td>20550</td>
<td>350.9 MID</td>
<td>0.3 LT</td>
<td>4970</td>
<td>14.0</td>
<td>258</td>
<td>118</td>
</tr>
</tbody>
</table>

NOTE:
1. VOLCANO CONFIGURATION
2. LEVEL FLIGHT
3. SHADED SYMBOLS DENOTE TRIM POINTS
4. BALL-CENTERED FLIGHT
5. PBA CENTERED AND LOCKED

TOTAL DIRECTIONAL CONTROL TRAVEL = 5.6 INCHES
TOTAL LATERAL CONTROL TRAVEL = 9.7 INCHES
TOTAL LONGITUDINAL CONTROL TRAVEL = 10.2 INCHES

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**Figure 17**

**Collective-Fixed Static Longitudinal Stability**

**UH-60A USA S/N 84-23953**

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG CG LOCATION (FS)</th>
<th>AVG DENSITY (BL)</th>
<th>AVG OAT (FT)</th>
<th>AVG ROTOR CALIBRATED ALTITUDE (DEG C)</th>
<th>AVG SPEED (RPM)</th>
<th>AVG AIRSPEED (KTS)</th>
<th>AVG TRIM</th>
<th>AVG AVT GROSS WEIGHT</th>
<th>AVG CG LOCATION (FS)</th>
<th>AVG DENSITY (BL)</th>
<th>AVG OAT (FT)</th>
<th>AVG ROTOR CALIBRATED ALTITUDE (DEG C)</th>
<th>AVG SPEED (RPM)</th>
<th>AVG AIRSPEED (KTS)</th>
<th>AVG TRIM</th>
<th>AVG AVT</th>
</tr>
</thead>
<tbody>
<tr>
<td>20700</td>
<td>351.4 MID</td>
<td>0.3</td>
<td>LT 5140</td>
<td>15.0</td>
<td>258</td>
<td>82</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:**
1. Volcano Configuration
2. IRP Climb
3. Shaded symbols denote trim point
4. Ball-centered flight
5. PBA centered and locked

---

**Graphs:**

1. **Stabilator Position (deg) vs. Time:**
   - Total directional control travel = 5.6 inches

2. **Pitch Attitude (deg) vs. Time:**
   - Total lateral control travel = 9.7 inches

3. **Lateral Control Position (in.) vs. Calibrated Airspeed (kts):**
   - Total longitudinal control travel = 10.2 inches

---

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FIGURE 18
COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY
UH-60A USA S/N 84-23953

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG CG LOCATION (FS)</th>
<th>AVG DENSITY (BL)</th>
<th>AVG ALTITUDE (FT)</th>
<th>AVG OAT (DEG C)</th>
<th>AVG ROTOR SPEED (RPM)</th>
<th>CALIBRATED AIRSPEED (KTS)</th>
<th>AVG TRIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>20850</td>
<td>351.2 MID</td>
<td>0.3 LT</td>
<td>4850</td>
<td>15.5</td>
<td>258</td>
<td>83</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: 1. VOLCANO CONFIGURATION
2. 1000 FT. PER MIN. DESCENT
3. SHADED SYMBOLS DENOTE TRIM POINT
4. BALL-CENTERED FLIGHT
5. PFA CENTERED AND LOCKED

TOTAL DIRECTIONAL CONTROL TRAVEL = 5.6 INCHES

TOTAL LATERAL CONTROL TRAVEL = 9.7 INCHES

TOTAL LONGITUDINAL CONTROL TRAVEL = 10.2 INCHES
FIGURE 19
STATIC LATERAL-DIRECTIONAL STABILITY
UH-60A USA S/N 84-23953

<table>
<thead>
<tr>
<th>Symbol</th>
<th>GROSS Weight (LB)</th>
<th>CG Long (FS)</th>
<th>AVG Long Location (FT)</th>
<th>AVG Lat Location (FT)</th>
<th>AVG Density (N)</th>
<th>AVG OAT (DEG C)</th>
<th>AVG Rotor Speed (RPM)</th>
<th>AVG Calibrated Airspeed (KTS)</th>
<th>AVG Trim (Deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>©</td>
<td>20780</td>
<td>351.7</td>
<td>0.3</td>
<td>5300</td>
<td>18.0</td>
<td>258</td>
<td>82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>©</td>
<td>20460</td>
<td>350.8</td>
<td>0.3</td>
<td>5100</td>
<td>18.0</td>
<td>257</td>
<td>110</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: 1. VOLCANO CONFIGURATION
2. LEVEL FLIGHT
3. SHADED SYMBOLS DENOTE TRIM POINTS
4. PBA CENTERED AND LOCKED

- TOTAL LONGITUDINAL CONTROL TRAVEL = 10.2 INCHES
- TOTAL LATERAL CONTROL TRAVEL = 9.7 INCHES
- TOTAL DIRECTIONAL CONTROL TRAVEL = 5.6 INCHES
### FIGURE 20

**STATIC LATERAL-DIRECTIONAL STABILITY**

**UH-60A USA S/N 84-23953**

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG DENSITY (FT)</th>
<th>AVG LAT ALTITUDE (BL) (FT)</th>
<th>AVG OAT (DEG C)</th>
<th>AVG ROTOR SPEED (RPM)</th>
<th>AVG CALIBRATED AIRSPEED (KTS)</th>
<th>TRIM (FS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20710</td>
<td>351.4</td>
<td>0.3</td>
<td>4880</td>
<td>16.5</td>
<td>258</td>
<td>83</td>
</tr>
</tbody>
</table>

**NOTE:**

1. VOLCANO CONFIGURATION
2. IMP CLIMB
3. SHADED SYMBOLS DENOTE TRIM POINTS
4. PBA CENTERED AND LOCKED

![Graph](image)

**TOTAL LONGITUDINAL CONTROL TRAVEL = 10.2 INCHES**

**TOTAL LATERAL CONTROL TRAVEL = 9.7 INCHES**

**TOTAL DIRECTIONAL CONTROL TRAVEL = 5.6 INCHES**
### Figure 21

**STATIC LATERAL-DIRECTIONAL STABILITY**

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG CG LOCATION (FT)</th>
<th>AVG DENSITY (PSI)</th>
<th>AVG OAT (DEG C)</th>
<th>AVG Rotor Speed (RPM)</th>
<th>AVG CALIBRATED SPEED (KTS)</th>
<th>TRIM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20000</td>
<td>351.3 MIO</td>
<td>0.3 LT</td>
<td>4890</td>
<td>10.0</td>
<td>258</td>
<td>83</td>
</tr>
</tbody>
</table>

**NOTE:**
1. VOLCANO CONFIGURATION
2. 1000 FT, PER MIN. DESCENT
3. SHADED SYMBOLS DENOTE TRIM POINTS
4. PDA CENTERED AND LOCKED

#### Stabilator Position

- Chart with data points and trends showing stabilator position changes.

#### Roll Angle vs. Altitude

- Chart showing roll angle changes with altitude, with data points and trends.

#### Total Longitudinal Control Travel

- Chart depicting total longitudinal control travel with a measurement of 10.2 inches.

#### Total Lateral Control Travel

- Chart showing total lateral control travel with a measurement of 9.7 inches.

#### Total Directional Control Travel

- Chart illustrating total directional control travel with a measurement of 5.6 inches.

<table>
<thead>
<tr>
<th>Angle of Sideslip (Degrees)</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Right</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>
MANEUVERING STABILITY
SYMmetrical Pushovers and Pullups

Note: 1. Volcano Configuration
      2. PBA Centered and Locked

TOTAL LATERAL CONTROL TRAVEL = 9.7 INCHES
TOTAL LONGITUDINAL CONTROL TRAVEL = 10.2 INCHES

Normal Acceleration (g)
MANEUVERING STABILITY
SYMMETRICAL PUSHOVERS AND PULLUPS

UN-60A USA S/N 84-2353

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>GROSS WEIGHT (LB)</th>
<th>COG LOCATION (FS)</th>
<th>AVG L/G (BL) (FT)</th>
<th>AVG DENSITY (DEG C)</th>
<th>AVG OAT</th>
<th>AVG RPM</th>
<th>CALIBRATED CONDITION</th>
<th>TAS (KTS)</th>
<th>S/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>23000</td>
<td>350.550</td>
<td>0.3 LT</td>
<td>2430</td>
<td>12.5</td>
<td>320</td>
<td>100</td>
<td>100</td>
<td>84</td>
</tr>
<tr>
<td>O</td>
<td>26700</td>
<td>350.550</td>
<td>0.3 LT</td>
<td>5000</td>
<td>14.5</td>
<td>320</td>
<td>100</td>
<td>100</td>
<td>84</td>
</tr>
</tbody>
</table>

NOTE:
1. VOLCANO CONFIGURATION
2. PTA CENTERED AND LOCKED

TOTAL LATERAL CONTROL TRAVEL = 9.7 INCHES
TOTAL LONGITUDINAL CONTROL TRAVEL = 10.2 INCHES
FIGURE 24
MANEUVERING STABILITY
UH-60A USA S/N 84-23953

<table>
<thead>
<tr>
<th>SYM</th>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG LONG LOCATION (FT)</th>
<th>AVG LAT LOCATION (FT)</th>
<th>AVG DENSITY (LS)</th>
<th>AVG OAT (DEG C)</th>
<th>AVG ROTOR SPEED (RPM)</th>
<th>AVG CALIBRATED FLIGHT CONDITION AIRSPEED (KTS)</th>
<th>AVG TRIM</th>
<th>SAS TRIM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20970 350.5 MID 0.3 LT 7650 11.5 258 40 RIGHT TURN ON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>20940 350.5 MID 0.3 LT 7660 11.5 258 42 LEFT TURN ON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>20900 350.5 MID 0.3 LT 6650 11.5 258 40 RIGHT TURN OFF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>20850 350.5 MID 0.3 LT 6400 12.0 258 41 LEFT TURN OFF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: 1. VOLCANO CONFIGURATION  
2. SHADED SYMBOLS DENOTE TRIM POINT  
3. PBA CENTERED AND LOCKED

TOTAL LATERAL CONTROL TRAVEL = 9.7 INCHES

TOTAL LONGITUDINAL CONTROL TRAVEL = 10.2 INCHES
FIGURE 25
MANEUVERING STABILITY
UH-60A USA S/N 84-23953

<table>
<thead>
<tr>
<th>SYM</th>
<th>GROSS WEIGHT (LB)</th>
<th>AVG CG LOCATION (FT)</th>
<th>AVG DENSITY (DEG C)</th>
<th>OAT (°F)</th>
<th>AVG ROTOR SPEED (RPM)</th>
<th>CALIBRATED FLIGHT CONDITION</th>
<th>SAS</th>
<th>TRIM</th>
<th>TRIM</th>
<th>TRIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
<td>20910</td>
<td>350.7 MID</td>
<td>0.3 LT</td>
<td>7100</td>
<td>11.0</td>
<td>259</td>
<td>101</td>
<td>LEFT TURN ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>▲</td>
<td>20740</td>
<td>350.2 MID</td>
<td>0.3 LT</td>
<td>7050</td>
<td>11.5</td>
<td>257</td>
<td>102</td>
<td>LEFT TURN ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>○</td>
<td>20480</td>
<td>349.9 MID</td>
<td>0.3 LT</td>
<td>7900</td>
<td>10.0</td>
<td>259</td>
<td>102</td>
<td>RIGHT TURN OFF</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LEFT TURN OFF</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE:
1. VOLCANO CONFIGURATION
2. SHADED SYMBOLS DENOTE TRIM POINT
3. PBA CENTERED AND LOCKED

TOTAL LATERAL CONTROL TRAVEL = 9.7 INCHES
TOTAL LONGITUDINAL CONTROL TRAVEL = 10.2 INCHES

NORMAL ACCELERATION (g)

65
FIGURE 28
RIGHT DIRECTIONAL PULSE
UN-08A USA 5/N 84-22953

NOTE: 1. XI-150 TOLCAMS SYSTEM INSTALLED (FULL CANISTERS)
   2. MLA CENTERED AND LOCKED
   3. LEVEL FLIGHT

TIME - SEC.
LONGITUDINAL CONTROLLABILITY

UH-60A USA S/N 84-23953

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GROSS WEIGHT</td>
<td>CG LOCATION</td>
<td>DENSITY</td>
<td>OAT</td>
<td>ROTOR CALIBRATED SPEED</td>
<td>AIRSPEED</td>
</tr>
<tr>
<td>(LB)</td>
<td>(FS)</td>
<td>(BL)</td>
<td>(FT)</td>
<td>(DEG C)</td>
<td>(RPM)</td>
</tr>
<tr>
<td>20580</td>
<td>351.9 MID</td>
<td>0.3 LT</td>
<td>-180</td>
<td>15.0</td>
<td>259</td>
</tr>
</tbody>
</table>

NOTE: 1. XM-139 VOLCANO SYSTEM INSTALLED (FULL CANISTERS)
2. 50 FT WHEEL HEIGHT

TIME TO MAX PITCH ACCEL (SEC)

MAXIMUM PITCH ACCEL (DEG/SEC^2)

TIME TO 0.83 PITCH ATTACH AFTER ONE SECOND (SEC)

MAX PITCH RATE (DEG/SEC)

MAXIMUM PITCH RATE (DEG/SEC)

LONGITUDINAL CONTROL DISPLACEMENT FROM TRIM (INCHES)
FIGURE 43
LATERAL CONTROLLABILITY
UH-60A USA S/N 84-23953

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG CG LOCATION (FS)</th>
<th>AVG DENSITY (BL) (FT)</th>
<th>AVG ALTITUDE (FT)</th>
<th>AVG OAT (DEG C)</th>
<th>AVG ROTOR SPEED (RPM)</th>
<th>TRIM CALIBRATED AIRSPEED (KTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20390</td>
<td>350.5 MID</td>
<td>0.3 LT</td>
<td>-150</td>
<td>15.5</td>
<td>259</td>
<td>000</td>
</tr>
</tbody>
</table>

NOTE:
1. XM-139 VOLCANO SYSTEM INSTALLED (FULL CANISTERS)
2. 50 FT WHEEL HEIGHT
### Figure 44: Left Lateral Step

**UH-60A USA 5/N 04-23953**

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT</th>
<th>AVG CG LOCATION</th>
<th>AVG DENSITY</th>
<th>AVG OAT</th>
<th>AVG Rotor Speed</th>
<th>AVG AIRSPEED</th>
</tr>
</thead>
<tbody>
<tr>
<td>20340</td>
<td>350.1 MID</td>
<td>0.5 LT</td>
<td>-140</td>
<td>15.3</td>
<td>250</td>
</tr>
</tbody>
</table>

**Note:**
1. XM-139 Volcano system installed (full canisters)
2. 50 ft wheel height

### Graphs:

- **Pitch Rate (deg/sec)**
  - Rotor Rate (deg/sec)
  - Roll Rate (deg/sec)
  - Rudder Ped Pos-Inch
  - Lat Stick Pos-Inch
  - Long Stick Pos-Inch

**Graph Details:**

- **Axes:**
  - Time (sec)
  - RPM

- **Legend:**
  - Solid Line
  - Long Dash
  - Short Dash
  - Dotted Line

**Data Points:**

- RPM: 262, 258, 256, 254
- Pitch Rate: 20, 10, 0, -10
- Roll Rate: 20, 10, 0, -10
- Rudder Ped Pos: 5, 4, 3, 2, 1
- Lat Stick Pos: 6, 5, 4, 3
- Long Stick Pos: 7, 6, 5, 4
Figures 48
RIGHT LATERAL STEP
UN-60A USA S/N 84-23653

<table>
<thead>
<tr>
<th>AVG</th>
<th>AVG</th>
<th>AVG</th>
<th>AVG</th>
<th>TRIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>OIL</td>
<td>CG LOCATION</td>
<td>DENSITY</td>
<td>ALTITUDE</td>
<td>SPINDLE</td>
</tr>
<tr>
<td>(LO)</td>
<td>(FS)</td>
<td>(DL)</td>
<td>(FT)</td>
<td>(DEG C)</td>
</tr>
<tr>
<td>28340</td>
<td>358.1 UID</td>
<td>0.3 LT</td>
<td>-140</td>
<td>15.3</td>
</tr>
</tbody>
</table>

SHORT DASH LONG DASH SOLID LINE NOTE: 1. XM-139 VOLCANO SYSTEM INSTALLED (FULL CANISTERS)
2. 50 FT WHEEL WEIGTH

- Time - Sec.
- RPM
- Pitch Rate - Deg/Sec
- Roll Rate - Deg/Sec
- Pitch RT - Deg
- Roll RT - Deg
- Long Stick Pos - Inch
- Lat Stick Pos - Inch
### Figure 46
**Directional Controllability**

<table>
<thead>
<tr>
<th>AVG Gross Weight (LB)</th>
<th>AVG CG Location (FT)</th>
<th>AVG Density (BL)</th>
<th>AVG OAT (°C)</th>
<th>AVG Rotor Speed (RPM)</th>
<th>AVG Calibrated Airspeed (KTS)</th>
<th>TRIM (L.11)</th>
<th>(FS)</th>
<th>(IL11)</th>
<th>(FT)</th>
<th>(Dec C)</th>
<th>(RPM)</th>
<th>(KTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20100</td>
<td>349.0 MID</td>
<td>0.3 LT</td>
<td>-140</td>
<td>15.5</td>
<td>250</td>
<td>000</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**NOTE:**
1. XM-130 VOLCANO SYSTEM INSTALLED (FULL CANISTERS)
2. 50 FT WHEEL HEIGHT
Figure 49
LOW SPEED FORWAD AND REARWARD FLIGHT CHARACTERISTICS
UH-60A USA 9/91 8/9-8399

<table>
<thead>
<tr>
<th>STABILIZER</th>
<th>WEIHT (US)</th>
<th>LOAD (FL)</th>
<th>ALTITUDE (FT)</th>
<th>SPEED (KNOTS)</th>
<th>DISTANCE (FT)</th>
<th>CONFIGURATION</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

NOTE: 1. VERTICAL LINES DENOTE CONTROL EXCURSIONS
2. MACH CENTERED AND LOCKED
FIGURE 99
LOW SPEED RIGHT AND LEFT SIDEWARD FLIGHT CHARACTERISTICS
UH-60A USA 91-04-5548

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>WEIGHT (LB)</th>
<th>AGE LOCATION</th>
<th>ALTITUDE (FT)</th>
<th>GROSS WT (LBS)</th>
<th>OIL (QTS)</th>
<th>A/C</th>
<th>NOTES</th>
<th>FLIGHT CONFIGURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>3312</td>
<td>282:7118</td>
<td>8.2 L t -30</td>
<td>10.3</td>
<td>916</td>
<td>33</td>
<td>VOLTAGE</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: 1. VERTICAL LINES DENOTE CONTROL EXCURSIONS
2. PNE CENTERED AND LOCKED
SIMULATED SINGLE ENGINE FAILURE

AVG WEIGHT (lb) 20820
CG LOCATION 549.7 MID
LAT (FL) 0.3 FT
AVG DENSITY ALTITUDE (ft) 5200
AVG OAT (°F) 15.0
AVG REAR SPEED (RPM) 250
TRIM CALIBRATED AIRSPEED (KIAS) 110
SAS CONDITION ON
AIRCRAFT CONFIGURATION VOLCANO
FLIGHT CONDITION LEVEL

SHORT DASH
LONG DASH
SOLID LINE

CALL STRK POS-INCH
UP 105
DN 65

MAIN MOTOR SPEED - Z
100
95
90
85
80

NO1 ENG 0 - Z
120
60
30
0
-30
-60
-90
-120

NO2 ENG 0 - Z
120
60
30
0
-30
-60
-90
-120

S/TBL ANGLE - DEG
10
0
-10
-20
-30
-40

PITCH RTT-DEG
30
10
0
-10
-20

ROLL RTT-DEG PR T/K
20
10
0
-10
-20

N. UP
20
10
0
-10
-20

N. ON
-20
-10
0
10
20

SAND RTT-DEG PR T/K
20
10
0
-10
-20

N. RT
-10
-20
-30
-40
-50
-60

L. RT
-10
-20
-30
-40
-50
-60

SAND STRK POS-INCH
7
6
5
4
3

L. STRK POS-INCH
7
6
5
4
3

RUD PED POS-INCH
9
8
7
6
5
4
3
2
1
0

0 2 4 6 8 10 12 14 16 18 20
TIME - SEC.

93
FIGURE 84
SIMULATED SINGLE ENGINE FAILURE
UH-60A USAF 86-23960

<table>
<thead>
<tr>
<th>AFT</th>
<th>COG</th>
<th>C/A Location</th>
<th>LAT (UL)</th>
<th>AFT</th>
<th>Gt</th>
<th>AFT</th>
<th>THRU</th>
<th>CALM</th>
<th>ALTITUDE</th>
<th>SAT</th>
<th>AIRCRAFT CONFIGURATION</th>
<th>FLIGHT CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td></td>
<td>VOLC</td>
<td>NLP CLIM...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Graphs:**
- **Main Motor Speed:** 0 to 105
- **N1 Eng 0 - z:** 0 to 120
- **N2 Eng 0 - z:** 0 to 120
- **Roll Att-SEG:**
  - 0 to 20
  - -20
- **Pitch Att-SEG:**
  - 0 to 10
  - -10
- **Long Stb Pos-Inch:**
  - 0 to 9
  - 0
- **Lat Stb Pos-Inch:**
  - 0 to 9
  - 0
- **Aft Pos-Inch:**
  - 0 to 9
  - 0

**Time - Sec.:**
0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20

94
**Figure 55**

**Ship Airspeed Calibration**

**UH-60A USA S/N 84-23953**

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>15270</td>
<td>350.6</td>
<td>0.2</td>
<td>3350</td>
<td>13.5</td>
<td>Trailing Bomb</td>
</tr>
<tr>
<td>A</td>
<td>18600</td>
<td>350.6</td>
<td>0.2</td>
<td>6200</td>
<td>17.5</td>
<td>Trailing Bomb</td>
</tr>
<tr>
<td>□</td>
<td>17500</td>
<td>350.0</td>
<td>0.2</td>
<td>-10</td>
<td>16.0</td>
<td>Ground Speed Crse</td>
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</tbody>
</table>

**Notes:**
1. Normal Utility Configuration
2. Level Flight
3. Ball Centered Trim Condition
4. Main Rotor Speed = 258 RPM

**Polygonal Curve Fit**

\[ V_{CAL} = + 9.82068 + 0.94078 \times V_{IC} - 0.00007925 \times V_{IC}^2 + 0.0000057962 \times V_{IC}^3 \]
FIGURE 56
SHIP AIRSPEED CALIBRATION
UH-60A USA S/N 84-23953

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG C.G. LOCATION LONG (FS)</th>
<th>AVG DENSITY (AVG)</th>
<th>AVG OUTSIDE AIR TEMP. (DEG C)</th>
<th>TEST METHOD</th>
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<tbody>
<tr>
<td>20570</td>
<td>350.8</td>
<td>0.2</td>
<td>5200</td>
<td>TRAILING BOMB</td>
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NOTES: 1. VOLCANO CONFIGURATION
2. LEVEL FLIGHT
3. BALL CENTERED TRIM CONDITION
4. MAIN ROTOR SPEED=258 RPM

POLYNOMIAL CURVE FIT

\[ V_{CAL} = +3.13191 + 1.38065 \times V_{IC} - 0.0074085 \times V_{IC}^2 + 0.00003968 \times V_{IC}^3 \]
## APPENDIX F. PHOTOGRAPHS

<table>
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<tr>
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<td>Test Aircraft</td>
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<tr>
<td>VOLCANO Mounting Hardware</td>
<td>5 through 7</td>
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<tr>
<td>Fixed Provision Mounting Points</td>
<td>8 and 9</td>
</tr>
<tr>
<td>VOLCANO Launcher Racks</td>
<td>10 and 11</td>
</tr>
<tr>
<td>Launcher Racks with Canisters</td>
<td>12 and 13</td>
</tr>
<tr>
<td>Test Aircraft with VOLCANO Installed</td>
<td>14 and 15</td>
</tr>
<tr>
<td>Interface Control Panel</td>
<td>16</td>
</tr>
<tr>
<td>Ballast Locations</td>
<td>17 through 19</td>
</tr>
<tr>
<td>Instrumentation Package</td>
<td>20 and 21</td>
</tr>
<tr>
<td>External Modifications</td>
<td>22 through 25</td>
</tr>
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</table>
Photo 1. Front View, UH-60A Helicopter with XM-139 VOLCANO System Installed

Photo 2. Rear View, UH-60A Helicopter with XM-139 VOLCANO System Installed
Photo 3. Right Quarter View, UH-60A Helicopter with XM-139 VOLCANO System Installed

Photo 4. Left Side View, UH-60A Helicopter with XM-139 VOLCANO System Installed
Photo 5. Side View, VOLCANO Side Panel Installed
Photo 6. VOLCANO Side Panel Installed on Fixed Provision Mounting Points (Drag Strut in Stowed Position)
Photo 9. Fixed Provision Mounting Points with Fairings Removed

Photo 8. Fixed Provision Fairings Installed

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Photo 12. VOLCANO Launcher Racks During Installation of XM-88 (Practice) Mine Canisters

Photo 13. VOLCANO Launcher Racks Filled with XM-88 (Practice) Mine Canisters
Photo 14. Front View, VOLCANO Side Panel, Launcher Racks, and XM-88 (Practice) Mine Canisters Installed

Photo 15. Side View, VOLCANO Side Panel, Launcher Racks, and XM-88 (Practice) Mine Canisters Installed
Photo 16. VOLCANO Interface Control Panel Installed in Cockpit Center Console (Forward Left Corner Location)
Photo 17. Nose-Bay Ballast Mounting Location

Photo 18. Floor Mounted Ballast Location Aft of Pilot Seats
Photo 20. Right View of Test Instrumentation Installation

Photo 21. Left View of Test Instrumentation Installation
Photo 22. Boom System Installation and Nose-Mounted Temperature Probe
Photo 23. Main Rotor Instrumentation and Slip Ring Installation

Photo 24. Tail Rotor Instrumentation and Slip Ring Installation
Photo 25. Emergency Crew Door Handles
# DISTRIBUTION

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  Aeroflightdynamics Directorate (SAVRT-AF-D)
US Army Aviation Research and Technology Activity (AVSCOM)
  Propulsion Directorate (SAVRT-PN-D)
Defense Technical Information Center (FDAC)
US Military Academy, Department of Mechanics
  (Aero Group Director)
ASD/AFXT, ASD/ENF
US Army Aviation Development Test Activity (STEBG-CT)
Assistant Technical Director for Projects, Code: CT-24
  (Mr. Joseph Dunn)
6520 Test Group (ENML)
Commander, Naval Air Systems Command (AIR 5115B, AIR 5301)
Defense Intelligence Agency (DIA-DT-2D)
Headquarters United States Army Aviation Center and
  Fort Rucker (ATZQ-ESO-L)
US Army Aviation Systems Command (AMSAV-EA)
US Army Aviation Systems Command (AMSAV-EC)
US Army Aviation Systems Command (AMSAV-EF)
US Army Aviation Systems Command (AMCPM-BH-T)
Project Manager, Mines, Countermines, and Demolitions
  (AMCPM-MCD)