Operational Noise Data for CH-47D and AH-64 Army Helicopters

by

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The objectives of this study were to develop sound exposure level (SEL) versus distance curves for flight operations and time-average sound level (LEQ) contours versus distance for static operations for two new Army aircraft. Sound levels produced by the helicopters were measured for the aircraft both hovering and traveling at various speeds. The CH-47D was operated in both a heavily and a lightly loaded configuration; the heavy load was achieved by sling-loading a 10-ton Army truck.

The data show that the aircraft are quieter than the types they are replacing; the CH-47C and the AH-1G. Except at the highest speeds, sound variation with speed is not a large factor. In terms of sound variation with load, the CH-47D actually made less sound during level flight at full load than it did lightly loaded, although the sound did increase with load during takeoff and landing. As with other aircraft, the CH-47D makes more sound during landing than it does during level flight or takeoff, but the sound levels for the AH 64 are virtually independent of operation.

Only two of each aircraft were supplied. Both types of aircraft exhibited sound levels which were a little higher than expected, and more aircraft would have enhanced the statistical reliability of the data. In the future, a minimum of four aircraft of any type should be supplied. They should be measured in two groups of two, separated by at least 1 month in time to better insure the statistical reliability of the data.

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FOREWORD

This work was performed for the U.S. Army Materiel Command (AMC), Aviation
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COL Norman C. Hintz is Commander and Director of USA-CERL, and Dr. L. R.
Shaffer is Technical Director.
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1 INTRODUCTION

Background

In recent years, residential development has occurred near military and civilian airfields—areas subject to high noise levels from aircraft and airfield operations. To control this development, the U.S. Army has instituted the Installation Compatible Use Zone (ICUZ) Program. Like the Department of Defense's (DOD) Construction Criteria manual and Air Installations Compatible Use Zone program (AICUZ), the ICUZ program defines land uses compatible with various noise levels and establishes a policy for achieving such uses. Each document describes three noise zones which restrict land use in varying degrees to ensure compatibility with military operations. The ICUZ program stresses Army-unique noise sources such as blasts (e.g., artillery, armor, demolition) and rotary-wing aircraft.

Noise zone maps for the ICUZ program are developed by the Army Environmental Hygiene Agency (AEHA) using U.S. Army Construction Engineering Research Laboratory's (USA-CERL's) integrated noise contour system (INCS). This system can produce integrated noise zone maps for blast noise and fixed- and rotary-wing aircraft operations. Noise zone maps are produced using the USA-CERL-developed BNOISE-3.2 computerized prediction procedures; helicopter noise zone maps are developed using a USA-CERL-modified Air Force (AF) NOISEMAP Computer Prediction Program. Each of these computerized prediction procedures relies on three separate data sources: (1) source emissions data, (2) data detailing sound propagation from source to receiver, and (3) data defining the human and community response to the received noise.

Previous USA-CERL research has addressed these sets of data for then current rotary-wing aircraft and for blast noise prediction. In particular, USA-CERL Technical Report N-38 defines the noise emission characteristics for rotary-wing aircraft operating in the Army fleet during the late 1970s and USA-CERL Technical Report N-131 defines the noise emissions of the CH-47C and the UH-60A from testing conducted at Forts
Rucker and Campbell. Since then, the new CH-47D and AH-64 helicopters have been introduced; their emissions data are required by the Army for ICUZ and for environmental assessment.

USA-CERL Technical Report N-184 studied repeatability of rotary-wing aircraft source emissions and concluded with recommendations for statistical validity and a slightly revised microphone layout.

Objectives

The objectives of this study were to develop (1) sound exposure level (SEL) versus distance curves for flight operations and (2) time-average sound level (LEQ) contours versus distance for static operations for two new Army aircraft; the CH-47D and the AH-64.

Approach

In the past, helicopter noise emissions were measured by going to locations where the aircraft were based. The measurements require a flat, open field (650 ft radius) with no extraneous noise. Because this method of obtaining measurements presented a significant coordination problem and travel expense, it was decided to permanently install microphone positions, equipment housing, a grass landing pad, and weather sensing equipment for testing at the Bondville Field Station of the University of Illinois. Measurements for the CH-47D and AH-64 were performed at this site in accordance with the recommendation set forth in USA-CERL Technical Report N-184.

Mode of Technology Transfer

Data developed for helicopter SEL versus distance or speed and static operations LEQ versus distance will be entered in the INCS data base and will be immediately available for use by AEHA and other DOD organizations.

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2 DATA COLLECTION

Helicopter Operations

At Fort Rucker, one set of data had been based on the dynamic operations listed in Table 1.* Forty helicopters took part in that study; each aircraft flew the series of operations twice: once with the pilot and once with the copilot. Table 2 lists the aircraft types and loading conditions employed. The Fort Rucker study indicated that level flyover data adequately characterized the noise emissions of all other dynamic operations except landings. Therefore, for the study at Fort Campbell and this new study, concern centered only on level flyovers, landings, and static operations. Takeoffs are also measured separately since a takeoff must precede each landing.

At Forts Rucker and Campbell, cargo and utility aircraft were flown lightly loaded and fully loaded. Table 3 lists the operations performed by the helicopters at Fort Campbell. At both forts, the aircraft began by flying level flyovers at 300 ft above ground level (AGL). In the middle of the test, they performed static operations, and then resumed level flyovers. Four aircraft of each type were requested; each with a different crew.

For testing at the Bondville site, USA-CERL researchers requested four CH-47D and four AH-64 aircraft; only two of each could be obtained. Each CH-47D was flown twice fully loaded and twice partially loaded. Each condition was flown by the pilot and the copilot. To load the CH-47D, its sling was used to carry a 10-ton Army truck. The AH-64 were flown only with a fuel load and only twice each: once by the pilot and once by the copilot. Table 4 lists the operations performed at these tests.

The level flyovers were flown similarly to those at Forts Rucker and Campbell. The pilots were instructed to maintain straight, level, steady flight for at least 1.5 nautical miles before and after each dynamic operation. All teardrop turns, other ancillary maneuvers, and preparations for actual dynamic operation were performed beyond 1.5 nautical miles. Flying this distance allowed the pilot to stabilize the aircraft and provided enough time for 10-decibel (dB) down-sound-level points to be recorded on magnetic tape when the operation was flown at 300 ft AGL. Figure 1 illustrates the level flyover flight path. Landings began at 300 ft AGL on a ground track of 180 or 360 degrees and terminated at the center of the microphone array (Figure 2).

Static operations consisted of 0-pitch engine idle, in-ground and out-of-ground effect hovers. These measurements were performed over a grassy area in the center of the array (Figure 2). In-ground effect hovers were performed with the aircraft at a stabilized position between 0 and 5 ft above the ground. Out-of-ground hovers were performed at an altitude of 1 1/2 rotor diameters.

The pilots logged information about each operation flown. Typical entries from a pilot's log are shown in Appendix A.

*Tables and figures appear at the end of this report, beginning on p 15.
Microphone Placement

Figure 2 shows the layout for six microphones. With this arrangement, any flight alignment from Figure 1 (18-36, 6-24, 12-30) can be used depending on winds. The remaining four microphones are the sideline microphones. Landings and takeoffs are to the center of the array and static operations are performed at the array center. With operations at 300 ft AGL, the sideline microphones are 433 ft to the side, the slant distance (distance of the aircraft's closest approach to the microphone) is 527 ft.

Measurement Instrumentation

As at Fort Campbell, the acoustical instrumentation consisted of six B&K 4149 quartz-coated microphones on B&K 4921 outdoor microphone systems with silk wind-screens. Each microphone channel was recorded on a Nagra SJ channel (A.M.; 7-1/2 inches per second [ips], 60 dB dynamic range) and analyzed in the field for overall A-weighted SEL using a USA-CERL True Integrating Noise Meter. The six microphones were wired underground to the mobile Acoustics Field Laboratory.

Ground Tracking System

The tracking system used at Forts Campbell and Rucker consisted of two cameras and a theodolite to mark the position of an aircraft flying over the middle of the microphone array. At the Bondville Field Station, three cameras were used as shown in Figures 2 and 3. Stator poles in front of the camera positions were marked with uniform graduations. By examining photographs from those cameras, one could ascertain position information in three dimensions at the moment the pictures for the 300-ft-AGL test were taken. The theodolite used in earlier tests, was not needed since these modern aircraft with their radar altimeters are always close to the correct altitude.

Calibration

At the beginning of each reel of tape, the 1000-Hz electrostatic actuator built into the 4921 microphone systems was used to set a known level on the tape. The electrostatic actuators were tested with B&K 4220, 124-dB pistonphones before and after the entire measurement program. (Calibration of the electrostatic actuator with the B&K 4220 allows one to establish an absolute calibration value for each actuator.) Calibration was checked at the end of each measurement period.
3 DATA REDUCTION AND ANALYSIS

Camera Data

The graduated stator rod in the foreground of each photograph allowed calculation of altitude and lateral variation over the center of the flight track because the camera angle, distance to the stator rod, and distance between graduations on the stator rod were known (Figure 3).

Negatives of each helicopter were projected on the screen of a microfiche reader; measurements were taken in relation to the stator rod, and data were encoded into a microcomputer for further calculation and analysis. Given the information supplied by the pictures, algorithms were written that located the helicopter in three dimensions at the time the cameras were activated. The slant distance to each of the six microphones in the array was calculated based on the position of the helicopter in space and its forward speed.

Acoustical Data Reduction

A B&K 2131 Digital Frequency Analyzer or a Larson Davis 3100 Real Time Analyzer (LD) interfaced to a Hewlett Packard (HP) 9816 computer was used for data reduction. The procedure for the analysis system was as follows. When a helicopter was first detected, the analysis equipment was started. After the helicopter being analyzed was no longer detectable, analysis stopped. The full one-third octave spectrum for each microphone for each 0.5 sec (with a "slow" time response) was stored in the HP computer or the LD analyzer depending on the analyzer used.

The problem of different types of noise being present is inherent in any analysis procedure. However, noise from different sources only becomes significant when it approaches the signal level. The sources of noise include: (1) background acoustical, (2) electrical, and (3) recording tape. In this study, three respective methods were used to determine the combined noise level.

For the first type of noise--ambient noise--a recording was made either immediately before or after the helicopter arrived or departed the area. This reading reflected wind, vehicles, birds, and other environmental sounds that occurred during the tests.

Electrical noise--the noise of the system that is constant at different gain settings--was measured by attaching a dummy microphone to the input amplifier at a microphone station and measuring the resultant level on playback from tape.

The third noise--tape noise--was measured by shorting the input to one channel and recording. On playback, the level was measured.

These three noise measurements were summed to calculate a composite noise level (CNL). This was developed in one-third octaves for each gain setting used. This "correcting" CNL was compared to the resultant one-third octave spectra for each 0.5 sec. One-third octave bands in any 0.5-sec interval were flagged if their level came within 10 dB of the corresponding CNL value. If the difference was 3 dB or more, the one-third octave band was "corrected" on an energy basis; otherwise it was deleted. For all noise readings taken, gain settings throughout the system were held the same as they were when the helicopter data were recorded, or the changes were noted and accounted for.
Acoustical Data Analysis

The final data were developed in four steps. First, the 0.5-sec time interval having the maximum A-weighted value (slow) was determined, and the entire one-third octave spectrum for this 0.5-sec interval was stored as a separate record. Second, the A-weighted SEL was calculated for the time-interval during which the A-weighted level sound was within 10 dB of the maximum level (determined in first step). Third, from the positional information on the photographs, the closest approach of the aircraft to each microphone for each individual flyover was determined. Finally, the maximum spectrum and distance of closest approach were used to convert the raw field-measured SEL (A-weighted) to an equivalent SEL for a day with a standard temperature of 15 °C (59 °F) and relative humidity of 70 percent.

During this final step, A-weighted SEL versus distance relations were established. Distance causes three factors to vary: air absorption (the one-third octave spectrum was used to determine the effect of air absorption), the $1/r^2$ amplitude change of a point acoustical source, and the apparent durational change of a source moving in a straight line at various constant speeds. Appendix A of USA-CERL Technical Report N-38 contains a detailed description of this analysis procedure, which is structured after the AF procedure that was developed to reduce similar fixed-wing aircraft acoustical data. As with current practice of the Federal Aviation Administration (FAA) and AF, the durational factor is constrained to also account for excess ground attenuation. So SEL versus distance curves include air absorption and a $-13 \log d/d_0$ term which accounts for distance, duration and excess absorption where: (1) $1/r^2$ is proportional to $-20 \log d/d_0$, (2) duration is proportional $+10 \log d/d_0$, and (3) excess attenuation is proportional to $-3 \log d/d_0$.

Static Operations Acoustical Data Analysis

Hover and engine idle data were analyzed by finding the time-average one-third octave spectra at each microphone. These were energy-averaged and time-average sound level (LEQ) versus distance data developed using detailed propagation models for ground-to-ground sound propagation.

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4 RESULTS

Sound Exposure Level Versus Distance

Figures 4, 5, and 6 illustrate the developed SEL versus distance curves for level flyovers at a speed of 130 knots (300 ft AGL), landings, and takeoffs respectively for the CH-47D; 130 knots is reported since this is the typical cruise speed of the CH-47D and the AH-64. For the heavily loaded "landing," the CH-47D actually brought the sling-loaded truck to the landing pad and hovered with the truck resting on the ground. As with the earlier CH-47 data, a landing creates substantially more noise than does a level flyover at all but the highest speed.

The noise from the heavily loaded aircraft (44,000 versus 31,000 lbs) should have been about 1.5 dB louder. However, the change in weight results in a change in center-of-gravity and cyclic trim. This apparently reduces the blade-vortex interaction noise such that the loaded aircraft is actually quieter during level flyover, although it is noisier during takeoff or landing.

Figure 7 illustrates similar SEL versus distance data developed for the AH-64 for level flyovers at a speed of 130 knots, landings, and takeoffs. Appendix B contains tabular summaries of these AH-64 and CH-47D data and other similar results. There is little difference between operations and the increase in noise evident for other aircraft during landings is not present in the case of the AH-64.

Hover Data

Figures 8 and 9 illustrate time-average A-weighted sound level for in- and out-of-ground effect hover and for engine idle for the lightly and heavily loaded CH-47D and for the AH-64, respectively. The data are developed for both a hard surface such as a heliport in a paved, built-up area and for a soft surface such as the typical airport with its large expanses of open grass fields. These data are derived by averaging the time-average one-third octave level at each microphone and using the procedures described by Wolf and Raspet to determine the decay of these levels with distance.

Variation of Sound Exposure Level With Speed

Figure 10 illustrates the measured variation of SEL with speed for the CH-47D and AH-64 at a slant distance of 200 m. These data are also tabulated in Appendix B.
5 CONCLUSIONS AND RECOMMENDATIONS

SEL versus distance curves for the CH-47D and AH-64 were developed. These particular data for the CH-47D show that a heavily loaded aircraft is actually quieter than a lightly loaded one. For this reason, the data curves for a lightly loaded aircraft are recommended for general use. As with all other Army rotary-wing aircraft, landing noise of the CH-47D and AH-64 is substantially greater than is cruise speed level flyover noise, but the increase is only marginal for the AH-64.

As was found with earlier studies, the variation of SEL with speed is rather modest, except for aircraft at very high speeds. The variation of SEL with speed data will be incorporated into a planned new version of the helicopter noise contour program which will be based on FAA work. So, in the future, this capability will be available when (1) aircraft speeds differ significantly from the typical speeds, (2) the situation warrants this precision, and (3) the aircraft operational data are accurate enough to reliably indicate aircraft position, altitude, and speed as a function of time.

Noise data from both of these aircraft are a little higher than expected. In the future, a minimum of four of each aircraft is recommended. The measurements should be done in two groups at least 1 month apart to better ensure statistical reliability.

The control of blade-vortex noise by cyclic trim offers a potential means to mitigate CH-47D noise and should be the subject of further study.
Table 1

Dynamic Operations Performed at Fort Rucker

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<td>2. Level</td>
<td>180</td>
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<td>4. NOE</td>
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<td>5. Ascent</td>
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<td>135</td>
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<td>13. Landing</td>
<td>180</td>
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<td>14. Takeoff</td>
<td>180</td>
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*Nap of the earth (NOE) operations were not used in the analysis because of the inability to predict aircraft position.

Table 2

Helicopter Types and Loading Conditions Measured at Fort Rucker

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<th>Helicopter Model</th>
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*LF = level flyover; IGE = in-ground effect; OGE = out-of-ground effect.
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1. All level flyovers (LF) flown at 300 ft AGL.
2. These measurements began using a heading of 180 or 360. If 180 was chosen, then all the headings were the reverse of those shown in the table. These tests only used the 18-36 alignment, but the other two (12-30, 06-24) could have been used had the winds required it.
3. The CH-47D, sling-loaded, "took off" and "landed" from and to an OGE hover such that the load just touched the ground in the center of the array.
4. Maximum speed that the aircraft could fly that day (recorded in pilot's log).
5. Could not be performed for sling-loaded CH-47D.
Figure 1. Flight track for level flyovers. The solid path shows the tear-drop turn and the alignment (18-36) used for these tests. The dashed lines show the alternate alignments (06-24, 12-30) which could have been used had winds required one of them.
Figure 2. Test site layout. The pair of microphones (06-24, 18-36, or 12-30) most aligned with the wind are used as the flyover microphones. The other four microphones are the sideline microphones. With a flight altitude of 300 ft AGL, the sideline microphones are at a slant distance of 527 ft. Hovers, takeoffs and landings are to the center of the array. The cameras are wired together and fired electronically when the aircraft (flyover) is in the center of the array.

Figure 3. Typical camera site. Elevation through center of array. Aircraft height is determined by distance from camera to array center and to stator pole, and height of helicopter in picture (in stator pole markings).
Figure 4. SEL vs slant distance for lightly and heavily loaded CH-47D aircraft performing 300-ft AGL level flyovers at 130 knots indicated air speed.

Figure 5. SEL vs slant distance for lightly and heavily loaded CH-47D aircraft performing landings. The heavy load is a sling-loaded 10-ton truck so the landing is to a 35 ft hover.
Figure 6. SEL vs slant distance for lightly and heavily loaded CH-47D aircraft performing takeoffs. The heavy load is a sling-loaded 10-ton truck so the takeoffs are from a 35 ft hover.

Figure 7. SEL vs slant distance for AH-64 aircraft performing 300-ft AGL level flyovers at 130 knots, takeoffs, and landings.
Figure 8a. Average (for all directions) A-weighted LEQ vs distance for lightly loaded CH-47D aircraft performing zero-pitch engine-idle, IGE hover, and lightly and heavily loaded aircraft performing OGE hover. The propagation is for over a hard surface.

Figure 8b. Average (for all directions) A-weighted LEQ vs distance for lightly loaded CH-47D aircraft performing zero-pitch engine-idle, IGE hover, and lightly and heavily loaded aircraft performing OGE hover. The propagation is for over a soft surface.
Figure 9a. Average (for all directions) A-weighted LEQ vs distance for AH-64 aircraft performing zero-pitch engine-idle, IGE hover, and OGE hover. The propagation is for over a hard surface.

Figure 9b. Average (for all directions) A-weighted LEQ vs distance for AH-64 aircraft performing zero-pitch engine-idle, IGE hover, and OGE hover. The propagation is for over a soft surface.
Figure 10. Variation of SEL with speed for CH-47D (lightly and heavily loaded) and AH-64 aircraft performing 300-ft AGL level flyovers at a slant distance of 200 m.
PILOT'S LOG

Rotary Wing Aircraft Noise Measurements
Construction Engineering Research Lab
August 1986
AH-64 Test

Aircraft Identification 83-23789

Date 4 Aug 86
Set Number SET 1
Gross Weight 14287

Run Number

TAKE OFF
CT -- 6, 24, 12, 30, 18, 36
Radio call 10 sec. prior to takeoff
"10 seconds"
Radio at Takeoff
"Takeoff"
Perform normal climb and acceleration to
300 ft AGL
130 kts IAS
Takeoff time 106
Distance (ft) from takeoff
to reach 300 ft AGL 4030
(note terrain feature)
Distance (ft) from start of roll
to reach kts IAS 500 D
Fuel weight 1640
Heading 360
Rotor speed (average) 1069
Run Number 2
LEVEL FLYOVER
GT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 300
IAS: 40, 70, 100, 130, max kts
Heading 180
At 1/2 mile before colored ground marker, radio "Mark"
Mark time 11:15
Set Alt 2992
Record:
Height Alt 300 feet
Pressure Alt 680 feet
FAT 24
Airspeed 130 kts (IAS)
Ground speed 250 kts (from Doppler)
Motor speed 220 (100 - 225 rpm)
A/C Heading 162
Engine Torque #1 67 % #2 57 %
Fuel lbs (total) 250 lbs.

Run Number 3
LEVEL FLYOVER
GT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 300
IAS: 40, 70, 100, 130, max kts
Heading 36
At 1/2 mile before colored ground marker, radio "Mark"
Mark time 11:13
Set Alt 2992
Record:
Height Alt 300 feet
Pressure Alt 760 feet
FAT 24
Airspeed 130 kts (IAS) 134
Ground speed 255 kts (from Doppler)
Motor speed 160 % (100 - 225 rpm)
A/C Heading 36
Engine Torque #1 71 % #2 64 %
Fuel lbs (total) 1480 lbs.
Run Number. 4

LEVEL FLYOVER

CT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 500
IAS: 40, 60, 100, 130, max kts
Heading 140
At 1/2 mile before colored ground marker, radio "Mark"
Mark time 11:21
Set Alt 29.92
Record,

Height AGL 300 feet
Pressure Alt 750 feet
FAT 24 OC
Airspeed 70 kts (IAS) 72
Gndspeed 130 kts (from Doppler)
Rotorspeed 100 % (100 = 225 rpm)
A/C Heading 180
Engine Torque #1 40 #2 39 %
Fuel lbs (total) 1463 lbs.

Run Number. 5

LEVEL FLYOVER

CT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 500
IAS: 40, 60, 100, 130, max kts
Heading 260
At 1/2 mile before colored ground marker, radio "Mark"
Mark time 11:23
Set Alt 29.92
Record,

Height AGL 300 feet
Pressure Alt 650 feet
FAT 24 OC
Airspeed 70 kts (IAS) 71
Gndspeed 142 kts (from Doppler)
Rotorspeed 100 % (100 = 225 rpm)
A/C Heading 360
Engine Torque #1 39 #2 29 %
Fuel lbs (total) 14120 lbs.
Run Number __6____

LEVEL FLYOVER

GT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 300
IAS: 40, 70, 100, 130, max kts
Heading 17°
At 1/2 mile before colored ground marker, radio "Mark"
Mark time 11
Set Alt 29.92
Record,
Height AGL 300 feet
Pressure Alt 680 feet
FAT 24° C
Airspeed 100 kts (IAS) 99
Gndspeed 191 kts (from Doppler)
Rotorspeed 100 % (100 = 225 rpm)
A/C Heading 14°
Engine Torque #1 18 % #2 45 %
Fuel lbs (total) 137 lbs.

Run Number __7____

LEVEL FLYOVER

GT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 300
IAS: 40, 70, 100, 130, max kts
Heading 36°
At 1/2 mile before colored ground marker, radio "Mark"
Mark time 11
Set Alt 29.92
Record,
Height AGL 300 feet
Pressure Alt 680 feet
FAT 14° C
Airspeed 100 kts (IAS) 99
Gndspeed 201 kts (from Doppler)
Rotorspeed 100 % (100 = 225 rpm)
A/C Heading 70°
Engine Torque #1 18 % #2 45 %
Fuel lbs (total) 137 lbs.
Run Number 8
LEVEL FLYOVER
GT -- 6, 12, 24, 30, 36
Altitude: 300 ft. AGL or 300
IAS: 40, 70, 100, 130, max kts
Heading 190
At 1/2 mile before colored ground marker, radio "Mark"
Mark time 1135
Set Alt 29.92
Record,
Height AGL 380 feet
Pressure Alt 680 feet
FAT 24°C
Airspeed 149 kts (IAS) 149
Gndspeed 279 kts (from Doppler)
Rotorspeed 100% (100 = 225 rpm)
A/C Heading 190°
Engine Torque #1 94% #2 91%
Fuel lbs (total) 1240 lbs.

Run Number 9
LEVEL FLYOVER
GT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 100
IAS: 40, 70, 100, 130, max kts
Heading 36°
At 1/2 mile before colored ground marker, radio "Mark"
Mark time 1138
Set Alt 29.92
Record,
Height AGL 300 feet
Pressure Alt 680 feet
FAT 25°C
Airspeed 149 kts (IAS) 143
Gndspeed 285 kts (from Doppler)
Rotorspeed 100% (100 = 225 rpm)
A/C Heading 360°
Engine Torque #1 94% #2 92%
Fuel lbs (total) 1227 lbs.
Run Number 10

LEVEL FLYOVER

CT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 300
IAS: 40, 70, 100, 130, max kts
Heading 150

At 1/2 mile before colored ground marker, radio "Mark"
Mark time 1649
Set Alt 29.92
Record,

Height AGL 300 feet
Pressure Alt 710 feet
FAT 26°C
Airspeed 40 kts (IAS) 44
Onspeed 82 kts (from Doppler)
Rotspeed 180 % (100 = 225 rpm)
A/C Heading 180

Engine Torque 1 40 %
Fuel lbs (total) 942.9 lbs.

Run Number 11

LEVEL FLYOVER

CT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 300
IAS: 40, 70, 100, 130, max kts
Heading 360

At 1/2 mile before colored ground marker, radio "Mark"
Mark time 1657
Set Alt 29.92
Record,

Height AGL 300 feet
Pressure Alt 710 feet
FAT 26°C
Airspeed 40 kts (IAS)
Onspeed 94 kts (from Doppler)
Rotspeed 180 % (100 = 225 rpm)
A/C Heading 360

Engine Torque 1 42 %
Fuel lbs (total) 2410 lbs.
Run Number / 2 /

LEVEL FLYOVER

CT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. ACL or 300
IAS: 40, 70, 100, 130, max kts
Heading 36
At 1/2 mile before colored ground marker,
radio "Mark"
Mark time 16 50
Set Alt 29.92
Record,

Height AL 300 feet
Pressure Alt 710 feet
FAT 2.6 0°C
Airspeed 130 kts (IAS) 128
Gndspeed 24 kts (from Doppler)
Rotorspeed 100 % (100 = 225 rpm)
A/C Heading 16
Engine Torque #1 71 % #2 76 %
Fuel lbs (total) 235 lbs.

Run Number / 3 /

LEVEL FLYOVER

CT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. ACL or 300
IAS: 40, 70, 100, 130, max kts
Heading 36
At 1/2 mile before colored ground marker,
radio "Mark"
Mark time 16 50
Set Alt 29.92
Record,

Height AL 300 feet
Pressure Alt 710 feet
FAT 2.6 0°C
Airspeed 130 kts (IAS) 135
Gndspeed 25 kts (from Doppler)
Rotorspeed 100 % (100 = 225 rpm)
A/C Heading 36
Engine Torque #1 72 % #2 77 %
Fuel lbs (total) 2310 lbs.
LANDING

GT - 6, 24, 12, 30, 98, 96

Begin from "tear drop" turn.

300 ft AGL, 130 kts IAS,

At 1/2 mile before colored ground marker,

radio "Mark"

At touchdown, radio "touchdown"

Mark time 170.1

Distance from pad (ft)

when descent was initiated 3000

Fuel weight 2300

Run Number 15

R/IDLE

At pad center:

c-en-ground 100%

in-ground effect

out-of-ground effect hover

Heading -- 6, 24, 12, 30, 18, 36

Altitude (wheels in ft AGL) 0

Start time 1504

Fuel weight 2250

Engine torque #1 17 #2 16

HAT 25 °C

Rotor speed 100 °
Run Number 16

HOVER/HOLD

At pad center:
- on-ground 100%
- in-ground effect
- out-of-ground effect hover

Heading -- 6, 24, 12, 30, 18, 36
Altitude (wheels in ft AGL) 5

Start time 1704
Fuel weight 22.00
Engine torque #1 59 #2 58
FAT 25°C
Rotor speed 1007 rpm

Run Number 17

HOVER/HOLD

At pad center:
- on-ground 100%
- in-ground effect
- out-of-ground effect hover

Heading -- 6, 24, 12, 30, 18, 36
Altitude (wheels in ft AGL) 80

Start time 1707
Fuel weight 2.00
Engine torque #1 70 #2 69
FAT 25°C
Rotor speed 1950 rpm
Run Number 12

TAKE OFF

CT - 6, 12, 18, 24, 30, 36

Radio call 10 sec. prior to takeoff

"10 seconds"

Radio at Takeoff

"Takeoff"

Perform normal climb and acceleration to 300 ft AGL

130 kts IAS

Takeoff time 17:10

Distance (ft) from takeoff to reach 300 ft AGL 4000

(note terrain feature)

Distance (ft) from start of roll to reach kts IAS 5000

Fuel weight 2130

Heading 18

Rotor speed (average) 100°

Run Number 12

LEVEL FLYOVER

CT - 6, 12, 18, 24, 30, 36

Altitude: 300 ft AGL or 300

IAS: 40, 70, 100, 130, max kts

Heading 36

At 1/2 mile before colored ground marker, radio "Mark"

Mark time 17:15

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 756 feet

FAT 26° C

Airspeed 70 kts (IAS) 74

Groundspeed 146 kts (from Doppler)

Rotorspeed 1100 % (100 = 225 rpm)

A/C Heading 36

Engine Torque #1 38 %, #2 37 %

Fuel lbs (total) 2090 lbs.
Run Number 26

LEVEL FLYOVER

GT - 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 302
IAS: 40, 70, 100, 130, max kts
Heading 18
At 1/2 mile before colored ground marker, radio "Mark"
Mark time 1:11.8
Set Alt 29.92
Record,

Height AGL 300 feet
Pressure Alt 750 feet
FAT 26° 0.00
Airspeed 20 kts (IAS) 741
Gndspeed 12.2 kts (from Doppler)
Rotorspeed 1008 % (100 = 225 rpm)
A/C Heading 15
Engine Torque #1 40 % #2 50 %
Fuel lbs (total) 2040 lbs.

Run Number 26

LEVEL FLYOVER

GT - 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 302
IAS: 40, 70, 100, 130, max kts
Heading 36
At 1/2 mile before colored ground marker, radio "Mark"
Mark time 1:17.2
Set Alt 29.92
Record,

Height AGL 300 feet
Pressure Alt 750 feet
FAT 26° 0.00
Airspeed 141 kts (IAS) 349
Gndspeed 212 kts (from Doppler)
Rotorspeed 1108 % (100 = 225 rpm)
A/C Heading 36
Engine Torque #1 30 % #2 20 %
Fuel lbs (total) 1962 lbs.
Run Number 22
LEVEL FLYOVER
CT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 300
IAS: 40, 70, 100, 130, max kts
Heading 16
At 1/2 mile before colored ground marker, radio "Mark"
Mark time 17.23
Set Alt 29.92
Record,
Height AGL 300 feet
Pressure Alt 250 feet
FAT 26 oC
Airspeed 142 kts (IAS)
Gndspeed 267 kts (from Doppler)
Rotorspeed 122 % (100 = 225 rpm)
A/C Heading 12
Engine Torque #1 5% #2 7%
Fuel lbs (total) 177 lbs.

Run Number 23
LEVEL FLYOVER
CT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 300
IAS: 40, 70, 100, 130, max kts
Heading 36
At 1/2 mile before colored ground marker, radio "Mark"
Mark time 17.23
Set Alt 29.92
Record,
Height AGL 300 feet
Pressure Alt 750 feet
FAT 26 oC
Airspeed 130 kts (IAS)
Gndspeed 258 kts (from Doppler)
Rotorspeed 67 % (100 = 225 rpm)
A/C Heading 36
Engine Torque #1 7% #2 67%
Fuel lbs (total) 1890 lbs.
Run Number 24
LEVEL FLYOVER
CT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 200
IAS: 40, 70, 100, 130, max kts
Heading 19
At 1/2 mile before colored ground marker, radio "Mark"
Mark time 17:29
Set Alt 29.92
Record,
Height AGL 300 feet
Pressure Alt 160 feet
FAT 26° C
Airspeed 132 kts (IAS)
Gndspeed 247 kts (from Doppler)
Kotorspeed 170 % (100 = 225 rpm)
A/C Heading 18°
Engine Torque #1 5/2 % #2 6/8 %
Fuel lbs (total) 1660 lbs.

Run Number 25
LEVEL FLYOVER
CT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 200
IAS: 40, 70, 100, 130, max kts
Heading 26°
At 1/2 mile before colored ground marker, radio "Mark"
Mark time 17:31
Set Alt 29.92
Record,
Height AGL 300 feet
Pressure Alt 750 feet
FAT 26° C
Airspeed 100 kts (IAS)
Gndspeed 205 kts (from Doppler)
Kotorspeed 100 % (100 = 225 rpm)
A/C Heading 36°
Engine Torque #1 5/2 % #2 4/8 %
Fuel lbs (total) 1840 lbs.
Run Number 26

LEVEL FLYOVER

GT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 300
IAS: 40, 70, 100, 130, max kts
Heading 15
At 1/2 mile before colored ground marker,
radio "Mark"
Mark time 17 36
Set Alt 29.92
Record,
Height AGL 300 feet
Pressure Alt 750 feet
FAT 26° C
Airspeed 100 kts (IAS) 164
Gndspeed 194 kts (from Doppler)
Rotorspeed 100 % (100 = 225 rpm)
A/C Heading 18
Engine Torque #1 48 % #2 46 %
Fuel lbs (total) 1837 lbs.

Run Number 27

LEVEL FLYOVER

GT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 300
IAS: 40, 70, 100, 130, max kts
Heading 36
At 1/2 mile before colored ground marker,
radio "Mark"
Mark time 17 36
Set Alt 29.92
Record,
Height AGL 300 feet
Pressure Alt ___ feet
FAT 26° C
Airspeed 45 kts (IAS) 45
Gndspeed 98 kts (from Doppler)
Rotorspeed 100 % (100 = 225 rpm)
A/C Heading 36
Engine Torque #1 40 % #2 39 %
Fuel lbs (total) 1790 lbs.
Run Number 28

LEVEL FLYOVER

GT -- 8, 12, 16, 24, 30, 36
Altitude: 300 ft. AGL or 300
IAS: 40, 70, 100, 130, max kts
Heading 18
At 1/2 mile before colored ground marker, radio "Mark"
Mark time 1739
Set Alt 29.92
Record,
Height AGL 300 feet
Pressure Alt 760 feet
FAT 26°C
Airspeed 40 kts (IAS) 146
Gndspeed 284 kts (from Doppler)
Rotorspeed 100% (100 = 225 rpm)
A/C Heading 18
Engine Torque #1 2-7 % #2 2-8 %
Fuel lbs (total) 1750 lbs.

Run Number 29

LEVEL FLYOVER

GT -- 8, 12, 16, 24, 30, 36
Altitude: 300 ft. AGL or 300
IAS: 40, 70, 100, 130, max kts
Heading 34
At 1/2 mile before colored ground marker, radio "Mark"
Mark time 1747
Set Alt 29.92
Record,
Height AGL 300 feet
Pressure Alt 760 feet
FAT 26°C
Airspeed 120 kts (IAS) 129
Gndspeed 248 kts (from Doppler)
Rotorspeed 100% (100 = 225 rpm)
A/C Heading 34
Engine Torque #1 2-7 % #2 2-9 %
Fuel lbs (total) 1700 lbs.
Run Number 30
LEVEL FLYOVER
GT -- 6, 12, 18, 24, 30, 36
Altitude: 300 ft. AGL or 300
IAS: 40, 70, 100, 130, max kts
Heading 19
At 1/2 mile before colored ground marker,
radio "Mark"
Mark time 17:47
Set Alt 29:92
Record,
Height AGL 300 feet
Pressure Alt 260 feet
FAT 0 C
Airspeed 150 kts (IAS) 132
Groundspeed 252 kts (from Doppler)
NDB Speed 180 kts (100 = 225 rpm)
A/C Heading 19
Engine Torque #1 70 % #2 60 %
Fuel lbs (total) 1688 lbs.

Run Number 31
LANDING
GT -- 6, 24, 12, 30, 18, 36
Begin from "tear-drop" turn,
300 ft AGL, 130 kts IAS,
At 1/2 mile before colored ground marker,
radio "Mark"
At touchdown, radio "Touchdown"
Mark time 17:50
Distance from pad (ft)
when descent was initiated 2000
Fuel weight 1570
APPENDIX B:

TABULAR DATA FOR FIGURES IN REPORT

Table B1
Variation in SEL Vs Slant Distance

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Operation</th>
<th>50</th>
<th>100</th>
<th>200</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>5000</th>
<th>10,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy CH-47D</td>
<td>LF*</td>
<td>99.2</td>
<td>95.0</td>
<td>90.8</td>
<td>84.8</td>
<td>79.9</td>
<td>74.7</td>
<td>67.0</td>
<td>60.4</td>
</tr>
<tr>
<td>Light CH-47D</td>
<td>LF*</td>
<td>104.8</td>
<td>100.7</td>
<td>96.6</td>
<td>90.8</td>
<td>86.0</td>
<td>80.7</td>
<td>72.4</td>
<td>64.8</td>
</tr>
<tr>
<td>Heavy CH-47D</td>
<td>Land</td>
<td>108.6</td>
<td>104.5</td>
<td>100.2</td>
<td>94.1</td>
<td>88.9</td>
<td>83.1</td>
<td>74.2</td>
<td>66.9</td>
</tr>
<tr>
<td>Light CH-47D</td>
<td>Land</td>
<td>101.8</td>
<td>97.5</td>
<td>92.9</td>
<td>86.5</td>
<td>81.0</td>
<td>74.7</td>
<td>65.3</td>
<td>58.0</td>
</tr>
<tr>
<td>Heavy CH-47D</td>
<td>Takeoff</td>
<td>102.6</td>
<td>98.4</td>
<td>94.0</td>
<td>87.8</td>
<td>82.5</td>
<td>76.7</td>
<td>68.1</td>
<td>61.2</td>
</tr>
<tr>
<td>Light CH-47D</td>
<td>Takeoff</td>
<td>99.5</td>
<td>95.2</td>
<td>90.6</td>
<td>83.9</td>
<td>77.9</td>
<td>70.7</td>
<td>59.4</td>
<td>52.0</td>
</tr>
<tr>
<td>AH-64</td>
<td>Land</td>
<td>99.2</td>
<td>95.0</td>
<td>90.6</td>
<td>84.1</td>
<td>78.3</td>
<td>71.1</td>
<td>59.1</td>
<td>49.6</td>
</tr>
<tr>
<td>AH-64</td>
<td>LF*</td>
<td>98.1</td>
<td>94.0</td>
<td>89.7</td>
<td>83.5</td>
<td>78.0</td>
<td>71.5</td>
<td>60.6</td>
<td>51.0</td>
</tr>
<tr>
<td>AH-64</td>
<td>Takeoff</td>
<td>96.3</td>
<td>92.1</td>
<td>87.6</td>
<td>81.2</td>
<td>75.6</td>
<td>68.9</td>
<td>58.2</td>
<td>49.2</td>
</tr>
</tbody>
</table>

*LF is a level flyover at 300 ft AGL and 130 knots indicated air speed.

Table B2
Versions of Static Average LEQ With Distance Over Soft Ground (Yearly Average)

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Operation</th>
<th>100*</th>
<th>200</th>
<th>300</th>
<th>500</th>
<th>700</th>
<th>1000</th>
<th>1200</th>
<th>1400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy CH-47D</td>
<td>OGE Hover</td>
<td>91.0</td>
<td>82.6</td>
<td>76.1</td>
<td>68.2</td>
<td>63.8</td>
<td>59.1</td>
<td>57.2</td>
<td>55.4</td>
</tr>
<tr>
<td>Light CH-47D</td>
<td>OGE Hover</td>
<td>88.0</td>
<td>79.9</td>
<td>73.1</td>
<td>65.2</td>
<td>60.7</td>
<td>55.6</td>
<td>53.6</td>
<td>51.8</td>
</tr>
<tr>
<td>Light CH-47D</td>
<td>IGE Hover</td>
<td>84.9</td>
<td>75.8</td>
<td>70.0</td>
<td>64.0</td>
<td>60.9</td>
<td>56.7</td>
<td>55.0</td>
<td>53.8</td>
</tr>
<tr>
<td>Light CH-47D</td>
<td>Engine Idle</td>
<td>83.2</td>
<td>74.8</td>
<td>68.9</td>
<td>62.2</td>
<td>58.6</td>
<td>54.1</td>
<td>52.4</td>
<td>51.1</td>
</tr>
<tr>
<td>AH-64</td>
<td>OGE Hover</td>
<td>88.0</td>
<td>79.4</td>
<td>72.9</td>
<td>65.0</td>
<td>60.7</td>
<td>55.8</td>
<td>54.0</td>
<td>52.2</td>
</tr>
<tr>
<td>AH-64</td>
<td>IGE Hover</td>
<td>77.7</td>
<td>67.9</td>
<td>62.9</td>
<td>58.9</td>
<td>55.5</td>
<td>51.4</td>
<td>48.4</td>
<td>47.1</td>
</tr>
<tr>
<td>AH-64</td>
<td>Engine Idle</td>
<td>70.2</td>
<td>61.1</td>
<td>55.7</td>
<td>50.6</td>
<td>47.1</td>
<td>42.7</td>
<td>40.1</td>
<td>38.6</td>
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</tbody>
</table>

*Distance in meters.
Table B3

Variation of SEL Vs Speed (IAS) for 300-ft AGL Level Flyovers at a Slant Distance of 200 m

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>40</th>
<th>70</th>
<th>100</th>
<th>130</th>
<th>MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>AH-64</td>
<td>88.8</td>
<td>88.5</td>
<td>88.2</td>
<td>89.7</td>
<td>90.6⁺¹</td>
</tr>
<tr>
<td>Light CH-47D</td>
<td>91.9</td>
<td>91.1</td>
<td>93.2</td>
<td>96.6</td>
<td>99.5⁺²</td>
</tr>
<tr>
<td>Heavy CH-47D</td>
<td>94.6</td>
<td>90.3</td>
<td>88.7</td>
<td>90.8⁺³</td>
<td></td>
</tr>
</tbody>
</table>

¹about 145 knots
²about 135 knots
³about 119-120 knots
USA-CERL DISTRIBUTION

Chief of Engineers
ATTN: CERD-L
ATTN: CEEC-CE
ATTN: CEEC-EA
ATTN: CEEC-EI (2)
ATTN: CEEC-ZA
ATTN: CEEC-M (2)

US Army Aviation System Cmd 63120
ATTN: AMCPM-CH47M (2)
ATTN: AMCTM-AAH-SEA (2)

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