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

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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 gropus of two, separated by at least 1 month in time to better insure the statistical reliability of the data.

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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 (because of possible changes in cyclic trim), the CH-47D actually made less sound during level flight at full load than it

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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.

FOREWORD

This work was performed for the U.S. Army Materiel Command (AMC), Aviation Systems Command, under IAO AAH 676-86, dated April 1986, and IAO 19-5-BK092, dated November 1986, as part of their responsibilities under Army Regulation (AR) 200-1 and the AMC Supplement to AR 200-1. The Technical Monitors were MAJ James O'Connor and Jim Pliml for the CH-47D and the AH-64, respectively.

The investigation was conducted by the Environmental (EN) Division of the U.S. Army Construction Engineering Research Laboratory (USA-CERL). Dr. R. K. Jain is Chief, EN. The Technical Editor was Gloria J. Wienke, Information Management Office.

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.[1] 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.[2] 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.[3] 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[4] and USA-CERL Technical Report N-131 defines the noise emissions of the CH-47C and the UH-60A from testing conducted at Forts

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[1]Army Regulation (AR) 200-1, *Environmental Protection and Enhancement*, Chapter 7 (U.S. Army Corps of Engineers [USACE], 15 June 1982).

[2]DOD 4270.1-M, *Construction Criteria* (Department of Defense [DOD], 1972); DOD Instruction 4165-57, *Air Installations Compatible Use Zones* (DOD, 1973).

[3]Lincoln L. Little, Violetta I. Pawlowska, and David L. Effland, *Blast Noise Prediction Volume II: BNOISE 2.3 Computer Program Description and Program Listing*, Technical Report N-98/ADA099335 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1981); R. D. Horonjeff, R. R. Kandurkuri, and N. H. Reddinghius, *Community Noise Exposure Resulting From Aircraft Operation: Computer Program Description*, Aerospace Medical Research Laboratory Report AMRL-TR-73-109 (Bolt Beranek and Newman, 1974).

[4]B. Homans, L. Little, and P. Schomer, *Rotary Wing Aircraft Operational Noise Data*, Technical Report N-38/ADA051999 (USA-CERL, 1978).

Rucker and Campbell.[5] 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.[6]

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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[5]P. D. Schomer, Aaron Averbuch, and Richard Raspet, *Operational Noise Data for UH-60A and CH-47C Army Helicopters*, Technical Report N-131/ADA118796 (USA-CERL, June 1982).

[6]Paul D. Schomer, *Rotary-Wing Aircraft Noise Measurements: Analysis of Variations and Proposed Measurement Standard*, Technical Report N-184/ADA146207 (USA-CERL, September 1984).

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 windscreens. 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 thoedolite 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 base; 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.[7] 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.[8]

[7] Bishop, D. E., and W. J. Galloway, *Community Noise Exposure Resulting From Aircraft Operations: Acquisition and Analysis of Aircraft Noise and Performance Data*, Aerospace Medical Research Laboratory Report AMRL-TR-73-107 (Bolt Beranek and Newman, 1975).

[8] R. K. Wolf and R. Raspet, "Investigation of the Dependence of Excess Attenuation of Aircraft Noise on Distance," *J. Acoust. Soc. Am.*, Suppl. 1, Vol 80 (1986), pp S8-S9.

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 Peformed at Fort Rucker

Operation	Beginning Ground Track (GT) (degrees)
1. Level	360
2. Level	180
3. NOE*	360
4. NOE	180
5. Ascent	360
6. Descent	180
7. Descent	360
8. Ascent	180
9. Left turn	315
10. Right turn	45
11. Right turn	225
12. Left turn	135
13. Landing	180
14. Takeoff	180

*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

Helicopter Model	Loading Condition
OH-58	Normal
AH-1G	Normal
UH-1M	Normal
UH-1H	Maximum or Normal
UH-1B	Maximum or Normal
CH-47B	Maximum or Normal
CH-54	Maximum or Normal
TH-55	Normal

Table 3

Dynamic Operations Performed at Fort Campbell
by CH-47C and UH-1H

	Operation*	Altitude (ft)	Speed (knots)	GT (degrees)
1	LF	300	80	280
2	LF	300	80	100
3	LF	300	40	280
4	LF	300	40	100
5	LF	300	100	280
6	LF	300	100	100
7	LF	300	60	280
8	LF	300	60	100
9	LF	300	120	280
10	LF	300	120	100
11	LF	300	80	280
12	LF	300	80	100
13	LF	300	100	280
14	LF	300	100	100
15	Landing	-	-	280
16	IGE Hover			
17	OGE Hover			
18	Takeoff	-	-	280
19	LF	1000	80	100
20	LF	1000	80	280
21	LF	1000	100	100
22	LF	1000	100	280
23	LF	1000	120	100
24	LF	1000	120	280
25	LF	1000	60	100
26	LF	1000	60	280
27	LF	1000	100	100
28	LF	1000	100	280
29	LF	1000	80	100
30	LF	1000	80	280

*LF = level flyover; IGE = in-ground effect; OGE = out-of-ground effect.

Table 4

Typical Order of Operations Performed at Bondville

	Operation[1]	Speed (Knots)	Heading[2]
A	Calibration	-	
B	Background Noise	-	
1	Takeoff[3]	-	360
2	LF	130	180
3	LF	130	360
4	LF	70	180
5	LF	70	360
6	LF	100	180
7	LF	100	360
8	LF	MAX[4]	180
9	LF	MAX[4]	360
10	LF	40	180
11	LF	40	360
12	LF	130	180
13	LF	130	360
14	Land[3]		180
15	Eng. Idle[5]		180
16	IGE-Hover[5]		Into Wind
17	OGE-Hover		Into Wind
18	Takeoff[3]		180
	Background		
19	LF	70	360
20	LF	70	180
21	LF	MAX[4]	360
22	LF	MAX[4]	180
23	LF	130	360
24	LF	130	180
25	LF	100	360
26	LF	100	180
27	LF	40	360
28	LF	40	180
20	LF	130	360
30	LF	130	180
31	Land[3]		
	Background		

[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.

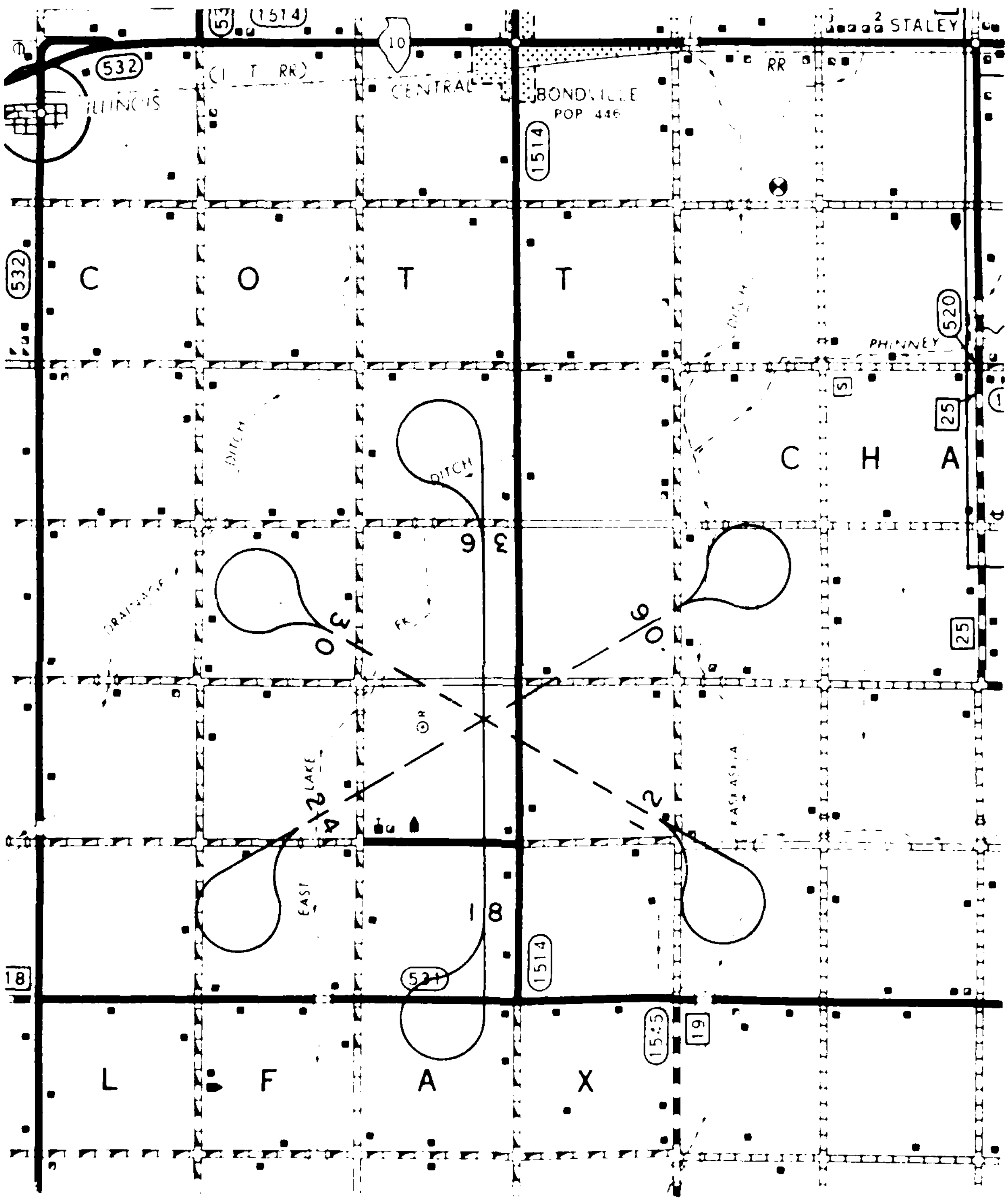

Figure 1. Flight track for level flyovers. The solid path shows the tear-drop turn and the alignment (18-36) used for these tests. The dashed lines show the alternate alignments (06-24, 12-30) which could have been used had winds required one of them.

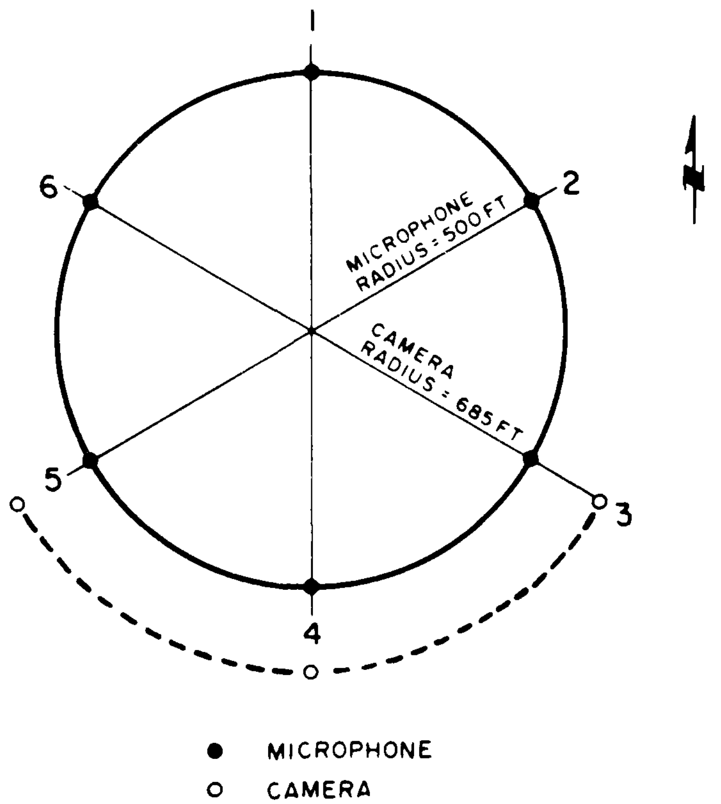

Figure 2. Test site layout. The pair of microphones (06-24, 18-36, or 12-30) most aligned with the wind are used as the flyover microphones. The other four microphones are the sideline microphones. With a flight altitude of 300 ft AGL, the sideline microphones are at a slant distance of 527 ft. Hovers, 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.

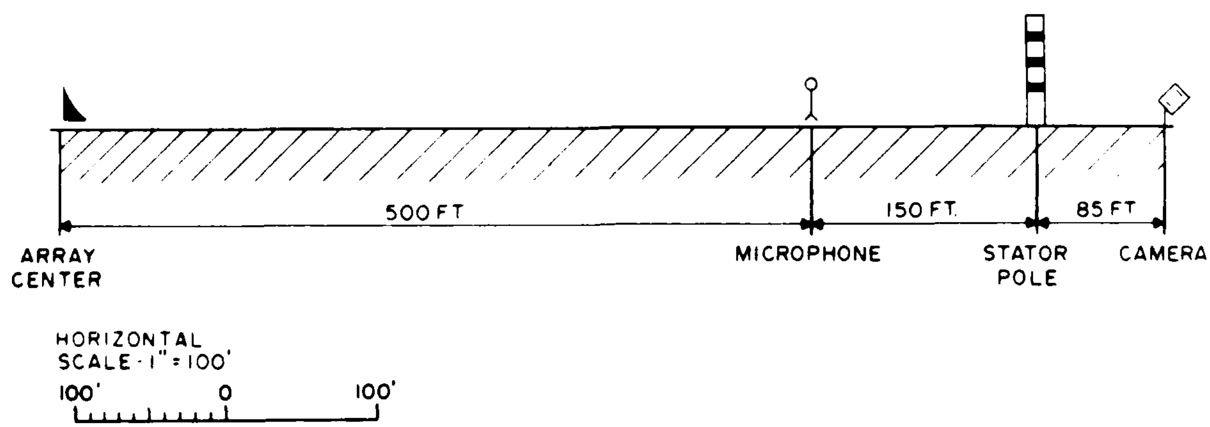

Figure 3. Typical camera site. Elevation through center of array. Aircraft height is determined by distance from camera to array center and to stator pole, and height of helicopter in picture (in stator pole markings).

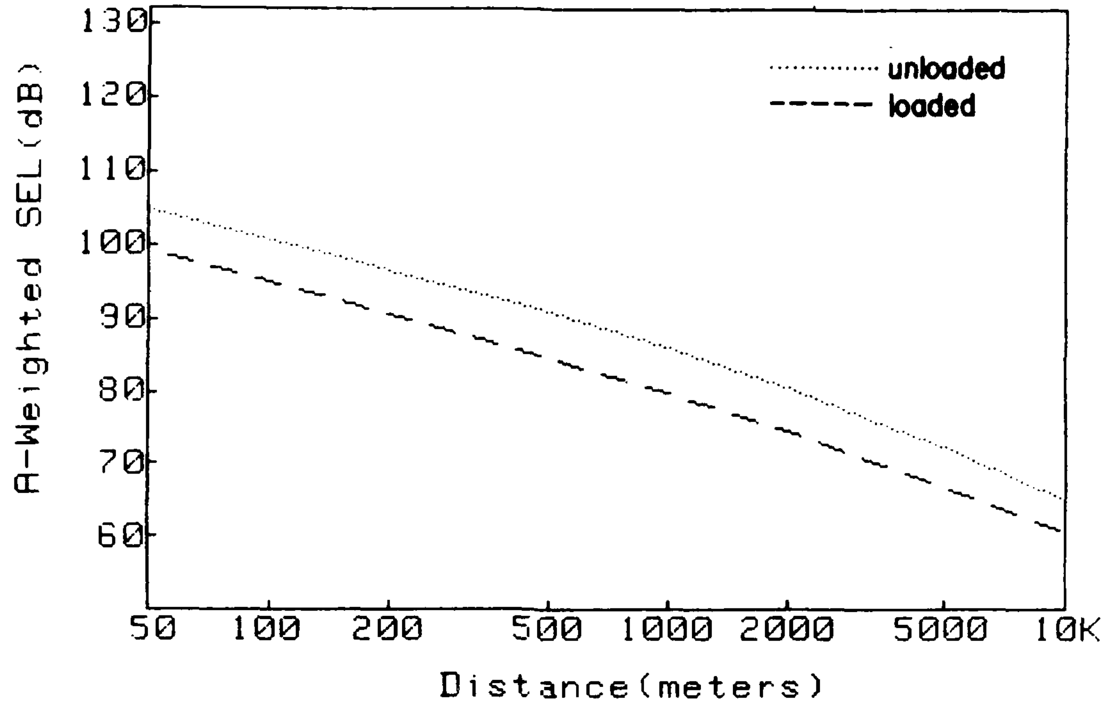

Figure 4. **SEL vs slant distance for lightly and heavily loaded CH-47D aircraft performing 300-ft AGL level flyovers at 130 knots indicated air speed.**

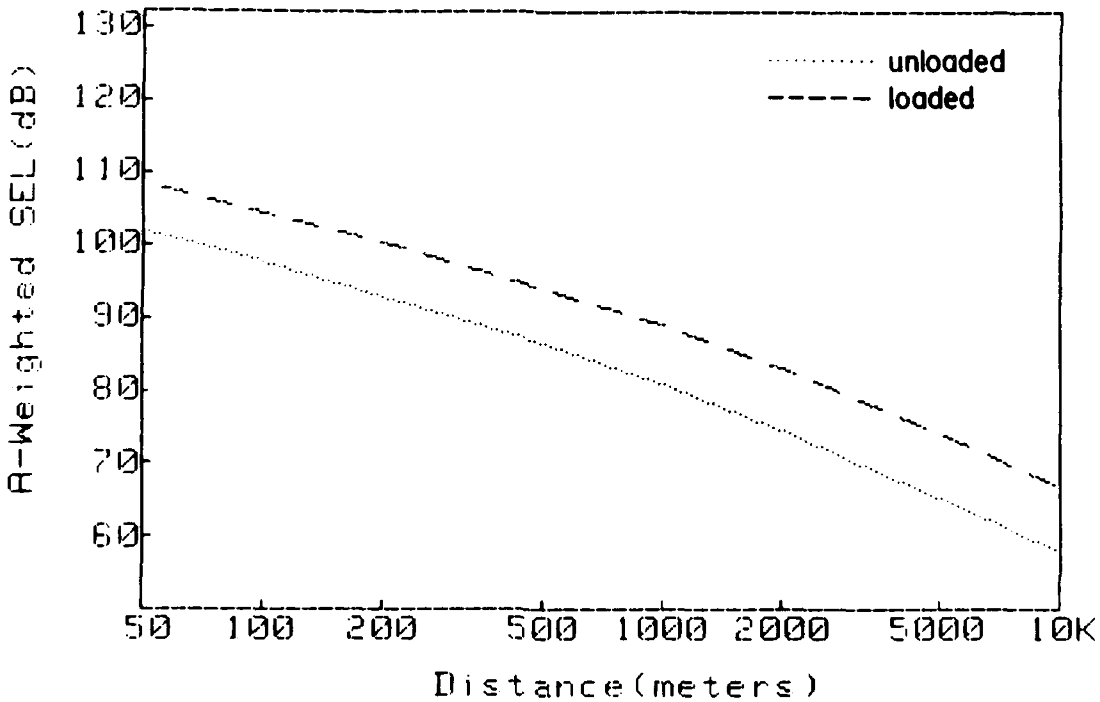

Figure 5. **SEL vs slant distance for lightly and heavily loaded CH-47D aircraft performing landings.** The heavy load is a sling-loaded 10-ton truck so the landing is to a 35 ft hover.

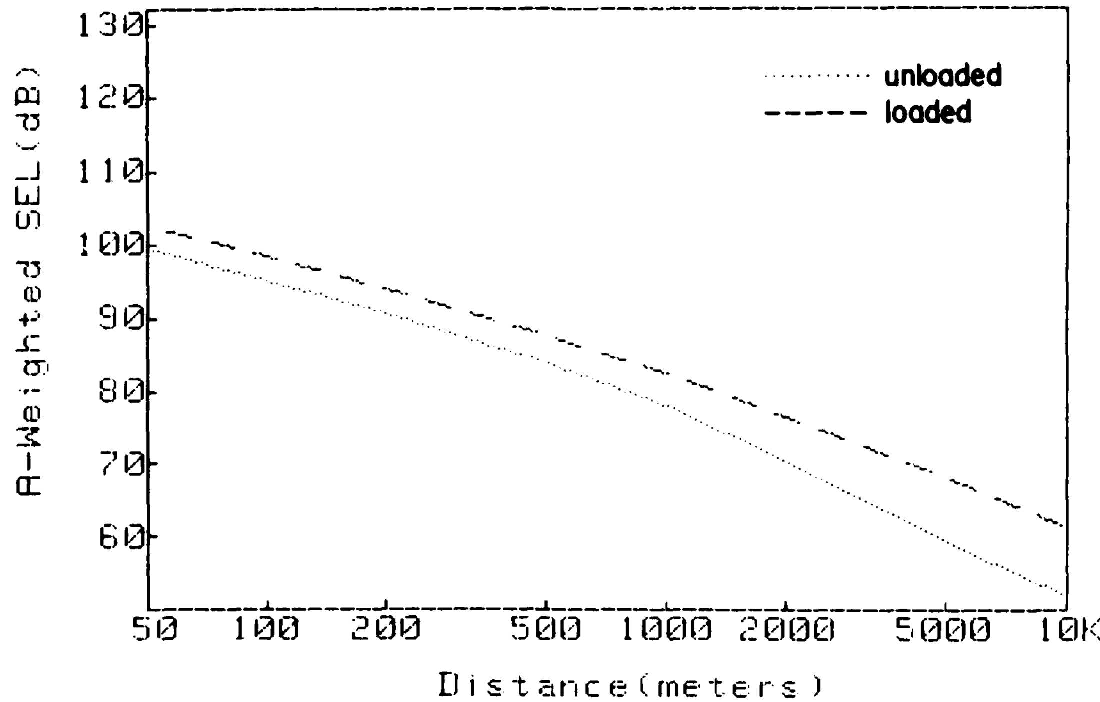

Figure 6. **SEL vs slant distance for lightly and heavily loaded CH-47D aircraft performing takeoffs.** The heavy load is a sling-loaded 10-ton truck so the takeoffs are from a 35 ft hover.

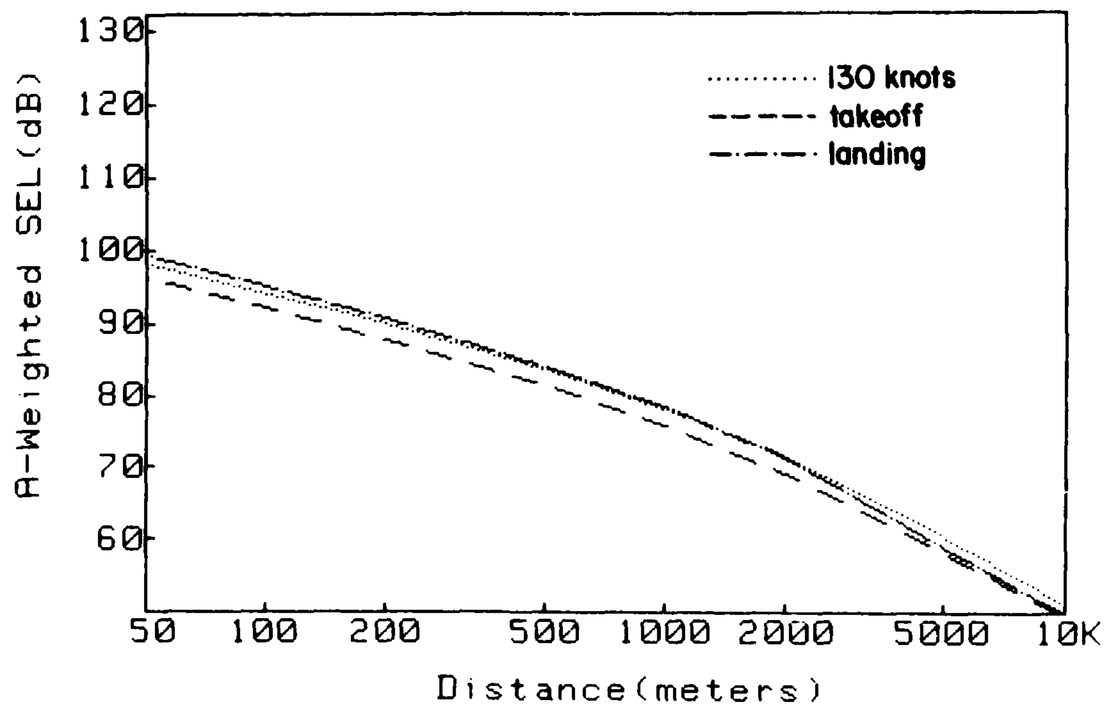

Figure 7. **SEL vs slant distance for AH-64 aircraft performing 300-ft AGL level flyovers at 130 knots, takeoffs, and landings.**

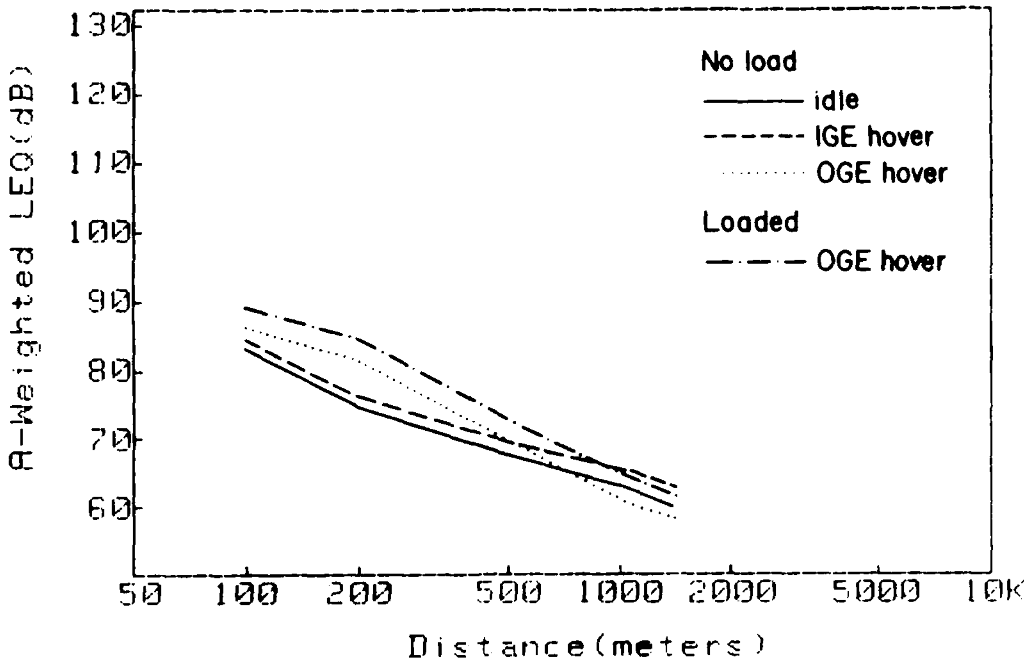

Figure 8a. Average (for all directions) A-weighted LEQ vs distance for lightly loaded CH-47D aircraft performing zero-pitch engine-idle, IGE hover, and lightly and heavily loaded aircraft performing OGE hover. The propagation is for over a hard surface.

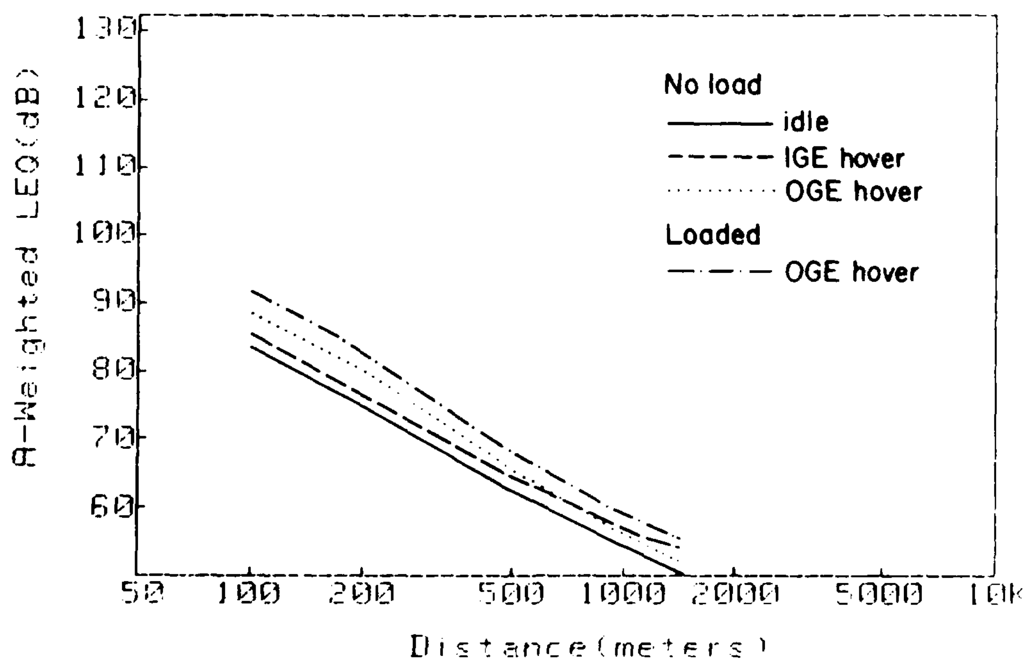

Figure 8b. Average (for all directions) A-weighted LEQ vs distance for lightly loaded CH-47D aircraft performing zero-pitch engine-idle, IGE hover, and lightly and heavily loaded aircraft performing OGE hover. The propagation is for over a soft surface.

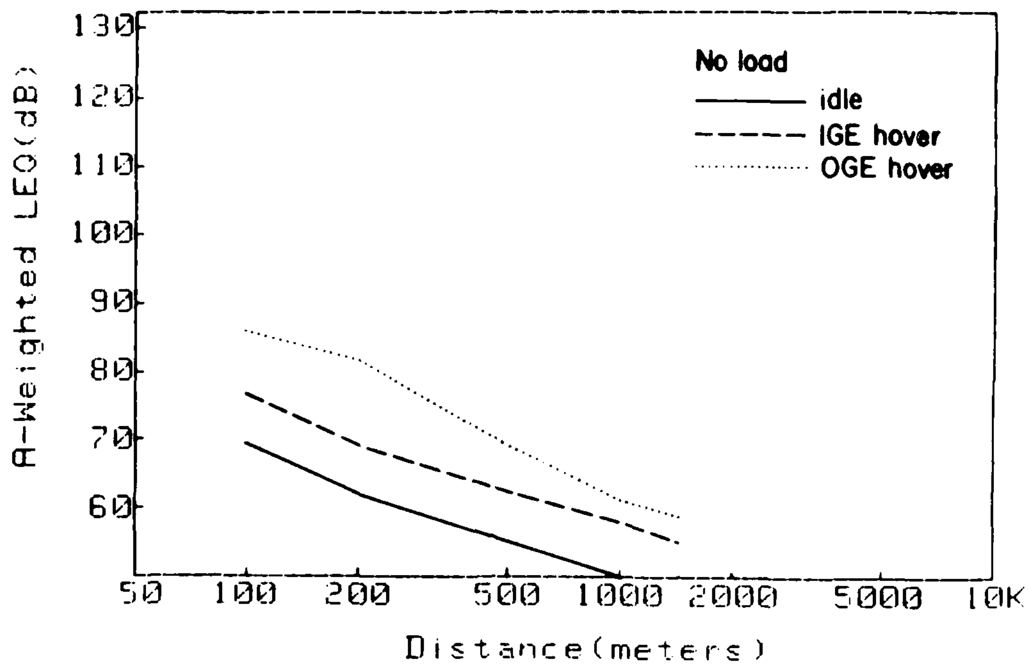

Figure 9a. **Average (for all directions) A-weighted LEQ vs distance for AH-64 aircraft performing zero-pitch engine-idle, IGE hover, and OGE hover. The propagation is for over a hard surface.**

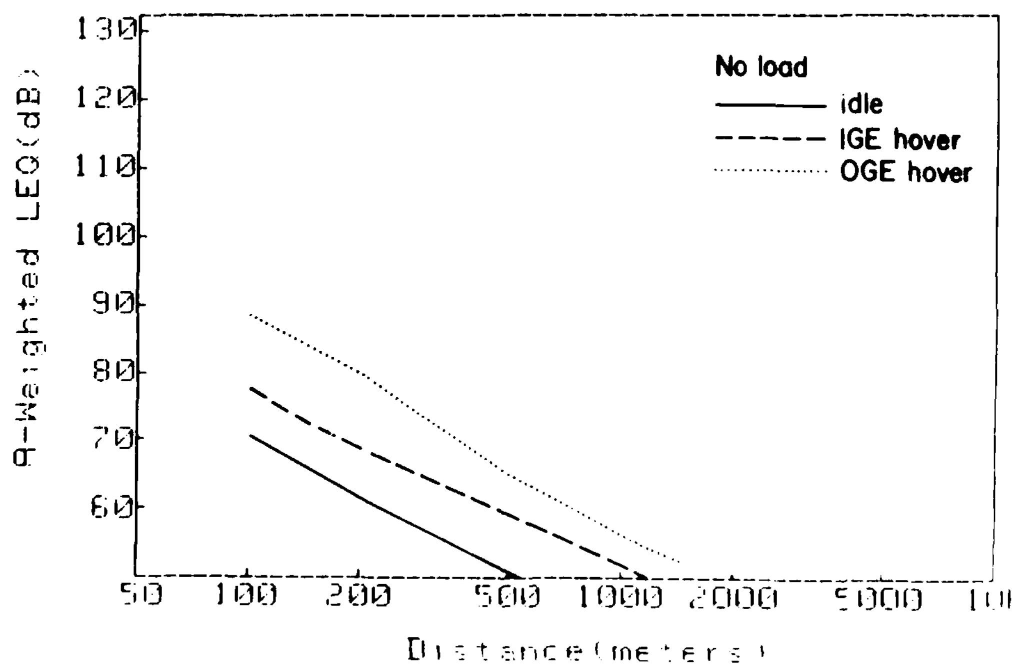

Figure 9b. **Average (for all directions) A-weighted LEQ vs distance for AH-64 aircraft performing zero-pitch engine-idle, IGE hover, and OGE hover. The propagation is for over a soft surface.**

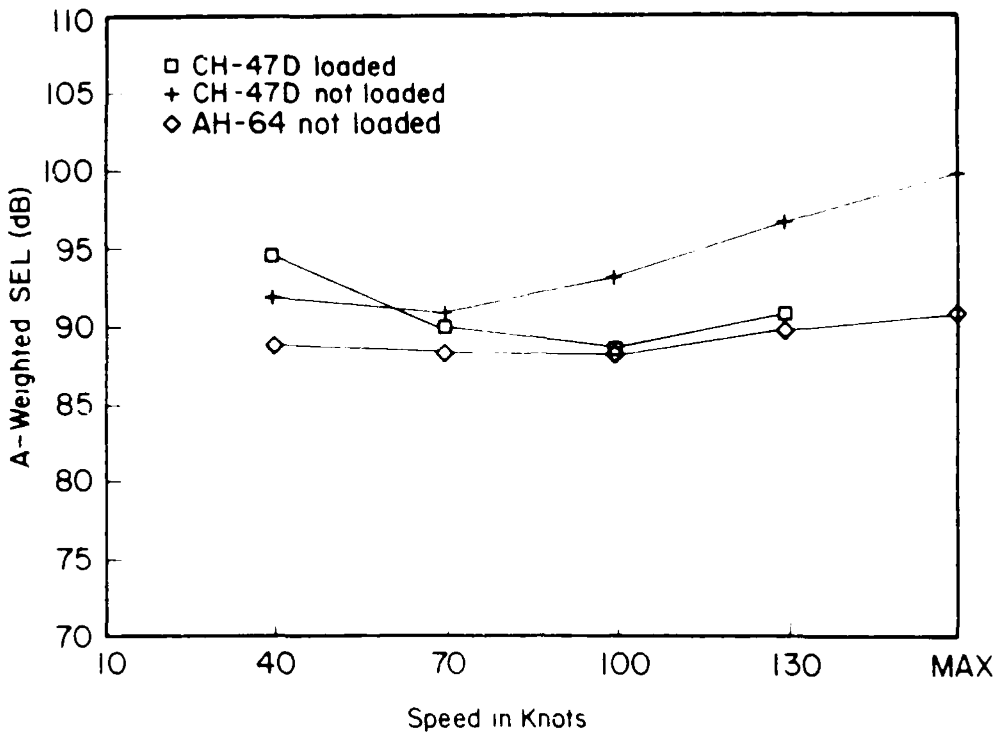

Figure 10. **Variation of SEL with speed for CH-47D (lightly and heavily loaded) and AH-64 aircraft performing 300-ft AGL level flyovers at a slant distance of 200 m.**

APPENDIX A:

TYPICAL PILOT'S LOG

PILOT'S LOG

Rotary Wing Aircraft Noise Measurements

Construction Engineering Research Lab

August 1986

AH64 Test

Aircraft Identification 83 23789

Date 4 AUG 86

Set Number SET 1

Gross Weight 14287

Run Number 1

TAKE OFF

GT -- 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 1106

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 1640

Heading 360

Rotor speed (average) 100%

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 1110

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 680 feet

FAT 25 °C

Airspeed 130 kts (IAS)

Gndspeed 250 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 180

Engine Torque #1 67 % #2 65 %

Fuel lbs (total) 1620 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 1113

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 760 feet

FAT 24 °C

Airspeed 130 kts (IAS) 134

Gndspeed 255 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 360

Engine Torque #1 71 % #2 69 %

Fuel lbs (total) 1480 lbs.

Run Number 4

LEVEL FLYOVER

GT -- 6, 12, 18, 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 1121

Set Alt 29.92

Record,

Height AGL 302 feet

Pressure Alt 750 feet

FAT 24 oC

Airspeed 70 kts (IAS) 72

Gndspeed 136 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 18

Engine Torque #1 40 % #2 39 %

Fuel lbs (total) 1460 lbs.

Run Number 5

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 1123

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 38 %

Fuel lbs (total) 1420 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 180

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

Mark time 1124

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 680 feet

FAT 24 oC

Airspeed 100 kts (IAS) 99

Gndspeed 171 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 180

Engine Torque #1 40 % #2 45 %

Fuel lbs (total) 1375 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 360

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 oC

Airspeed 100 kts (IAS) 99

Gndspeed 201 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 360

Engine Torque #1 48 % #2 40 %

Fuel lbs (total) 1320 lbs.

Run Number 8

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 1135

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 680 feet

FAT 24 oC

Airspeed 149 kts (IAS) 149

Gndspeed 279 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 180

Engine Torque #1 92 % #2 91 %

Fuel lbs (total) 1200 lbs.

Run Number 9

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 1138

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 680 feet

FAT 25 oC

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) 1180 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 180

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 oC

Airspeed 40 kts (IAS) 44

Gndspeed 82 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 180

Engine Torque #1 40 % #2 38 %

Fuel lbs (total) 2420 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 36

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 oC

Airspeed 40 kts (IAS)

Gndspeed 94 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 36

Engine Torque #1 42 % #2 40 %

Fuel lbs (total) 2410 lbs.

Run Number 12

LEVEL FLYOVER

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

Altitude: 300 ft. AGL or 360

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

Heading 18

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

Mark time 1656

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 710 feet

FAT 26 oC

Airspeed 130 kts (IAS) 128

Gndspeed 242 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 18

Engine Torque #1 71 % #2 70 %

Fuel lbs (total) 2350 lbs.

Run Number 13

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 1653

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 730 feet

FAT 2 oC

Airspeed 130 kts (IAS) 135

Gndspeed 258 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 36

Engine Torque #1 72 % #2 71 %

Fuel lbs (total) 2310 lbs.

Run Number 14

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 1701

Distance from pad (ft)

when descent was initiated 3000

Fuel weight 2300

Run Number 15

[redacted]R/IDLE

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) 0

Start time 1504

Fuel weight 2250

Engine torque #1 17 #2 16

FAT 25 °C

Rotor speed 100%

Run Number 16

HOVER/[redacted]

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 1706

Fuel weight 2240

Engine torque #1 59 #2 58

FAT 25 °C

Rotor speed 100%

Run Number 17

HOVER/[redacted]

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 2200

Engine torque #1 70 #2 68

FAT 25 °C

Rotor speed 100%

Run Number 18

TAKE OFF

GT -- 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 1710

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 19

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 1715

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 750 feet

FAT 26 °C

Airspeed 70 kts (IAS) 74

Gndspeed 146 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 36

Engine Torque #1 38 % #2 37 %

Fuel lbs (total) 2090 lbs.

Run Number 20

LEVEL FLYOVER

GT -- 6, 12, 18, 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 1118

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 750 feet

FAT 26 oC

Airspeed 70 kts (IAS) 74

Gndspeed 132 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 18

Engine Torque #1 [illegible] % #2 25 %

Fuel lbs (total) 2040 lbs.

Run Number 21

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 1122

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 750 feet

FAT 26 oC

Airspeed 141 kts (IAS) 140

Gndspeed 212 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 36

Engine Torque #1 81 % #2 80 %

Fuel lbs (total) 1960 lbs.

Run Number 22

LEVEL FLYOVER

GT -- 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 1723

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 750 feet

FAT 26 oC

Airspeed 142 kts (IAS) 139

Gndspeed 267 kts (from Doppler)

Rotorspeed 120 % (100 = 225 rpm)

A/C Heading 18

Engine Torque #1 61 % #2 79 %

Fuel lbs (total) 1910 lbs.

Run Number 23

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 1726

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 750 feet

FAT 26 oC

Airspeed 130 kts (IAS) 132

Gndspeed 258 kts (from Doppler)

Rotorspeed ______ % (100 = 225 rpm)

A/C Heading 36

Engine Torque #1 70 % #2 62 %

Fuel lbs (total) 1890 lbs.

Run Number 24

LEVEL FLYOVER

GT -- 6, 12, 18, 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 1728

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 760 feet

FAT 26 oC

Airspeed 132 kts (IAS) 132

Gndspeed 247 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 18

Engine Torque #1 67 % #2 66 %

Fuel lbs (total) [illegible] lbs.

Run Number 25

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 1731

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 750 feet

FAT [illegible] oC

Airspeed 100 kts (IAS) [illegible]

Gndspeed 205 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 36

Engine Torque #1 50 % #2 48 %

Fuel lbs (total) [illegible] lbs.

Run Number 26

LEVEL FLYOVER

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

Altitude: 300 ft. AGL or 307

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

Heading 18

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

Mark time 1733

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 750 feet

FAT 26 °C

Airspeed 100 kts (IAS) 104

Gndspeed 194 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 18

Engine Torque #1 48 % #2 46 %

Fuel lbs (total) 1832 lbs.

Run Number 27

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 1736

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt ______ feet

FAT 26 °C

Airspeed 40 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 -- 6, 12, 18, 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 oC

Airspeed 40 kts (IAS) 40

Gndspeed 84 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 12

Engine Torque #1 3[illegible] % #2 36 %

Fuel lbs (total) 1750 lbs.

Run Number 29

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 1742

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 760 feet

FAT 26 oC

Airspeed 130 kts (IAS) 129

Gndspeed 248 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 36

Engine Torque #1 70 % #2 6[illegible] %

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 1747

Set Alt 29.92

Record,

Height AGL 300 feet

Pressure Alt 760 feet

FAT [illegible] oC

Airspeed 130 kts (IAS) 132

Gndspeed 252 kts (from Doppler)

Rotorspeed 100 % (100 = 225 rpm)

A/C Heading 19

Engine Torque #1 70 % #2 69 %

Fuel lbs (total) 1600 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 1750

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

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

*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)**

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

*Distance in meters.

Table B3

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

Indicated Air Speed (Knots)

Aircraft	40	70	100	130	MAX
AH-64	88.8	88.5	88.2	89.7	90.6[1]
Light CH-47D	91.9	91.1	93.2	96.6	99.5[2]
Heavy CH-47D	94.6	90.3	88.7	-	90.8[3]

[1]about 145 knots
[2]about 135 knots
[3]about 119-120 knots

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