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Heliport Noise Model

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1 Introduction

The Heliport Noise Model (HNM) is the United States standard for predicting civil helicopter noise exposure in the vicinity of heliports and airports. HNM Version 1 is the culmination of several years of work in helicopter noise research, field measurements and software development. Up until now, the Federal Aviation Administration (FAA) has had access to only rudimentary helicopter noise prediction tools to use in airport planning. This is in sharp contrast to the modeling of fixed-wing aircraft noise in which the FAA's Integrated Noise Model (INM) has evolved to become the most widely accepted civil airport noise exposure model [Ref. 1]. HNM is now embarking on the same research and development path and under the auspices of the same group that developed INM.

FAA is responsible for the operation and maintenance of the safe and efficient system of air transportation in the United States. FAA must also promote air commerce and enable future aviation development. In light of public awareness of the effects of environmental factors upon their lives, FAA is challenged to discover ways to understand and control the impact of aircraft noise. The Integrated Noise Model (INM) and the Heliport Noise Model (HNM) are two of the key tools to study and manage aircraft noise while sustaining aviation growth.

The growth of the civil helicopter fleet has intensified the demand for additional heliports. However, public concern over environmental factors are imposing restrictions on both existing heliport operations and new construction at an increasing rate. Before HNM, the FAA was unable to provide appropriate technical guidance for planners, operators, and other government agencies in evaluating noise exposure around heliports. HNM is a planning tool by which the heliport operator and local jurisdictions can analyze alternative actions to achieve practical compatibility between helicopter operations and heliport neighbors.

1.1 Background

Since 1968, FAA has continually followed a three pronged approach to aviation noise abatement and environmental protection: (1) by reducing noise at the source through scientific research and regulatory action, (2) by routing aircraft along paths into and out of airports so as to minimize noise impact on airport neighbors, and (3) by encouraging local noise compatibility planning. To control aircraft noise at the source, the FAA promulgated a regulation in 1969 that established noise standards for turbojet aircraft of new type design [Ref. 2]. In following years, amendments were added to the regulation to prescribe: new noise limits, new test conditions, standards for propeller driven small airplanes, production controls, operating limitations, and acoustic change approvals. The cornerstone of the third prong in FAA's noise abatement program is Part

150 of the Federal Aviation Regulations [Ref. 3]. Through the adoption of Part 150, FAA has standardized both the noise measurement unit which is to be used for noise assessment, i.e., the Day Night Average Sound Level (DNL) and the mathematical calculation procedure for determining DNL, i.e. the Integrated Noise Model.

However none of these regulations applied to helicopters or heliports. In 1988, FAA issued a new rule which adds to the Federal Aviation Regulations noise certification standards applicable to helicopters [Ref. 4]. This rule provides commonality between U.S. standards and those adopted by the International Civil Aviation Organization (ICAO). In addition, the rule contains technical standards for noise measurement and procedures for conducting and evaluating helicopter noise tests. At the time that the helicopter noise standards were undergoing the rule making process, FAA was evaluating the need to extend the benefits of FAR Part 150 to heliportoperators. Access to Part 150 was denied to the operators of freestanding public use heliports because there were few public use heliports and adequate computational tools for generating noise contours around heliports were not available. The recent opening of several prototype heliports and the development of the Heliport Noise Model prompted expansion of Part 150 to include freestanding public use heliports.

Having foreseen the eventual need for heliport noise analysis, the FAA began conducting controlled helicopter noise measurement programs in 1976. Initially the plan was to add helicopter noise prediction capability to the established Integrated Noise Model, but INM does not provide the flexibility of input to accommodate the variability in helicopter operations. In addition, most of the INM noise prediction equations, which have been standardized by the Society of Automotive Engineers (SAE) [Ref. 5], do not apply to helicopter noise. In 1982, the FAA produced a technical report which accumulated the results of all previous FAA helicopter measurement tests with the purpose of establishing a helicopter noise data base for use in environmental impact assessment [Ref. 6]. This work became the basic building block upon which the Heliport Noise Model was created.

1.2 Description

The Heliport Noise Model is a computer program used for determining the levels of noise near heliports which are expressed in terms of the Day-Night Average Sound Level (DNL). DNL is a measure of the total amount of acoustical energy received at a given point over a 24 hour period, with all noise received between the hours of 10 pm and 7 am "weighted" with a 10 decibel penalty imposed because people are more sensitive to noise at night. HNM Version 1 works on a variety of personal computers and contains:

- *Data Base of 21 helicopters*
- *Noise curves for hard and soft surface static modes and for left, right and center in-flight modes*
- *Test takeoff, approach and ground taxi profiles*
- *Algorithms for hard and soft surfaces, duration, directivity, source noise, lateral effects, and noise fractions*
- *Graphical input of helipads and flight tracks*
- *Map option - to draw heliport surrounding area*

The HNM source code conforms to the American National Standard Programming Language FORTRAN 77, as described in the American National Standards Institute (ANSI) X3.9-1978 standard and as implemented in the Microsoft FORTRAN Compiler Version 4.01 [Ref. 7]. HNM was written for the IBM personal computer systems and compatibles with the following minimum configuration:

- 512 kilobytes of Random Access Memory (RAM)
- 20 megabyte Hard Disk Drive
- 360 kilobyte or 1.2 megabyte 5-1/4 inch Floppy Disk Drive
- Floating Point Math Coprocessor (8087, 80287, 80387)
- IBM Enhance Graphics Interface (EGA)
- Dot Matrix Printer
- Pen Plotter that can be driven by Hewlett Packard Graphics Language (HPGL)

Use of HNM is made easier with the addition of the optional Summagraphics Summasketch Series MM1201 Graphics Tablet

The HNM distribution package comes complete with User's Guide and floppy diskettes containing the installation procedure, executable files, database, test case and peripheral device drivers for the following:

- 3 types of graphics display monitors,
- 13 types of pen plotters,
- 25 kinds of printers,
- and the Summagraphics Tablet.

1.3 Output

HNM's primary outputs are Day Night Average Sound Level (DNL) contours which are presented in tabular form or as plots (Figure 1). A noise contour is simply a continuous line on a map connecting all locations experiencing the same noise exposure level. HNM can also generate printouts, called grid reports, of the calculated noise levels at selected locations. To produce any of these outputs requires a data base of helicopter noise and performance characteristics, a set of mathematical equations to model both aircraft flight and sound generated by the helicopters, and various data describing the heliport and the helicopter activity. HNM provides the first two features, but the user, i.e. the person running the model, is responsible for the last.

1.4 Noise Metric

The selection of DNL for heliport noise assessment was not simply based upon the fact that FAA had established this metric as the standard for airport noise assessment in FAR Part 150, but was predicated on FAA funded research into the effects of the frequency of operations at heliports and the unique nature of helicopter source noise [Ref.

8]. The results of the study indicate that the patterns of individual reactions to helicopter noise are broadly consistent with the principles contained in the DNL index, and that there is insufficient evidence to support an impulsiveness correction to a helicopter noise metric. Use of the DNL indices for heliport applications was in question due to the low average number of helicopter operations (usually less than 50 a day) as compared to conventional aircraft operations with which the indices were originally developed. It was uncertain whether the indices could adequately report the relative importance of heliport noise levels and the number of noise events. The research described in this report was designed to investigate the reactions of community residents to noise from low numbers of helicopter operations. The final design of the study, which incorporated both laboratory and field study techniques, surveyed residents during periods where, unknown to them, helicopter operations were controlled.

The patterns of reactions to helicopter noise observed in this study are broadly consistent with the additive-logarithmic model implied by L_{EQ}-based noise indices. Reactions are represented as well or better by a logarithmic transformation of the number of noise events than by a simple linear representation of number of noise events. Sound Exposure Level (SEL) and Effective Perceived Noise Level (EPNL) appear to be approximately equally successful in representing noise level in relation to human response. The data also support the inclusion of duration as it is represented in the L_{EQ}-based indices. The inclusion of a measure of the duration of flights improves the ability of a noise index to predict annoyance and, equally important, can account for substantial differences between helicopter types. The data reviewed in the report do not provide support for an impulsiveness correction in a helicopter noise metric which already takes duration into account. The relative effect of noise level and number of events is not significantly different from that implied by the L_{EQ}-based indices. Reactions to helicopter noise increased steadily above 45 dB (L_{EQ}, for 9 hour study day).

2 Noise Data Base

Table 1 presents a list of helicopters which comprise HNM Data Base No. 1. Each helicopter is associated with both performance data and sets of noise-distance tables for stationary and in-flight operating modes. The noise curves for the four stationary modes represent ground idle, flight idle, hover-in-ground-effect, and hover-out-of-ground-effect. The noise data for these quasi-stationary modes consist of tables of the values for the maximum A-weighted sound level (AL_m) at eight distances ranging from 200 to 10,000 feet. For each of these modes there is a data table for propagation over acoustically hard ground (e.g., pavement) and over acoustically soft ground (e.g., grass). The data base also contains coefficients to define the acoustical emission directivity pattern for each static mode. The noise curves for the three moving operations represent takeoff, landing and level flyover. The noise data for these moving operational modes consist of tables of the values of Sound Exposure Level (SEL) at the same eight distances mentioned above. For the level flyovers, the data are given for one typical air speed. Values of SEL at other speeds are calculated using stored constants which are applied to a second order regression equation on main rotor tip speed.

2.1 Sources

One objective of this report is the thorough documentation of data used in developing noise-distance relationships. The following paragraphs provide a brief synopsis of each primary reference used in developing final noise curves as presented in Appendix A:

FAA EE-79-03 [Ref. 9] - This report presented the results of a 1978 FAA test in which acoustical, tracking, meteorological and cockpit data were acquired for eight helicopters. Data from this test were reported with and without corrections to standard acoustical day conditions of 77°F, 70% R.H. Data were provided for 6 degree approaches, takeoffs, and 500 foot level-flyovers.

FAA-EE-81-16 [Ref. 10] - This report presented the results of a 1980 FAA test in which acoustical, tracking, meteorological, and cockpit data were acquired for the S-76, A-109, UH-60A, and 206-L helicopters. Data were reported with and without corrections to standard acoustical day conditions of 77°F, 70% R.H. Data were provided for 6 degree approaches, takeoffs, and level flyovers with speed and altitude variations.

FAA-EE-77-94 [Ref. 11] - This report presented results of a 1976 FAA test which included hover, level flyover and approach operations. Meteorological and cockpit data were provided along with acoustical, data although tracking information was unavailable. The level flyover events included speed variations which permitted derivation of speed-versus-noise-level functions.

CERL Technical Report N-38 [Ref. 12] - This document provided Sound Exposure Level (SEL) versus distance curves for eight helicopter types including the UH-1H, UH-1N, and UH-1B models which are closely related to the UH-1N. This document also provided important information the noise characteristics associated with ground effect hover as well as takeoff, approach, and level flyover.

2.2 Noise Data Reduction

The measurement programs acquired both recorded and direct read acoustical data. The analog magnetic tape recordings were filtered and digitized using the GenRad 1921 one-third octave real-time analyzer. Recording system frequency response adjustments were applied, assuring overall linearity of the recording/reduction system. The stored 24 one-third octave sound pressure levels (SPLs) for each of the one-half second integration periods making up each event comprise the base of "raw data." Data reduction followed the basic FAR-36 procedures. The raw spectral data were adjusted by sloping the spectrum at -2 dB per one-third octave for those one-third octaves (above 1.25 kHz) where the signal-to-noise ratio was less than 5 dB. This procedure was applied in cases involving no more than 9 "missing" one-third octaves. The shaping of the spectrum over this range (up to 9 bands) deviated from the FAR 36 procedures in that the extrapolation includes four more missing bands than normally allowed. However, in this specific case, it was felt that use of the technique was justified as the high frequency spectral shape for most helicopters was observed to fall off regularly at 2 dB per one-third octave.

2.3 Position and Atmospheric Absorption Corrections

"As measured" data were used as the basis from which to compute the "Corrected" data. The process of correcting data for position and atmospheric absorption included the following adjustments:

1. From the measured 24 one-third octave SPLs of the maximum noise spectra to the standard acoustical data conditions utilizing 10-meter meteorological data.

2. For the change in atmospheric absorption associated with the difference in slant range between the actual and reference position of the helicopter at the time of maximum noise.

3. For the spherical spreading associated with the difference in slant range between the actual and reference positions of the helicopter at the time of maximum noise.

The analysis system utilizes a dynamic response time in the processing software which is equivalent to the sound level meter "slow response" characteristics. As cited above, this effective response is required under provisions of FAR-36.

2.4 Noise Curve Development

The fundamental SEL vs. Closest Point of Approach (CPA) distance relationship reflects the change in sound due to the combined effects of spherical spreading and atmospheric absorption through the international sound absorption atmosphere (Table 2). The "Simplified" procedure, to correct for atmospheric absorption and position, consists of applying adjustments derived from differences between actual and reference conditions to the "As Measured" sound exposure level (SEL). The adjustments are calculated based on actual conditions at the moment of the maximum A-weighted level measured (L_{Amax}). The method employed includes the following:

1. A-weighted sound levels (L_A) are computed for each "as measured" data record (one every 0.5 seconds) over the length of the helicopter noise level time history. The L_{Amax} level, its spectrum, and the initial and final 10 dB down data records are identified.

2. The resultant sound level (L_A) are numerically integrated over the period of the 10 dB down duration to obtain the "as measured" SEL for the actual flight path as defined by the CPA distance.

$$L_{AE} = 10\log\left[\sum_{i=1}^{n} 10^{0.1L_{A_i}}\right]0.5$$

3. The position of the aircraft at the time of L_{Amax} and the closest point approach distance are obtained.

4. The L_{Amax} "as measured" spectrum (24-1/3 octave band sound pressure levels) are adjusted to account for differences between test day atmospheric losses and those losses that would have occurred if the meteorological conditions had been such as to yield losses as determined by the SAE reference absorption rates (see Table 2).

5. The reference sound propagation distance (SR_R) is calculated for the L_{Amax} data record.

6. The L_{Amax} spectrum is further adjusted for the change in atmospheric absorption associated with the difference between the actual slant range (SR) and SR_R sound propagation paths using the SAE reference atmospheric absorption coefficients. In addition, losses associated with spherical spreading as a result of differences between the actual and reference propagation paths are accounted for.

7. The adjusted SPL values of the L_{Amax} spectrum are converted to an adjusted A-weighted level L_{Aadj} and a correction term (Δ) to be algebraically applied to the as measured SEL calculated.

$$\Delta_1 = L_{A_{adj}} - L_{A_m}$$

8. The difference between the reference (V_R) and actual ground speed (V), and the new distances, effect the event duration. The effect of the new

duration on the sound exposure level (SEL) at the new distance is taken into account by a duration adjustment terms (Δ_2) where:

$$\Delta_2 = 10\log(CPA/CPA_R) + 10\log(V/V_R)$$

9. SEL at the new distance is obtained by adding the $_1$ and $_2$ terms and the "as measured" SEL.

2.5 Integrated vs. Simplified Adjustment Methods

Based upon an analysis of the derivation of noise-distance curves, a decision was made to use the "simplified adjustment method rather than the "integrated" procedure. Even though, the latter is recommended in SAE AIR 1845 when full spectrum time history data is available as it is for most of the noise data in HNM. Both adjustment procedures are fully described in AIR 1845 [Ref. 5] and will not be repeated here.

The integrated method of adjusting all data throughout the significant portion of the aircraft noise signal does in fact achieve the desired result but is unnecessarily laborious and requires extreme care insure measured sound levels are free from contamination from background acoustic noise or measuring system electronic noise. This can result in anomalous high frequency spectral shaping of the adjusted data, most especially near the 10 dB down points of the adjusted noise level time history, producing incorrect results which are not always readily apparent.

The simplified procedure is more manageable since adjustments to decay the test data to new distances are only applied to a single spectral record, the spectrum of the maximum A-weighted record. Care to insure the "as measured" data are free of contamination is still necessary but is not as critical as with the integrated procedure. The problems with the "simplified" procedure lies with the value selected for the constant (k) for the distance duration adjustment ($_2$).

Noise-distance curves generated for four helicopters using the integrated procedure and the simplified procedure with k = 7.5 and k = 10.0 were compared and differences tabulated in Table 3. Note that the k = 10.0 data compares very closely, over the 200 to 10,000 foot distance, with that derived from the integrated procedure while k = 7.5 data agrees with the integrated curve in the vicinity of 500 feet with errors as high as 4.0 dB at 10,000 feet. The "as measured" data in these cases were generated from 500 foot level flyovers. Noise-distance curves generated from 1,000 foot flyover data where available using the integrated procedure and the simplified procedure with k = 10.0 in the distance duration adjustment terms produce identical SEL vs distance relationship. Thus, it is cost effective and less prone to error to use the simplified rather than the integrated procedure to generate SEL/distance curves. Further considering the differences noted using k = 7.5 in the simplified procedure, it is recommended that k = 10.0 be used in the $_2$ duration adjustment term.

3 Performance Data Base

Not only does HNM Version 1 contain data base of helicopter noise, but also, performance parameters and samples of departure and arrival profiles to guide the user. The three types of profiles used in HNM are takeoff, landing and taxi. Because there are so many ways to operate a helicopter, it is not possible to establish standard procedures for all helicopters at all heliports. For this reason, entry of profile data is a regular requirement of the model in describing operations at a specific heliport.

Rotorcraft Flight Manuals are published for each helicopter certificated under Federal Aviation Regulations. These manuals provide operating limitations, normal and emergency flight procedures, and some performance information. While the flight manual may be the best published source of performance data, there are many commonly used operational procedures which are not included. It is therefore essential that the planner undertaking a heliport noise impact analysis speak directly with helicopter operators to review in detail the way in which helicopters are flown at the particular facility.

HNM provides data on 13 operating modes as shown in Table 4. These data are drawn from operators manuals and the various helicopter noise measurement programs which generated the associated noise-distance curves [Refs. 9-12]. A performance profile is a series of segments which must include the following information:

- *Ground distance of the point from start (or end) of the operation in user specified units (feet, meters or international nautical miles).*
- *Altitude in feet above the heliport.*
- *Velocity in knots at the point (or, for static operations, the duration in seconds of the operation at the point).*
- *Operating mode (thrust name).*

Each profile must contain at least three segments, but no more than fourteen.

3.1 Takeoff Profiles

Of 13 helicopter operating modes identified in the HNM, nine modes may be appropriate for use in takeoff profiles (see Table 5). Table 6 contains an example which defines the takeoff profile illustrated in Figure 2. This sample takeoff profile is the same for all helicopters in Data Base No.1 and is usually referred as the Direct Flight Profile [Ref. 13]. It contains nine profile points which define eight profile segments and 5 operating modes (thrusts). For each of the defined points except the last point, the distance, altitude, velocity, and thrust are the values at that point. For static operations not involving horizontal movement, the duration entered at a point is the duration of the operation initiated at the point. For example, for point 1 at a distance of zero feet, the duration of 10 seconds is the duration of the operation at GIDLE thrust. For point 6 at a distance of 562 feet from the helipad and an altitude of 30 feet, 60 kts is the velocity at point 6, resulting from the acceleration of the previous segment (5-6).

3.2 Landing Profiles

Of the 13 helicopter operating modes identified in the HNM, eight modes may be appropriate for use in landing profiles (see Table 7). Table 8 contains an example which defines the landing profile illustrated in Figure 3. The sample approach profile is the same for all helicopters in Data Base No. 1, and is defined as a constant speed approach to within 0.5 n.mi. of the pad at which point the helicopter decelerates while descending at a constant glideslope. It contains seven profile points which define six segments. For each of the defined points, the distance, altitude, velocity, and thrust are the values at that point, except for the last point. For static operations not involving horizontal movement, the duration entered at a point is the duration of the operation initiated at the point. For example, for point 5 at a distance of zero feet and altitude of fifteen feet, the duration of 3 seconds is the duration of the operation at HOGE thrust. For point 3 at a distance of 4,819 feet from the landing helipad and an altitude of 1,000 feet, the velocity of 60K is the velocity at point 3, resulting from the deceleration of the previous segment (2-3).

3.3 Taxi Profiles

Of the 13 helicopter operating modes identified in the HNM, seven may be appropriate for use in taxi profiles (see Table 9). Table 10 contains an example which defines the taxi profile. The sample taxi operation is the same for all helicopters in Data Base No. 1. It contains eight profile points which define six segments. The constant velocity segment for the "takeoff" portion of the taxi operation is combined with the constant velocity segment for the "landing" portion of the taxi operation. For each of the defined points, the distance, altitude, velocity, and thrust are the values at that point, except for the last point. However, for static operations not involving horizontal movement, the duration entered at a point is the duration of the operation initiated at the point. For example, for point 1 at a distance and altitude of zero feet, the duration of 10 seconds is the duration of the operation at GIDLE thrust.

Note that the flight idle noise thrust curve is used for constant velocity taxi segments if a helicopter has wheels. If the vehicle has no wheels, the HIGE noise curve is used. This distinction is made automatically by the program. The taxi profiles utilize software designed for takeoff and for landing operations to provide for all aspects of a taxi operation. However, the HNM will only allow takeoffs to occur at a designated takeoff/landing pad. Consequently, the "takeoff" portion of a taxi operation must begin at the takeoff/landing pad regardless of the actual initiation point of the taxi operation being modeled. When the helicopter is taxiing from the takeoff/ landing pad to the parking pad, the profile is being used in the "direct" sequence. However, when the helicopter taxies from the parking place to the takeoff/landing pad, the profile is given in "reverse" sequence as shown in the example in Table 11.

4 Calculation Procedures

The Heliport Noise Model, like any other computer program, is simply a set of equations tied together into a process. To calculate helicopter noise requires simulation of both its performance and source noise propagation. The general procedure for determining the sound exposure level is to extract a sound level from the reference acoustical data base at the appropriate distance and operational mode, and then to adjust the level to account for differences between actual conditions and the reference conditions associated with the data base.

4.1 Aircraft Position

The model represents helicopter flight as the combination of the appropriate profile and ground track definitions on a Cartesian coordinate system. A track is composed of up to sixteen segments which are alternately straight and curved. The calculation of single event noise exposure at any location requires not only the slant distance between the calculation point and each of the flight segments but also the values of the profile parameters, i.e. altitude, velocity and operating mode, of each segment.

4.2 Single Event Noise Exposure

For each helicopter type, the procedure for determining the sound exposure level at any location is to extract the appropriate level from the noise data base at the minimum distance between the helicopter and the location, and then to add adjustments to account for differences between actual conditions and the reference conditions of the data base. The adjustments to the basic noise level at distance, d, and for operating mode, O, takes the following form:

$$L_{AE} = L_{AE}(O,d) + \Delta_{L/R} + \Delta_{\beta} + \Delta_{M} + \Delta_{\phi} + \Delta_{d} + \Delta_{\Theta} + \Delta_{c} + \Delta_{V}$$

The factors are defined as follows:

$\Delta_{L/R}$ Left/Right Directivity: Each helicopter has a left or right side noise dominance depending upon the direction of rotation of the main rotor and the location of the tail rotor. In HNM Version 1, this phenomena is accommodated by the use of left, right and centerline noise curves for each of the in flight operational modes (takeoff, approach and level flight). The sideline noise curves have been normalized to an elevation angle of 45 degrees. For any angle between 45 degrees and overhead (90 deg.), the sound level is determined by interpolation between the reference elevation angles.

Δ_β Lateral Effect: For elevation angles of less than 45 degrees, the sound exposure level is calculated from the left or right noise curve with a correction for excess ground attenuation and source directivity that are helicopter specific. However, unlike fixed-wing aircraft, the adjustment is not necessarily an attenuation.

Δ_M Source Noise Correction: When the helicopter is in level flight cruise, an adjustment is made based upon the change in the Mach number of the advancing blade.

Δ_θ Static Directivity: Analysis of hover-in-ground-effect (HIGE) measurements resulted in the derivation of acoustical emission directivity patterns for both hard and soft surfaces.

Δ_d Static Duration: Duration of a static event, such as flight idle, becomes a multiplier to the acoustical energy.

Δ_ϕ Noise Fraction: The SEL database contained within HNM Version 1 assumes a helicopter flyby along a path that is straight and of infinite length. The sound exposure fraction of a flight segment is that portion of the total sound exposure for the infinite path that can be attributed to the finite, straight segment. Its derivation is based on a 90 degree dipole model of the time history of the sound received at an observer position. The noise fraction does not apply to static operations.

Δ_V Speed Duration Effect: Helicopter speed effects the duration of the noise event, thus, a change in velocity from the stored reference results in a decibel change due to change in duration.

Δ_C Conversion from A_{Lm} to SEL: Static noise data is stored as maximum A-weighted sound levels (A_{Lm}) which must be converted to SEL before use in deriving the cumulative level.

4.3 In-flight Operations

4.3.1 Source Noise Adjustment (Level Flyover ONLY)

This adjustment is necessary when the airspeed, temperature, or rotor RPM deviates from reference value. The adjustment is calculated using stored constants from a polynomial regression using the following equation:

$$\Delta_M = b_0 + b_1 (M_{ADV_t} - M_{ADV_r}) + b_2 (M_{ADV_t} - M_{ADV_r})^2$$

where;

B_0, and B_1 and B_2 are helicopter specific coefficients.

M_{ADV} is the advancing tip Mach Number as defined in the equation:

$$M_{ADV} = (1.689 \cdot V)[\pi \cdot D \cdot RPM)/60]/C$$

c is the speed of sound as defined in the equation:

$$C = 49.02\,(459.63/T)^{0.5}$$

4.3.2 Speed duration effect

$$\Delta_V = 10\log(V_t/V_r)$$

where;

V_r is the reference airspeed for the noise curve

V_t is the operational airspeed

4.3.3 Left/Right Directional Adjustment

In-flight directivity in terms of elevation angle is accounted for by three sets of SEL data for left, center and right. The left and right data are corrected to an elevation angle of 45° and the center data at 90°. At sites where the propagation angle is between -45° and 45°, a linear interpolation will be performed on the observed elevation angle between the centerline SEL value and the left or right 45° SEL value for all distances. In the absence of a helicopter specific function, a generalized (symmetrical left/right) low angle function will operate below 45°

4.3.4 Low Angle Adjustment

Between 45° and 15° on either side of the helicopter, a helicopter specific adjustment will be applied arithmetically to the appropriate 45 degree SEL value [Ref. 14]. This adjustment value will be determined using an equation of the following form:

$$\Delta_{L/R} = c_1 (t - 45)$$

where;

t is the observed elevation angle

c_1 is the helicopter specific slope

In all cases where the elevation angle between the observer and the helicopter is less than 15 degrees a separate function will be utilized. This relationship will be a linear function of theta. The relationship will take the form:

$$\Delta_\theta = d_0 + d_1 (15 - \theta)$$

Appendix B contains the lateral attenuation coefficients from the HNM data base.

4.3.5 Effect of Turns on Duration

The SEL data base contained within HNM Version 1 assumes a helicopter flyby along a path that is straight and of infinite length. Turning flight tracks are represented by a series of short straight line segments. The contribution of each segment to the change in duration time and therefore to the sound exposure level is estimated by computing the sound fraction of each straight segment [Ref. 15]. The sound exposure fraction of a flight segment is that portion of the total sound exposure for the infinite path of the noise data base that can be attributed to the finite, straight segment. Its derivation is based on a 90° dipole model of the time history of the sound received at an observer position. The fractional sound exposure components are then summed yielding values that are representative of the change in noise exposure resulting from flight path curvature.

4.4 Static Operations

Helicopters operating in a nominally static mode, such as, ground idle, flight idle, hover in ground effect and hover out of ground effect, tend to exhibit pronounced directive differences in their sound radiation patterns. This spatial variation in the emission of sound is accompanied by a continuous variation with time for any given radiation angle. In addition, the effect is different when over an acoustically hard surface, such as, concrete or asphalt, as opposed to a soft surface.

4.4.1 Directivity

The static data base consists of several categories:

- Analysis of hover-in-ground-effect measurements resulted in the derivation of acoustical emission directivity patterns for both hard and soft surfaces [Ref. 16]. The general form of the equation is illustrated in Figure 4. The directivity factor is an adjustment to the sound level as a function of the helicopter azimuth angle which is measured clockwise from the nose. The function is a least square error fit using five cosine terms and three sine terms. Appendix C provides the stored parameters for specific helicopters in the HNM data base.
- Omnidirectional noise data estimates derived from FAA noise estimation curves. These data will then be projected to other distances using the soft propagation relationships.

The directional pattern should be used only in situations where the helicopter will, throughout the year be used in a finite directional manner. If this cannot be assumed then spatial/time average, omnidirectional patterns should be utilized.

4.4.2 Conversion from AL_m to SEL

All static mode reference noise data is stored as maximum A-weighted Sound Level (ALm). When HIGE is used for a moving helicopter during a taxi operation, the ALm data is transformed into Sound Exposure Level (SEL) by means of a dipole function of the following form:

$$\Delta_c = 10\log[(\pi/2)(SR/V_f)]$$

where;

SR is the slant range distance to the helicopter, in feet

V_f is the airspeed, in feet/second

4.4.3 Duration

Duration of a static event, such as flight idle, becomes a multiplier to the acoustical energy in the following form:

$$\Delta_d = +10^{(0.1 L_{AE})}$$

where;

t is the duration of the static operation, in seconds

4.5 Cumulative Noise Exposure

As stated earlier, the Heliport Noise Model is a computer program used for determining the levels of noise near heliports which are expressed in terms of the Day-Night Average Sound Level (DNL) according to the following equation for discrete events:

$$L_{dn} = 10 \log \left[\sum_{i=1}^{n} 10^{(0.1 L_{AE}(i))} + 10 \sum_{j=1}^{m} 10^{(0.1 L_{AE}(j))} \right] - 49$$

where;

$L_{AE}(i)$ is the sound exposure level of the ith event during the day, i.e., 0700h to 2159h.

$L_{AE}(j)$ is the sound exposure level of the jth event during the night, i.e., 2200h to 0659h

In the model, it is convenient to calculate the yearly DNL by making use of the annual average number of helicopter operations per day and night for each helicopter type.

4.6 Contours

HNM's primary outputs are DNL contours which are presented in tabular form or as plots. A noise contour is simply a continuous line on a map connecting all locations experiencing the same noise exposure level. HNM Contours are derived, in the same manner as INM contours [Ref. 17], from the calculation of the noise surface due to helicopter operations. The noise surface is actually cumulative levels calculated at the intersections of an irregular grid; which is irregular because instead of constant spacing between intersections, the model makes decisions to generate more intersections as needed to produce a smooth noise surface. The contour lines are then found by interpolating between intersections.

5 Validation

FAA has used the best available data to the fullest extent possible in the development of Heliport Noise Model (HNM) Version 1.1. HNM is the culmination of several years of helicopter noise research involving manufacturers, Federal agencies, foreign governments and the Society of Automotive Engineers (SAE). FAA will continue to develop and refine HNM in the years to come to maintain its position as the state-of-the-art in heliport noise analysis.

As clearly stated in this report, HNM represents results of many helicopter noise measurement programs over the years. These tests have been conducted under rigorously controlled conditions involving generally small sample sizes. The purpose of the future HNM validation project is to determine the accuracy of both the computational methods and data base by comparing the model's calculations to monitored results. It has been the FAA experience in the INM Validation project [Refs. 18-20] that this process requires the evaluation of individual fundamental building blocks or components. Therefore it is the intent of the FAA to begin with the validation of the fundamental noise-distance relationships by obtaining large samples of helicopter flyover events at several heliports over a substantial portion of the year. Large and varied samples ensure that the results are statistically significant and without bias.

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Figures

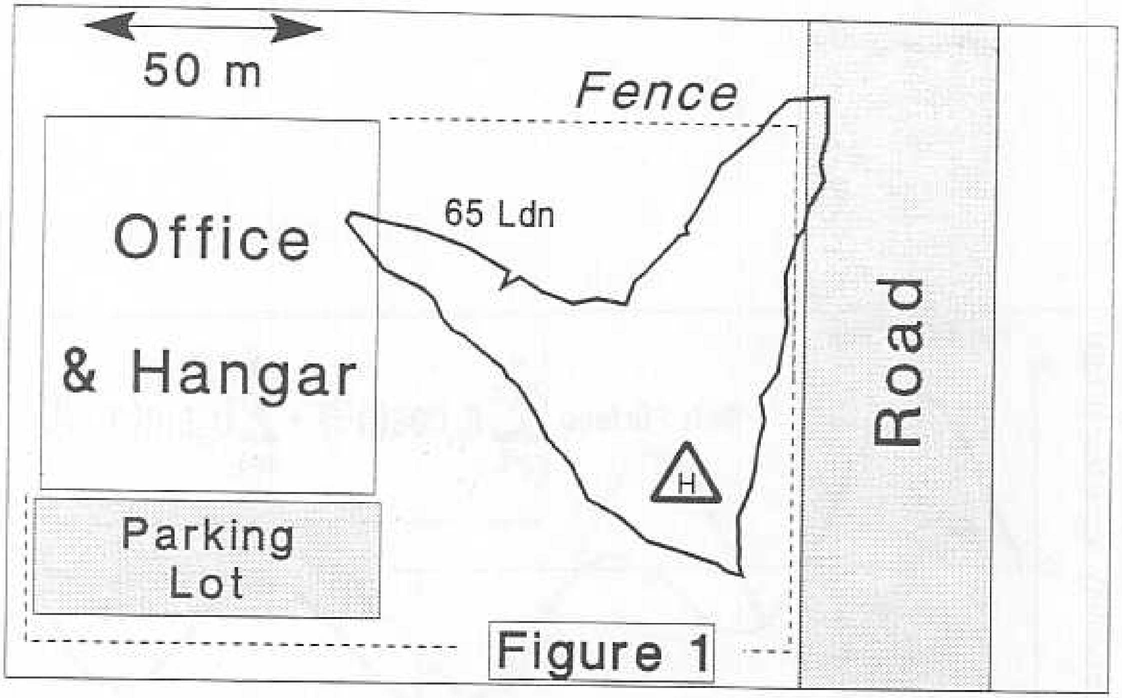

Figure 1

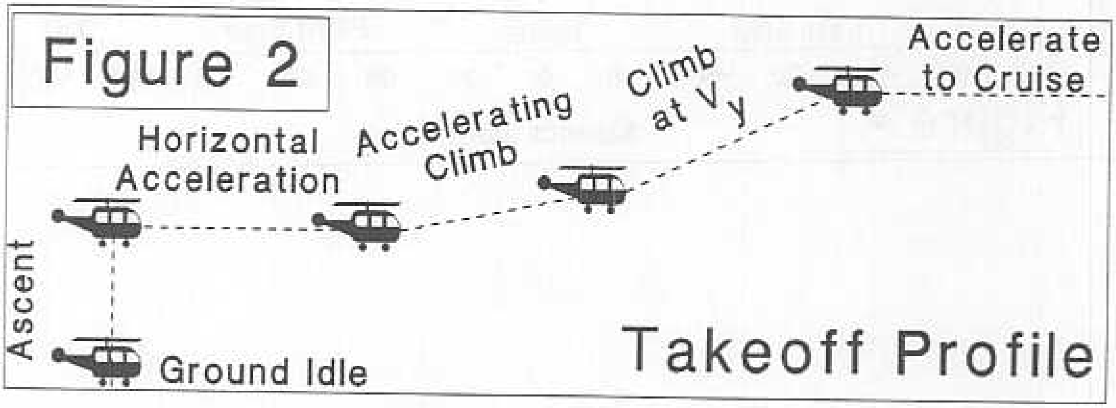

Figure 2

Takeoff Profile

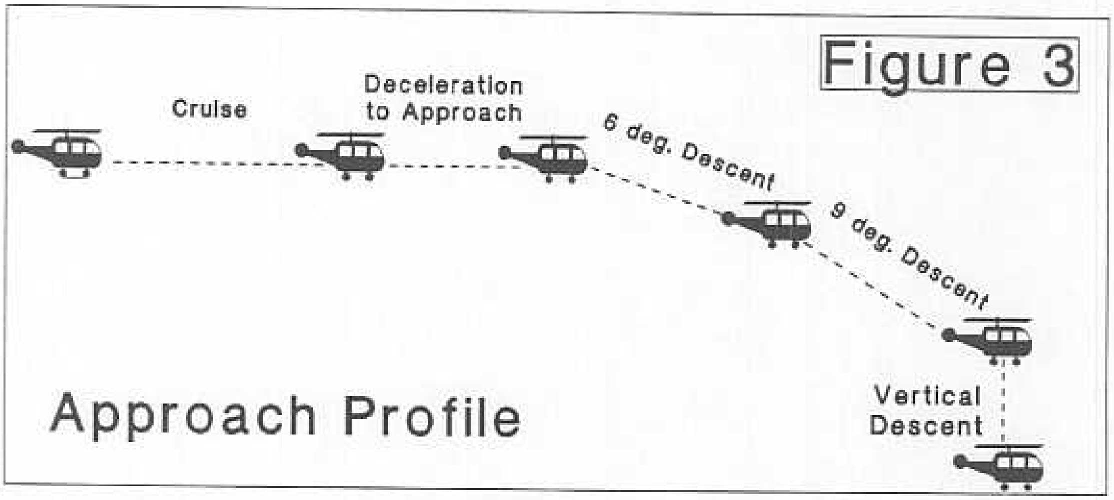

Figure 3

Approach Profile

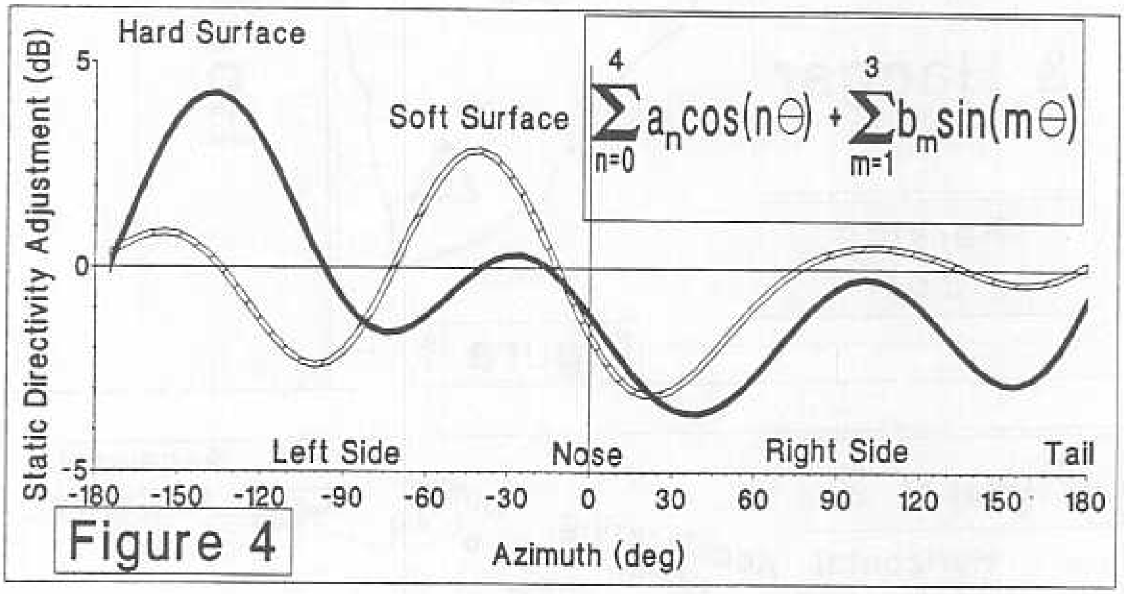
Hard Surface
Soft Surface
$\sum_{n=0}^{4} a_n \cos(n\Theta) + \sum_{m=1}^{3} b_m \sin(m\Theta)$
Static Directivity Adjustment (dB)
5
0
-5
Left Side
Nose
Right Side
Tail
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
Azimuth (deg)

Figure 4

Appendix C

Static Directivity Coefficients

Table A-2. **Helicopter Directivity Pattern Coefficients**

Helicopter	Path	Coefficients							
		- Cosine terms					- Sine terms		
		a_0	a_1	a_2	a_3	a_4	b_1	b_2	b_3
Bell 222	Hard	-0.59237	-1.14299	-0.17480	0.94277	-0.20000	-1.60432	0.77495	-1.75457
	Soft	-0.28927	-0.32619	0.02495	-0.57387	-0.49992	-0.24125	-1.22508	-1.49111
SA-365N	Hard	-0.51802	-2.08223	0.17497	-0.66764	-0.41251	-0.10988	0.60010	2.09008
	Soft	-0.70137	-2.10033	0.64005	-1.44973	0.97506	-0.33335	1.00994	0.03671
H500D	Hard	-2.12589	-5.61492	-0.14977	1.31477	0.72498	-2.35532	0.60002	-0.75586
	Soft	-2.56115	-5.73704	0.77528	-0.36318	-1.03748	-0.42319	2.09986	-1.27355
AS355F	Hard	-1.90408	-4.89956	0.70010	-0.55044	-0.28749	-2.77874	0.97506	1.47104
	Soft	-0.74464	-3.28579	-0.19996	-1.16419	-0.42496	-0.51265	0.90008	0.93731
AS350D	Hard	-1.41909	-4.11177	-0.13475	-0.78845	0.41755	-0.30721	2.19995	-1.17742
	Soft	-0.53827	-2.61368	0.99996	-0.38626	-0.06249	-0.07613	-0.62508	0.32383
S-76A	Hard	-1.52630	-4.66072	-1.02507	-2.53935	-0.16230	-0.84154	-1.29996	-1.49132
	Soft	-1.55469	-4.23485	0.07482	-1.26503	-0.91239	1.05798	-2.45005	-0.49191
BV234/CH47D	Hard	-1.20323	0.73770	1.02505	-0.28766	-1.87506	2.18797	1.72490	0.88796
	Soft	-2.16113	0.49999	3.32500	-0.94996	-2.97504	3.52078	1.22459	0.12090
R22HP	Hard	-0.42677	-1.47011	-1.47506	-0.47983	-0.96245	-1.09134	-0.54978	0.80869
	Soft	-1.22094	-3.72551	2.10003	0.37548	0.42499	-0.25517	-0.85026	-0.80538
MBB BK117	Hard	-6.03468	-8.29072	-1.49959	-0.75959	-1.83743	-4.39023	3.27523	-0.24072
	Soft	-2.11642	-2.58532	-1.99998	2.43556	-1.92514	1.31973	0.10033	2.56920
Augusta 109	Hard	-0.54193	-0.97634	-1.32480	2.27624	0.53742	0.03165	0.80009	-0.81431
	Soft	-0.85536	0.41072	-1.10018	-0.26048	-1.71252	-0.56129	-0.72472	2.78881

Tables

Table 1

Helicopters Stored in HNM Data Base

Storage	Helicopter Name	Description	Max. Weight (lbs.)
1	B212	Bell 212 (UH-1N)	10,500
2	S61	Sikorsky S-61 (CH-3A)	19,000
3	S64	Sikorsky S-64 (CH-54B)	42,000
4	CH47D	Boeing Vertol 234 (CH-47D)	48,500
5	H500D	Hughes 500D	2,550
6	BO105	Boelkow BO-105	5,070
7	B47G	Bell 47G	2,950
8	SA330J	Aerospatiale SA-330J	15,432
9	B206L	Bell 206L	4,000
10	A109	Augusta A-109	5,730
11	SA341G	Aerospatiale SA-341G	3,970
12	H300C	Hughes 300C	1,900
13	S65	Sikorsky S-65 (CH-53)	37,000
14	S70	Sikorsky S-70 (UH-60A)	20,250
15	S76	Sikorsky S-76	10,000
16	SA365N	Aerospatiale SA-365N	8,488
17	SA355F	Aerospatiale SA-355F	5,070
18	SA350D	Aerospatiale SA-350D	4,300
19	B222	Bell 222	7,800
20	R22HP	Robinson R22HP	1,300
21	BK117	Boelkow BK-117	6,283

Table 2

Attenuations Coefficients for Extrapolation of Duration Adjustments to Sound Exposure Level

Center Frequency of 1/3 Octave Band, Hz	Attenuation Coefficient decibels per 100 meters
50	.033
63	.033
80	.033
100	.066
125	.066
160	.098
200	.131
250	.131
315	.197
400	.229
500	.295
630	.361
800	.459
1,000	.590
1,250	.754
1,600	.983
2,000	1.311
2,500	1.705
3,150	2.295
4,000	3.115
5,000	3.607
6,300	5.245
8,000	7.213
10,000	9.836

Table 3

Comparison of Integrated vs Simplified Adjustment Procedure

Delta SEL(dB)*
at Closest Point of Approach Reference Distance (feet)

Helicopter	k**	200	400	630	1000	2000	4000	6300	10000
SA-365N	7.5	-0.7	-0.2	0.1	0.5	1.2	2.3	3.1	4.0
	10.0	0.3	0.1	-0.1	-0.2	-0.3	0.1	0.4	0.8
Bell 222	7.5	-0.7	0.0	0.6	1.0	1.8	2.4	2.9	3.5
	10.0	0.1	0.0	-0.1	0.0	0.1	-0.1	-0.1	0.0
S-76	7.5	-0.9	-0.3	0.2	0.6	1.3	2.0	2.5	3.1
	10.0	-0.1	0.0	-0.0	-0.1	-0.2	-0.2	-0.2	-0.1
UN-60A	7.5	-0.9	-0.2	0.1	0.5	1.1	1.8	2.4	2.9
	10.0	-0.1	-0.1	0.1	-0.2	-0.4	-0.4	-0.3	-0.3

---

* As measured data from 500 foot level flyovers measured at centerline

** Where k is duration constant in distance duration adjustment 2

Table 4

HNM Data Base
Operating Modes and Thrust Names

Operating Mode	Thrust Name	Default Thrust Name in the Data Base
Ground Idle	GIDLE	GIDLE
Flight Idle	FIDLE	FIDLE
Hover In Ground Effect	HIGE	HIGE
Hover Out of Ground Effect	HOGE	HOGE
Vertical Ascent	VASC[1]	HIGE/HOGE[2]
Takeoff at Constant Velocity (Vy)	TO	TO
Accelerating Horizontal Takeoff	ACLH[1]	TO
Accelerating Climbing Takeoff	ACLC[1]	TO
Level Flyover (Cruise)	LFLO	LFLO
Descent at Constant Velocity (Vy)	APPR	APPR
Decelerating Descent	DCLD[1]	APPR
Horizontal Deceleration	DCLH[1]	APPR
Taxi	HIGE	HIGE

Table 5

Takeoff Profiles
Operating Modes and Thrust Names

Operating Mode	Thrust Name	Default Thrust Name in the Data Base
Ground Idle	GIDLE	GIDLE
Flight Idle	FIDLE	FIDLE
Hover In Ground Effect	HIGE	HIGE
Hover Out of Ground Effect	HOGE	HOGE
Vertical Ascent	VASC[1]	HIGE/HOGE[2]
Takeoff at Constant Velocity (Vy)	TO	TO
Accelerating Horizontal Takeoff	ACLH[1]	TO
Accelerating Climbing Takeoff	ACLC[1]	TO
Level Flyover (Cruise)	LFLO	LFLO

Notes:

[1] The data base is designed to provide offset constants to add to the default noise curve. In the data base, these constants are zero until experimentally determined.

[2] If the final altitude is greater than 1.5 times the rotor diameter, HOGE is used by the model. Otherwise, HIGE is used.

Table 6

Sample Helicopter Takeoff Profile

Description	Distance (ft)	Altitude (ft)	Velocity or Duration IAS(K) or SEC	Thrust
1. Startup and Idle	0	0	10 (SEC)	GIDLE
2. Flight Idle Checks	0	0	10 (SEC)	FIDLE
3. Vertical Ascent to 15 ft. and Hover	0	0	3 (SEC)	HOGE
4. Horizontal Accel. to 30K (0.2g)	0	15	16 (K)	TO
5. Climb and Accel. to 60K at 30 ft.	100	15	30 (K)	TO
6. Climb at 1,700 ft./min.	562	30	60 (K)	TO
7. Accel. to Cruise	4,032	1,000	60 (K)	TO
8. Begin Cruise	6,786	1,000	100 (K)	LFLO
9. End of Cruise	99,999	1,000	100 (K)	

Table 7

Landing Profiles
Operating Modes and Thrust Names

Operating Mode	Thrust Name	Default Thrust Name in the Data Base
Ground Idle	GIDLE	GIDLE
Flight Idle	FIDLE	FIDLE
Hover In Ground Effect	HIGE	HIGE
Hover Out of Ground Effect	HOGE	HOGE
Descent at Constant Velocity (Vy)	APPR	APPR
Decelerating Descent	DCLD[1]	APPR
Horizontal Deceleration	DCLH[1]	APPR
Level Flyover (Cruise)	LFLO	LFLO

Notes:

[1] The data base is designed to provide offset constants to add to the default noise curve. In the data base, these constants are zero until experimentally defined.

Table 8

Sample Helicopter Landing Profile

Description	Distance (ft)	Altitude (ft)	Velocity/ Duration IAS(K) or SEC	Thrust
1. Cruise	99,999	1,000	100 (K)	LFLO
2. Decel. to Approach	10,535	1,000	100 (K)	APPR
3. 6½ Descent to 500 ft.	4,819	1,000	60 (K)	APPR
4. 9½ Decel. Descent	3,062	500	60 (K)	APPR
5. Hover and Vertical Descent	0	15	3 (SEC)	HOGE
6. Ground Idle	0	0	10 (SEC)	GIDLE
7. Stop	0	0	0	

Table 9

Operating Modes and Thrust Names

Operating Mode	Thrust Name	Default Thrust Name in the Data Base
Ground Idle	GIDLE	GIDLE
Flight Idle	FIDLE	FIDLE
Hover In Ground Effect	HIGE	HIGE
Hover Out of Ground Effect	HOGE	HOGE
Vertical Ascent	VASC[1]	HIGE/HOGE[2]
Taxi	HIGE	HIGE
Decelerating Descent	DCLD[1]	APPR

Notes:

[1] The data base is designed to provide offset constants to add to the default noise curve. In the data base, these constants are zero until experimentally defined.

[2] If the final altitude is greater than 1.5 times the rotor diameter, HOGE is used by the model. Otherwise, HIGE is used.

Table 10

Sample of Helicopter "Direct"* Taxi Profile

Description	Initial Distance (ft)	Initial Altitude (ft)	Initial Velocity/ Duration IAS(K) or SEC	Thrust
Takeoff Portion:				
1. Ground Idle	0	0	10 (SEC)	GIDLE
2. Vertical Ascent to 3 ft. and Acceleration	0	0	2 (SEC)	HIGE
3. Initial Horizontal Taxi Motion	0	3	10 (K)	HIGE
4. Constant Velocity**	5,280	3	10 (K)	
Landing Portion:				
1. Constant Velocity**	5,280	3	10 (K)	HIGE
2. Vertical Descent to Ground and Deceleration	0	3	2 (SEC)	HIGE
3. Ground Idle	0	0	30 (SEC)	GIDLE
4. Stop	0	0	0	

---

[*] This example is for a "direct" operation in which the helicopter starts from the takeoff/landing pad, moves to the parking pad, sits down and stops.

[**] The HNM combines two constant velocity segments into a single taxi segment with a length specified by the operator in the track definition. The "5280" feet is ignored.

Table 11

Sample of Helicopter "Reverse" Taxi Profile

Description	Initial Distance (ft)	Initial Altitude (ft)	Initial Velocity/ Duration IAS(K) or SEC	Thrust
Takeoff Portion:				
1. Ground Idle	0	0	10 (SEC)	GIDLE
2. Vertical Descent and Decel.	0	0	2 (SEC)	HIGE
3. Initial Horizontal Taxi Motion	0	3	10 (K)	HIGE
4. Constant Velocity**	5,280	3	10 (K)	
Landing Portion:				
1. Constant Velocity**	5,280	3	10 (K)	HIGE
2. Vertical Ascent and Accel.	0	3	2 (SEC)	HIGE
3. Flight Idle Check	0	0	120 (SEC)	FIDLE
4. Ground Idle	0	0	60 (SEC)	GIDLE
5. Stop	0	0	0	

---

[*] This example is for a "reverse" operation in which the initial GIDLE and FIDLE operations occur at the parking pad, the helicopter then moves to the takeoff pad, sits down, and idles for 10 seconds.

[**] The HNM combines two constant velocity segments into a single taxi segment with a length specified by the operator in the track definition. The "5280" feet is ignored.

TABLE A-3a.

HNM DATABASE 1

#1 NAME: BELL 212 SOURCE: TSC 48-FA-753-LR4 - 3 DEC. 86

SLANT DIST. (ft)	TAKEOFF @ 53.37 KTS			6° APPROACH @ 54.7 KTS			LEVEL FLYOVER @ 93.96 KTS		
	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	93.4	92.1	95.5	93.9	97.5	97.8	95.1	95.7	97.3
400	90.1	88.8	92.3	90.6	94.3	94.5	91.7	92.3	93.8
630	87.8	86.4	89.8	88.4	92.1	92.2	89.3	90.0	91.3
1,000	85.2	83.9	87.3	85.9	89.7	89.7	86.6	87.5	88.5
2,000	80.9	79.7	82.9	82.0	85.9	85.4	82.1	83.4	83.8
4,000	75.6	74.7	77.5	77.3	81.4	80.1	76.7	78.7	78.1
6,300	71.4	70.9	73.2	73.8	77.8	75.8	72.5	74.9	73.8
10,000	66.2	66.5	67.9	69.5	73.4	70.3	67.7	70.4	68.9
Coefficients: No Wheels,				DIA = 48.19 FT,			RPM = 324		
B0							0	0	0
B1							0	0	0
B2							0	0	0
R^2 (not input)									

STATIC CONDITIONS

SLANT DIST.	Ground Idle		Flight Idle		HIGE		HOGE	
	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
200								
400								
630								
1,000								
2,000								
4,000								
6,300								
10,000								

TABLE A-3b.

#2 NAME: SIKORSKY S-61 (CH3A) SOURCE: TSC 48-FA-753-LR5 - 3 DEC. 86

SLANT DIST. (ft)	TAKEOFF @ 73.21 KTS			6° APPROACH @ 73.59 KTS			LEVEL FLYOVER @ 129.6 KTS		
	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	96.8	95.3	96.3	95.1	95.0	94.8	96.1	93.3	95.0
400	93.3	91.8	92.9	91.6	91.7	91.3	92.5	89.7	91.5
630	90.7	89.2	90.5	89.2	89.3	88.9	90.0	87.2	89.0
1,000	87.9	86.2	87.8	86.5	86.8	86.3	87.2	84.3	86.3
2,000	83.2	81.2	83.2	81.9	82.7	81.8	82.5	79.5	81.6
4,000	77.5	75.1	77.7	76.9	77.8	76.3	76.6	73.8	76.0
6,300	73.1	70.3	73.3	72.0	74.0	72.1	72.0	69.3	71.5
10,000	67.9	64.6	68.1	66.9	69.6	67.1	66.5	63.9	66.3
Coefficients: Wheels,				DIA = 62 FT,			RPM = 203 .		
B0							0	0	0
B1							0	0	0
B2							0	0	0
R^2 (not input)									

STATIC CONDITIONS

SLANT DIST.	Ground Idle		Flight Idle		HIGE		HOGE	
	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
200								
400								
630								
1,000								
2,000								
4,000								
6,300								
10,000								

TABLE A-3c.

UNRUH
TSC-48-FA-753-LR1 - 14 NOV. 86
HNM DATABASE 1

#4 NAME: BOEING VERTOL CH-47D SOURCE: TSC-48-FA-653-LR24 - 16 SEPT. 86

SLANT DIST. (ft)	TAKEOFF @ 85 KTS (ICAO)			6° APPROACH AT 85 KTS (ICAO)			LEVEL FLYOVER @ 120 KTS		
	Left	Center	Right	Left	Center (simplified 10 dB)	Right	Left	Center (500 ft.)	Right
200	93.8	92.7	92.8	100.4	101.3	97.7	92.7	91.2	92.3
400	89.9	89.0	89.2	97.1	98.0	94.3	88.8	87.5	88.5
630	87.2	86.4	86.5	94.9	95.8	92.0	86.2	84.9	85.8
1,000	84.2	83.5	83.6	92.5	93.5	89.6	83.3	82.0	82.9
2,000	79.1	78.6	78.7	88.6	89.6	85.6	78.5	77.0	78.1
4,000	73.1	72.9	72.7	84.0	85.1	81.0	73.0	71.3	72.6
6,300	68.6	68.5	68.1	80.4	81.7	77.4	68.9	67.1	68.6
10,000	63.5	63.5	62.7	76.1	77.6	73.0	64.4	62.5	64.1
Coefficients: Wheels, 2 Rotors,				DIA = 60.0 FT,			RPM = 225		
B0							0	0	0
B1							36.97	42.21	33.86
B2							1418.53	2213.44	527.01
R^2 (not input)							1.00	1.00	1.00

STATIC CONDITIONS

SLANT DIST.	Ground Idle		Flight Idle		HIGE		HOGE	
	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
200						86.3		92.3
400						79.5		85.7
630						75.0		81.3
1,000						70.2		76.6
2,000						62.9		69.3
4,000						55.2		61.2
6,300						50.0		55.5
10,000						44.7		49.2
DIR					Yes	Yes		

TABLE A-3d.

UNRUH

HNM DATABASE 1

#5 NAME: HUGHES 500D

SOURCE: TSC-48-FA-753-LR1 - 14 NOV. 86
TSC-48-FA-653-LR22 - 29 AUG. 86

SLANT DIST. (ft)	TAKEOFF @ 62 KTS (ICAO)			6° APPROACH @ 62 KTS			LEVEL FLYOVER @ 111 KTS		
	Left	Center	Right	Left	Center	Right	Left (500 ft. alt. clock)	Center	Right
200	89.3	86.4	88.5	88.6	90.4	90.9	87.4	84.9	86.9
400	86.0	83.1	85.2	85.2	87.1	87.5	83.9	81.6	83.5
630	83.7	80.8	82.8	82.9	84.7	85.1	81.6	79.3	81.2
1,000	81.2	78.3	80.2	80.3	82.2	82.4	78.9	76.8	78.7
2,000	76.9	74.2	75.8	76.0	77.9	77.8	74.5	72.7	74.4
4,000	71.7	69.2	70.5	70.7	72.7	72.1	69.1	67.9	69.2
6,300	67.6	65.1	66.1	66.5	68.5	67.4	65.0	64.2	65.3
10,000	62.4	60.3	60.7	61.5	63.3	61.6	60.0	59.8	60.5
Coefficients: No Wheels,				DIA = 26.41 FT,			RPM = 492 .		
B0							-.27	-.17	.20
B1							24.06	-17.5	20.04
B2							810.41	183.63	470.06
R^2 (not input)							.78	.94	.81

STATIC CONDITIONS

SLANT DIST.	Ground Idle		Flight Idle		HIGE		HOGE	
	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
200						79.8		
400						73.1		
630						68.4		
1,000						63.4		
2,000						55.2		
4,000						46.3		
6,300						40.5		
10,000						34.7		
DIR					Yes	Yes		

TABLE A-3e.

#6 NAME: BOELKOW BO-105 SOURCE: TSC-48-FA-753-LR7 - 3 DEC. 86

SLANT DIST. (ft)	TAKEOFF @ 67.22 KTS			6° APPROACH @ 69.62 KTS			LEVEL FLYOVER @ 117 KTS		
	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	90.1	88.9	89.9	93.4	95.4	93.1	92.5	90.7	91.8
400	86.8	85.5	86.5	90.0	92.1	89.7	89.1	87.3	88.4
630	84.4	83.3	84.2	87.6	89.7	87.2	86.7	84.9	85.9
1,000	81.8	80.8	81.6	84.9	87.1	84.6	84.1	82.4	83.2
2,000	77.5	76.7	77.4	80.3	82.7	80.0	79.6	78.2	78.5
4,000	72.3	71.9	72.4	74.8	77.3	74.4	74.1	73.2	72.8
6,300	68.1	68.1	68.4	70.5	72.9	69.9	69.9	69.3	68.3
10,000	63.0	63.6	63.6	65.4	67.5	64.4.	64.9	64.6	63.0
Coefficients: No Wheels,				DIA = 32.23 FT,			RPM = 424		
B0							0	0	0
B1							0	0	0
B2							0	0	0
	R^2 (not input)								

STATIC CONDITIONS

SLANT DIST.	Ground Idle		Flight Idle		HIGE		HOGE	
	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
200								
400								
630								
1,000								
2,000								
4,000								
6,300								
10,000								

TABLE A-3f.

#8 NAME: AEROSPATIALE PUMA SA330J SOURCE: TSC-48-FA-753-LR2 - 3 DEC. 86

SLANT DIST. (ft)	TAKEOFF @ 69.39 KTS			6° APPROACH @ 69.62 KTS			LEVEL LEVEL FLYOVER @ 126 KTS		
	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	96.8	93.9	97.1	96.0	95.5	96.1	95.7	94.2	95.4
400	93.2	90.3	93.7	92.5	92.2	92.7	92.2	90.5	91.8
630	90.8	87.7	91.3	90.1	89.9	90.3	89.7	87.8	89.4
1,000	88.1	84.9	88.7	87.5	87.5	87.6	87.1	84.8	86.6
2,000	83.5	79.9	84.3	83.1	83.6	83.2	82.6	79.4	82.0
4,000	77.9	73.9	78.9	77.9	79.1	77.8	77.1	72.5	76.4
6,300	73.5	69.1	74.5	73.7	75.6	73.6	72.7	66.8	72.0
10,000	68.2	63.5	69.2	68.8	71.4	68.7	67.2	60.1	66.8

Coefficients: Wheels, DIA = 49 FT, RPM = 265

B0							0	0	0
B1							0	0	0
B2							0	0	0
R^2 (not input)									

STATIC CONDITIONS

SLANT DIST.	Ground Idle		Flight Idle		HIGE		HOGE	
	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
200								
400								
630								
1,000								
2,000								
4,000								
6,300								
10,000								

TABLE A-3g.

HNM DATABASE 1

TSC-48-FA-753-LR1 - 14 NOV. 86

#9 NAME: BELL 206L (LONG RANGER) SOURCE: TSC-48-FA-653-LR20 - 25 JULY 86

SLANT DIST. (ft)	TAKEOFF @ . KTS Left	Center	Right	° APPROACH @ KTS Left	Center	Right	LEVEL FLYOVER @ 115 KTS Left	Center	Right
							(300 ft. flyover)		
200							90.7	87.8	89.0
400							86.9	84.2	85.4
630							84.2	81.7	82.8
1,000							81.3	78.9	79.9
2,000							76.3	74.2	75.2
4,000							70.4	68.5	69.6
6,300							65.9	64.3	65.4
10,000							60.7	59.3	60.6
Coefficients: No Wheels,				DIA = 37.0 FT,			RPM = 394		
B0							0	0	0
B1							0	0	0
B2							0	0	0
	R^2 (not input)								

STATIC CONDITIONS

SLANT DIST.	Ground Idle Hard	Soft	Flight Idle Hard	Soft	HIGE Hard	Soft	HOGE Hard	Soft
200						76.1		
400						69.5		
630						65.0		
1,000						60.3		
2,000						52.8		
4,000						44.9		
6,300						39.7		
10,000						34.2		

TABLE A-3h.

HNM DATABASE 1

#10 NAME: AUGUSTA A109 UNRUH SOURCE: TSC-48-FA-653-LR19 - 24 JULY 86

SLANT DIST. (ft)	TAKEOFF @ 60 KTS			6° APPROACH @ 60 KTS			LEVEL FLYOVER @ KTS		
	Left	Center	Right	Left	Center	Right	Left	Center	Right
	Integrated						(500 ft. data)		
200	96.3	93.7	95.1	97.3	99.5	98.5	94.1	92.9	92.3
400	92.8	90.1	91.6	93.8	96.2	96.1	90.4	89.3	88.4
630	90.3	87.6	89.0	91.4	93.8	92.7	87.7	86.7	85.7
1,000	87.6	84.8	86.3	88.6	91.3	90.1	84.8	83.9	82.8
2,000	83.0	79.9	81.7	84.0	87.0	85.8	79.6	79.0	77.8
4,000	77.5	74.2	76.2	78.6	81.8	81.0	73.5	73.2	71.9
6,300	73.3	69.7	72.0	74.5	77.8	77.0	69.0	68.8	67.5
10,000	68.2	64.6	67.1	69.6	72.9	72.2	63.7	63.7	62.3
Coefficients: Wheels,				DIA = 36.09 FT,			RPM = 385		
B0							-.10	.10	.65
B1							46.30	53.26	53.98
B2							249.37	318.98	746.9
R^2 (not input)							1.00	1.00	.93

STATIC CONDITIONS

SLANT DIST.	Ground Idle		Flight Idle		HIGE		HOGE	
	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
200								
400								
630								
1,000								
2,000								
4,000								
6,300								
10,000								
DIR					Yes	Yes		

TABLE A-3i.

#11 NAME: AEROSPATIALE GAZELLE SA341G SOURCE: TSC-48-FA-753-LR3 - 3 DEC. 86

SLANT DIST. (ft)	TAKEOFF @ 63.56 KTS			6° APPROACH @ 64.64 KTS			LEVEL FLYOVER @ 127.8 KTS		
	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	94.5	91.7	93.5	93.5	91.3	90.3	90.1	87.4	89.8
400	90.3	87.6	89.4	90.1	87.9	86.7	86.3	83.6	86.0
630	87.2	84.6	86.3	87.7	85.6	89.2	83.6	80.9	83.2
1,000	83.6	81.1	82.6	85.1	83.1	81.3	80.5	77.7	80.0
2,000	77.1	74.8	75.9	80.8	78.8	76.3	75.0	72.2	74.3
4,000	69.6	67.1	67.8	75.8	73.8	70.2	68.0	65.2	67.1
6,300	64.2	61.2	62.0	71.9	69.8	65.5	62.5	59.7	61.5
10,000	58.0	54.4	55.7	67.4	65.1	60.4	56.2	53.3	55.1
Coefficients: No Wheels,				DIA = 34.44 FT,			RPM = 378		
B0							0	0	0
B1							0	0	0
B2							0	0	0
	R^2 (not input)								

STATIC CONDITIONS

SLANT DIST.	Ground Idle		Flight Idle		HIGE		HOGE	
	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
200								
400								
630								
1,000								
2,000								
4,000								
6,300								
10,000								

TABLE A-31.

#13 NAME: SIKORSKY S-65 (CH53) SOURCE: TSC-48-FA-753-LR6 - 4 DEC. 86

SLANT DIST. (ft)	TAKEOFF @ 73.9 KTS			6° APPROACH @ 75.58 KTS			LEVEL FLYOVER @ 146 KTS		
	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	99.8	96.7	97.3	97.5	99.3	99.8	97.3	97.2	99.5
400	96.4	93.4	94.1	94.2	96.1	96.6	93.8	93.8	96.0
630	94.1	91.0	91.7	91.9	93.9	94.4	91.4	91.3	93.5
1,000	91.6	88.4	89.3	89.4	91.4	92.1	88.7	88.6	90.7
2,000	87.4	84.1	85.2	85.3	87.5	88.2	84.2	84.0	86.0
4,000	82.3	78.9	80.3	80.7	82.9	83.8	78.7	78.4	80.3
6,300	78.4	74.8	76.5	77.1	79.4	80.5	74.5	74.0	75.9
10,000	73.5	69.9	71.9	73.0	75.4	76.5	69.5	68.9	70.6

Coefficients: Wheels, DIA = 72.25 FT, RPM = ?

B0							0	0	0
B1							0	0	0
B2							0	0	0
R^2 (not input)									

STATIC CONDITIONS

SLANT DIST.	Ground Idle		Flight Idle		HIGE		HOGE	
	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
200								
400								
630								
1,000								
2,000								
4,000								
6,300								
10,000								

TABLE A-3k.

HNM DATABASE 1

#14 NAME: SIKORSKY BLACKHAWK UH-60A (S-70) SOURCE: TSC-48-FA-653-LR17 - 21 JULY 86

SLANT DIST. (ft)	TAKEOFF @ 74 KTS			6° APPROACH @ 69 KTS			LEVEL FLYOVER @ 150 KTS		
	Left	Center	Right	Left	Center	Right	Left	Center	Right
	Integrated								
							(500 ft. alt.)		
200	91.3	89.5	92.1	94.9	97.6	100.0	100.7	98.0	101.0
400	87.5	85.7	88.4	91.4	94.3	96.7	97.1	94.4	97.2
630	84.7	83.1	85.8	89.0	92.0	94.4	94.6	91.9	94.5
1,000	81.7	80.2	82.9	86.3	89.7	92.0	91.8	89.0	91.6
2,000	76.6	75.4	78.2	81.9	85.8	88.1	87.1	84.2	86.6
4,000	70.8	69.9	72.8	76.9	81.4	83.5	81.4	78.4	80.8
6,300	66.6	65.6	68.8	73.1	78.0	79.9	77.0	73.9	76.4
10,000	61.9	60.8	64.1	68.6	74.1	75.6	72.0	68.7	71.2
Coefficients: Wheels,				DIA = 53.67 FT,			RPM = 285		
B0							.03	-.73	-.87
B1							17.47	9.86	25.33
B2							1207.72	988.71	734.35
	R^2 (not input)						1.00	.86	.84

STATIC CONDITIONS

SLANT DIST.	Ground Idle			Flight Idle			HIGE			HOGE	
	Hard	Soft		Hard	Soft		Hard	Soft		Hard	Soft
200											
400											
630											
1,000											
2,000											
4,000											
6,300											
10,000											

TABLE A-31.

UNRUH
TSC-48-FA-753-LR1 - 14 NOV. 86
HNM DATABASE 1

#15 NAME: SIKORSKY S-76 SPIRIT SOURCE: TSC-48-FA-653-LR23 - 4 SEPT. 86

SLANT DIST. (ft)	TAKEOFF @ 74 KTS (ICAO)			6° APPROACH @ 74 KTS			LEVEL FLYOVER @ 130 KTS		
	Left	Center	Right	Left	Center	Right	Left	Center	Right
	Simplified K = 10								
200	94.0	90.0	92.6	92.0	95.6	96.3	94.1	91.3	92.9
400	90.6	86.3	89.3	88.6	92.4	93.0	90.6	87.6	89.4
630	88.1	83.6	86.9	86.2	90.2	90.7	88.1	84.8	86.9
1,000	85.4	80.5	84.4	83.7	87.9	88.3	85.4	81.8	84.2
2,000	80.8	75.2	80.1	79.4	84.1	84.3	80.6	76.4	79.5
4,000	75.1	68.6	74.7	74.4	79.8	79.6	74.7	69.8	73.8
6,300	70.6	63.5	70.4	70.6	76.4	75.9	70.1	64.7	69.3
10,000	65.1	57.6	65.1	66.2	72.4	71.3	64.8	58.9	64.2
Coefficients: Wheels,				DIA = 44.00 FT,			RPM = 293 .		
B0							-.03	-.01	.16
B1							84.33	73.8	80.73
B2							945.34	1346.11	803.32
R^2 (not input)							1.00	1.00	.99

STATIC CONDITIONS

SLANT DIST.	Ground Idle		Flight Idle		HIGE		HOGE	
	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
200						82.3		
400						75.9		
630						71.5		
1,000						67.0		
2,000						59.8		
4,000						52.3		
6,300						47.1		
10,000						41.6		
DIR					Yes	Yes		

TABLE A-3m.

UNRUH
TSC-48-FA-753-LR1 - 14 NOV. 86
HNM DATABASE 1

#16 NAME: AEROSPATIALE DAUPHIN SA365N SOURCE: TSC-48-FA-653-LR14 - 27 JUNE 86

SLANT DIST. (ft)	TAKEOFF @ 74 KTS			6° APPROACH @ 75 KTS (ICAO)			LEVEL FLYOVER @ 120 KTS		
	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	95.6	95.2	91.8	99.0	95.4	No Data	91.5	88.8	90.8
400	91.6	91.2	87.8	94.6	92.0	No Data	87.8	84.8	86.6
630	88.7	88.1	84.9	91.8	89.6	No Data	84.6	81.8	83.5
1,000	85.3	84.6	81.7	88.8	87.1	No Data	81.3	78.5	80.1
2,000	79.5	78.4	76.5	83.9	82.8	No Data	75.4	72.8	74.4
4,000	72.8	70.7	70.6	78.2	77.9	No Data	69.0	66.1	68.0
6,300	67.8	64.7	66.2	73.9	74.2	No Data	64.4	61.4	63.4
10,000	62.5	57.7	61.3	68.9	69.8	No Data	59.4	56.1	58.5
Coefficients: Wheels,				DIA = 39.10 FT,			RPM = 365		
B0							-.04	.58	.09
B1							28.23	20.77	25.5
B2							350.61	591.75	321.28
R^2 (not input)							.97	.83	.98

STATIC CONDITIONS

SLANT DIST.	Ground Idle		Flight Idle		HIGE		HOGE	
	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
200						87.3		89.0
400						80.5		82.3
630						75.7		77.7
1,000						70.6		72.7
2,000						61.9		64.6
4,000						51.7		55.3
6,300						44.1		48.4
10,000						36.1		40.6
DIR					Yes	Yes		

TABLE A-3n.

UNRUH
TSC-48-FA-753-LR1 - 14 NOV. 86

HNM DATABASE 1

#17 NAME: AEROSPATIALE TWIN STAR SA355F SOURCE: TSC-48-FA-653-LR18 - 22 JULY 86

SLANT DIST. (ft)	TAKEOFF @ 63 KTS (ICAO) Left	Center	Right	6° APPROACH @ 63 KTS (ICAO) Using Integrated Procedure Left	Center	Right	LEVEL FLYOVER @ 116 KTS (500 ft. data) Left	Center	Right
200	92.7	89.2	93.8	94.9	94.6	92.0	88.7	87.8	89.5
400	89.2	85.6	90.2	91.6	91.3	88.5	85.2	84.3	86.0
630	86.6	83.1	87.7	89.2	89.0	86.0	82.7	81.8	83.6
1,000	83.8	80.3	84.9	86.7	86.5	83.3	79.9	79.1	80.8
2,000	79.0	75.6	80.1	82.5	82.4	78.6	75.3	74.6	76.2
4,000	73.4	70.1	74.2	77.5	77.5	73.1	69.9	69.2	70.6
6,300	68.9	65.8	69.6	73.5	73.6	69.0	65.6	65.2	66.4
10,000	65.6	60.9	64.2	68.7	69.1	64.1	60.7	65.1	61.6
Coefficients: No Wheels,				DIA = 35.07 FT,			RPM = 394		
B0							.10	.13	-.05
B1							33.68	25.56	42.77
B2							473.99	587.59	562.23
R^2 (not input)							.95	.91	.98

STATIC CONDITIONS

SLANT DIST.	Ground Idle Hard	Soft	Flight Idle Hard	Soft	HIGE Hard	Soft	HOGE Hard	Soft
200						80.9		86.5
400						74.6		80.1
630						70.4		75.7
1,000						66.0		71.1
2,000						59.7		63.7
4,000						51.7		55.6
6,300						46.3		49.7
10,000						40.2		43.3
DIR					Yes	Yes		

TABLE A-3o.

UNRUH
TSC-48-FA-753-LR1 - 14 NOV. 86
HNM DATABASE 1

#18 NAME: AEROSPATIALE ASTAR SA350D SOURCE: TSC-48-FA-653-LR21 - 13 AUG. 86

SLANT DIST. (ft)	TAKEOFF @ 63 KTS (ICAO)			6° APPROACH @ 63 KTS (ICAO)			LEVEL FLYOVER @ 116 KTS		
	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	92.5	89.2	92.5	92.1	94.2	90.9	88.5	87.1	89.7
400	88.8	85.5	88.8	88.7	90.9	87.3	84.7	83.5	86.1
630	86.2	82.9	86.4	86.4	88.6	84.9	82.1	80.8	83.5
1,000	83.3	80.0	83.6	83.8	86.1	82.2	79.3	78.0	80.6
2,000	78.5	75.1	78.8	79.4	82.0	77.6	74.4	73.2	75.7
4,000	72.5	69.3	73.0	74.2	77.1	72.2	68.6	67.5	69.8
6,300	67.8	65.1	68.4	70.0	73.3	68.1	64.2	63.3	65.2
10,000	62.5	60.2	63.0	65.0	68.7	63.3	58.9	58.4	59.9
Coefficients: No Wheels,				DIA = 35.11 FT,			RPM = 386		
B0							.04	.58	.09
B1							28.23	20.77	25.5
B2							350.61	591.75	321.28
R^2 (not input)							.97	.83	.98

STATIC CONDITIONS

SLANT DIST.	Ground Idle		Flight Idle		HIGE		HOGE	
	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
200						77.5		
400						71.2		
630						67.0		
1,000						62.6		
2,000						55.6		
4,000						48.0		
6,300						42.5		
10,000						36.2		
DIR					Yes	Yes		

TABLE A-3p.

UNRUH HNM DATABASE 1
TSC-48-FA-753-LR1 - 14 NOV. 86
#19 NAME: BELL 222 SOURCE: TSC-48-FA-653-LRRH - 27 JUNE 86

SLANT DIST. (ft)	TAKEOFF @ 65 KTS (ICAO)			6° APPROACH @ 65 KTS (ICAO)			LEVEL FLYOVER @ 123 KTS		
	Left	Center	Right	Left	Center	Right	Left	Center	Right
	Integrated								
200	90.4	90.6	90.6	93.2	96.6	94.3	92.1	90.9	92.7
400	86.7	86.8	86.9	89.6	93.3	90.9	88.3	87.2	89.1
630	84.2	84.2	84.1	87.2	91.1	88.5	85.7	84.6	86.5
1,000	81.4	81.3	81.4	84.6	88.8	86.0	82.8	81.7	83.8
2,000	76.6	76.5	77.0	80.1	85.0	81.9	78.1	77.0	79.2
4,000	71.2	71.0	71.9	75.0	80.6	77.1	72.7	71.5	74.2
6,300	67.2	66.9	68.0	71.0	77.2	73.5	68.7	67.5	70.3
10,000	62.6	62.2	63.7	66.4	73.3	69.3	64.1	62.9	65.9
Coefficients: Wheels,				DIA = 39.80 FT,			RPM = 348 .		
B0							-.06	.09	-.27
B1							39.29	26.44	75.00
B2							119.05	59.52	178.57
R^2 (not input)							1.00	.99	.99

STATIC CONDITIONS

SLANT DIST.	Ground Idle		Flight Idle		HIGE		HOGE	
	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
200						74.2		84.3
400						68.0		77.9
630						63.9		73.6
1,000						59.7		69.0
2,000						53.2		61.6
4,000						46.5		53.3
6,300						41.9		47.1
10,000						36.9		40.1
DIR					Yes	Yes		

NOTE: This helicopter has 12° approaches at several speeds and other data.

TABLE A-3q.

HNM DATABASE 1

#20 NAME: ROBINSON R22HP SOURCE: UNRUH

SLANT DIST. (ft)	TAKEOFF @ KTS			° APPROACH @ KTS			LEVEL FLYOVER @ KTS		
	Left	Center	Right	Left	Center	Right	Left	Center	Right
200									
400									
630									
1,000									
2,000									
4,000									
6,300									
10,000									
Coefficients: No Wheels,				DIA = 25.17 FT,			RPM = 530		
B0									
B1									
B2									
R^2 (not input)									

STATIC CONDITIONS

SLANT DIST.	Ground Idle		Flight Idle		HIGE		HOGE	
	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
200								
400								
630								
1,000								
2,000								
4,000								
6,300								
10,000								
DIR					Yes	Yes		

TABLE A-3r.

#21 NAME: BOELKOW BK 117 SOURCE: UNRUH

SLANT DIST. (ft)	TAKEOFF @ KTS			° APPROACH @ KTS			LEVEL FLYOVER @ KTS		
	Left	Center	Right	Left	Center	Right	Left	Center	Right
200									
400									
630									
1,000									
2,000									
4,000									
6,300									
10,000									
Coefficients: No Wheels,				DIA = 36.09 FT,			RPM = 391 .		
B0									
B1									
B2									
	R^2 (not input)								

STATIC CONDITIONS

SLANT DIST.	Ground Idle		Flight Idle		HIGE		HOGE	
	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
200								
400								
630								
1,000								
2,000								
4,000								
6,300								
10,000								
DIR					Yes	Yes		

Appendix B

Lateral Effects Coefficients

L

Table 5.1 Heliport Noise Model
Lateral Attenuation Coefficients for ΔdB

	$\Delta dB = B(\beta - 45°)$ $15° \le \beta \le 45°$		$\Delta dB = D + E(\beta - 45°)$ $0° \le \beta \le 15°$	
Helicopter Type	A* [dB]	B [dB/Deg]	D [dB]	E [dB/Deg]
Aerospatiale AS350D	-2.68	0.0422	-13.38	-0.404
Aerospatiale AS355D	-0.68	-0.0154	-9.412	-0.329
Aerospatiale AS365N	-2.02	0.00165	-12.08	-0.401
Agusta A-109	2.86	-0.0476	-2.32	-0.125
Bell 206L	-1.48	0.0429	-11.01	-0.324
Bell 222	-0.968	0.0063	-14.24	-0.468**
Boeing Vertol 234/CH47D	2.26	-0.0754	-3.53	-0.193
Hughes 500D/E	-6.69	0.0784	-21.44	-0.636
MBB BK117A-1	-0.16	0.0009	-8.37	-0.278
Robinson R22	0.12	-0.0160	-7.80	-0.276
Sikorsky S-76	-3.01	0.0217	-10.46	-0.327**
Sikorsky UH-60A	-2.63	0.0061	-13.29	-0.437
Generic‡	-1.53	0.0086	-11.08	-0.361

*For reference only; used in computation of E.

**Λ_0 taken from Table 4.3; otherwise, $\Lambda_0 = 4.02$.

‡Average of all data, excluding the BV234/CH47D Twin Rotor.

HNM

ÒRDYS DSPLAY = "Word12a0E

1. Get coordinates for block of observers. Observer elevations = 0.

2. Read airport data (Altitude, Temperature, # Flights) from the flight file.

3. Get speed of sound at the airport. $C = 49.02 \times (T)^{0.5}$, where T is the airport temperature from part 2.

   For each flight:

4. Get flight operational data, including category, traffic type, # operations, rotor diameter, user RPM, & reference RPM.

5. Get equivalent daytime operations for LDN metric.

6. Read static & moving noise curve data & coefficients, and the corresponding speed value for each noise category. The reference speed is the speed used for the noise curve for the level flight thrust mode (LFLO or LFLY), center directivity. Note that static noise data is in the form of maximum noise data.

7. Get logarithms of distances used in the noise curves.

   For each segment:

8. Get segment geometry, including start position, length, unit vector, speed/duration, change in speed/duration, & thrust mode. There is no change in thrust mode. The thrust mode refers to a type of static or moving operation & a set of corresponding noise values.

   For each observer:

9. Get noise fraction for either a static or moving segment.

   a. For a static segment the noise fraction is equal to 1. Get the emission angle θ, the angle between the flight segment and a segment drawn from the observer to the start of the flight segment, and using operations in the horizontal plane. The emission angle is zero if the helicopter is over the observer.

   b. For a moving segment, get the noise fraction using a 3rd order 90-degree dipole function for an observer along a segment, and a 3rd order monopole function for an observer ahead of or behind a segment. Compute the emission angle in 3-d space. (The noise fraction in HNM 2.2 is like that in INM 4.11, while the noise fraction in HNM 1 is like that in INM 3.10, except that there is no special HNM algorithm for noise behind a helicopter during takeoff.)

10. Get the side of the flight as a function of the emission angle.

    HAND = 1: the right side, for $\theta \leq 180°$.
    HAND = 2: the left side, for $\theta > 180°$.

11. Get parameters used for calculation at the CPA of the flight segment, and at the end of the segment.

    ALT = Altitude at the CPA of the segment.
    VEL = Speed/duration at the CPA of the segment.
    ALTEND = Altitude at the end of the segment.
    HALT = The higher of ALT and ALTEND.
    THR = Thrust mode, i.e. type of flight, for the entire segment.

    ALT = SEGSTR(3) + DAS×UNIT(3).
    ALTEND = SEGSTR(3) + LENGTH×UNIT(3).
    HALT = MAX(ALT, ALTEND).
    THR = THRSTR.

    a. For a static segment the duration DUR is the speed value at the start of the segment, VELSTR. The variable VEL = 0.

    b. For a moving segment which is a moving HIGE, (thrust mode 6), the speed VEL at the CPA of the segment has the same value as VELSTR, the value of the speed at the start of the segment.

    c. For a moving segment which is not a moving HIGE, the speed VEL at the CPA of the segment is given by

       VEL = VELSTR + (DAS/LENGTH)×VELDEL,

       i.e., the speed at the CPA of the segment is found by linear interpolation of distance along the segment.

12. Get the sideline distance to the observer.

13. Get the log of the slant range distance.

14. Set the duration DUR to zero for an interpolated static segment with a length > 0.1 ft.

15. Get the single event noise level and the fractional noise level depending on the thrust mode, i.e., the type of flight, for the segment.

    a. For a taxi or moving hover in ground effect (HIGE, thrust mode # 6), use the static noise values in the noise table for the helicopter, and use column 3 (static hover in ground effect, HIGE) with wheels, column 2 (flight idle, FIDL) without wheels. Get SENL by interpolation of distances (i.e., logs of distances), in the noise table. If the helicopter has no wheels indicating the use of column 2, and at the same time there is no FIDL noise data in column 2, then use static HIGE noise data from column 3, but reduced by 5 dB. (<u>Note that the distance interpolation does not appear to be working in this case, for distances ≥ 200 ft., according to the HNM source program</u>.) For a distance < 200 ft., limit change in SEL to 20 DB/decade. Again, for no wheels and no FIDL noise data, use static HIGE data from column 3, reduced by 5 dB, and there is no distance interpolation to worry about for distances < 200 ft., only the offset value.

For the moving HIGE there are no lateral adjustment factors. Apply the correction to convert an interpolated maximum noise level to a single event level using the equation

$$SENL = SENL + 10\times\log[(\pi/2)\times(r0/V)$$

where r0 is the slant range in feet, and V is the velocity at the CPA in ft./sec.

The weighted fractional noise level WFNL is given by

$$WFNL = WHTOPS\times NOISFR\times 10^{(SENL/10)}$$

where WHTOPS is the equivalent daytime operations for the flight, and NOISFR is the noise fraction for the observer d segment.

b. For a moving segment, (thrust mode indicator 7 or greater), the SEL noise tables for the helicopter are used.
For the thrust modes:

Takeoff at constant velocity -- TO
Accelerating horizontal takeoff -- ACLH
Accelerating Climbing takeoff -- ACLC

use the center takeoff noise curve, TOFF-C.

For the thrust modes:

Descent at constant velocity -- APPR
Decelerating descent -- DCLD
Horizontal Deceleration -- DCLH

use the center approach noise curve, APPR-C.

For the thrust mode:

Level flyover (cruise) -- LFLO

use the center level flyover noise curve, LFLY-C.

The noise level is obtained first by distance interpolation in the appropriate noise table. The change in SEL is limited to 10 dB per decade for a distance of < 200 ft.

Note that according to the HNM source code, if the noise data for the takeoff thrust mode center directivity (TO-C, column 2 for moving thrust modes), are to be used, and no noise data are present, then the noise data for the takeoff thrust mode right directivity (TO-R, column 3 for moving thrust modes) are used, and the noise values are reduced by 5 dB. In addition, if in this case the log of the distance is 200 or more, then there is no distance interpolation being done. If the observer-segment distance is different from any of the noise table distances, then the noise for the noise table distance value that is less than the actual distance is used. If, however, the observer-segment distance is equal to one of the noise table distances, then the noise in the noise table for this distance is used. . (These procedures should not be occurring, and they probably will not occur anyway because helicopters with no noise are prevented from being used by the HNMRUN front-end program).

Next the angle BETA = ALT/DCP is computed, where ALT is the altitude at the CPA of the segment, and DCP is the distance from the observer to the closest point on the flight segment, which is:

(1) LRVEC, the distance from the observer to the start of a flight segment for an observer behind a segment.

(2) SLR, the perpendicular slant range distance from the observer to the CPA of the flight segment, for an observer astride a segment.

(3) LSVEC, the distance from the observer to the end of a flight segment for an observer ahead of a segment.

The maximum value of BETA is set to 90°.

If the angle BETA is ≤ 45°, then a lateral adjustment factor, which is a function of BETA, and of noise table coefficients if available from the appropriate table, is computed. If the angle BETA is > 45° then no lateral adjustment factor.

Following this a noise value is computed via distance interpolation from either the right or left noise table, depending on the emission angle, which has the same thrust mode as the center noise table already used for the flight segment. Then if the angle BETA is < 45°, the final uncorrected noise is the interpolated noise from the right or left noise table, reduced by the lateral adjustment factor. However, if the angle BETA is ≥ 45°, then the final uncorrected noise is a function of BETA and of the interpolated noise values from both the center noise table and either the right or left noise table used for the thrust mode for the segment, with no reduction due to a lateral adjustment factor, since there is no lateral adjustment factor for BETA ≥ 45°.

An additional correction is made to the SENL from the noise table in the case that the thrust mode is Level flyover, LFLO. A blade tip Mach number correction is applied based on the speed at the CPA of the flight segment and on the helicopter reference speed, which is the speed for the center noise table for the Level flyover thrust mode. First, a correction is obtained from the center coefficient table for the level flyover thrust mode, and then from either the right or left coefficient table for the level flyover thrust mode, depending on the emission angle. If the angle BETA defined above is < 45°, then the final correction is taken from either the left or right coefficient table for the level flyover thrust, depending on the emission angle. However, if the angle BETA is ≥ 45°, then the final correction is a function of the angle BETA and initial corrections obtained from both the center coefficient table and either the right or left coefficient table, depending on emission angle, for the level flyover thrust mode.

If the segment thrust mode is LFLO for level flyover, then the blade tip Mach number correction is added to the single event level obtained from the noise tables. Otherwise, the single event level from the noise table remains as is for the moving segment, with no blade tip Mach number correction.

As in the case for the moving HIGE thrust mode described in part a., the weighted fractional noise level for a moving segment is given by the expression

$$WFNL = WHTOPS \times NOISFR \times 10^{(SENL/10)}$$

where WHTOPS is the equivalent daytime operations for the flight, and NOISFR is the noise fraction for the observer and segment.

c. For a static segment, i.e., with a thrust mode indicator of 5 or less, noise tables for static thrust modes for a helicopter are used. If the thrust mode is vertical ascent (VASC), then either the static HIGE noise table or the HOGE noise table is used depending on the rotor diameter. Initially the HIGE noise table is chosen, but if the altitude at either the CPA of the segment or at the end of the segment is 1.5 × the rotor diameter, then the HOGE noise table is used.

For whatever static thrust mode is used, get the interpolated single event noise level from the appropriate noise table using distance interpolation, and limit the change in noise to 20 dB per decade if the distance is < 200 ft. There is no lateral adjustment for the static thrust modes.

If the ground idle (GIDL, static thrust mode #1) is chosen in a profile for a given aircraft, and if there is no noise data for the GIDL thrust mode, then use the noise data for the static hover in ground effect (HIGE, static thrust mode #3) noise curve for the given helicopter, but reduced by 15 dB. If the flight idle (FIDL, static thrust mode #2) is chosen in a profile for a given aircraft, and if there is no noise data for the FIDL thrust mode, then use the noise data for the static HIGE noise curve for the given helicopter, but reduced by 5 dB. If the hover out of ground effect (HOGE, static mode #4) is chosen in a profile for a given aircraft, and if there is no noise data for the HOGE thrust mode, then use the noise data for the static HIGE noise curve for the given helicopter.

(Note that in the cases of using HIGE data for non-existent FIDL or HOGE data, the distance interpolation does not appear to be working for distances ≥ 200 according to the HNM source program, but the noise for the noise table distance value that is less than the actual distance is used. For distances < 200 there is no distance interpolation to worry about, only an offset value.)

Next a directivity correction is applied based on the emission angle of the helicopter & database coefficients for the appropriate thrust mode. The directivity correction is then added to the interpolated noise level obtained from the noise table.

There is the possibility of obtaining a ground attenuation correction to the noise level, but there are no ground attenuation algorithms in the HNM program, and so ground attenuation is not computed.

Finally, the weighted fractional noise level is given by the expression

$$\mathrm{WFNL} = \mathrm{WHTOPS} \times \mathrm{DUR} \times \mathrm{NOISFR} \times 10^{(\mathrm{SENL}/10)}$$

where DUR is the duration time of the static segment, equal to the speed value for the segment, and where the variables WHTOPS and NOISFR have been defined above in parts a., and b. Since the noise fraction NOISFR is equal to 1 for a static segment, then the expression becomes

$$\mathrm{WFNL} = \mathrm{WHTOPS} \times \mathrm{DUR} \times 10^{(\mathrm{SENL}/10)}$$

16. Convert the value WFNL to decibels by subtracting 49.4, the base 10 logarithm of 86,400 seconds per day, from the result in part 15.

17. For irregular grid significance testing, the regular grid diagonal for track significance testing is equal to one-third of the diagonal length of the regular grid window, with a minimum length of 1800 ft.

18. The formula for average noise for noise significance testing is:

$$\text{Average noise} = 2 \times (10^{-|\text{tolerance}/10|} - 1) \times \text{total noise}/\text{number of flights}$$

INM

1. Get Flight file airport data, including terrain data if available.

2. Get block of observer coordinates, observer altitudes = 0.

3. Mdify observer altitudes if terrain data given.

   For each flight:

4. Read flight operational data, including number of operations.

5. Compute equivalent daytime operations.

6. Read EPNL and SEL noise data for the flight.

7. Get logs of noise distances.

   For each segment:

8. Read geometry for flight segment from flight file, including position of start of segment, segment length, unit vector, speed, change in speed, thrust, & change in thrust.

9. Set segment altitude to MSL if terrain data is used, otherwise leave at AFE.

   For each observer:

10. Get noise fraction for observer & segment, as well as slant range distance. An exact 4th order 90 degree dipole formula is used for all positions of observer relative to flight segment, with the exception of the observer behind a segment during takeoff roll. For this case the noise fraction is computed in the following steps:

    a. A preliminary noise fraction is computed using a third order monopole algorithm as a function of the segment length and the distance from the observer to the end of the segment.

    b. A directivity multiplier is then computed using an algorithm provided in SAE AIR 1845, and the result is then modified using a smoothing function if the distance from the observer to the start of the segment is > 2500 ft.

    c. The directivity multiplier, which is in units of decibels, is converted to units of energy.

    d. A final noise fraction is computed by multiplying the preliminary noise fraction obtained in part a. by the directivity multiplier obtained in part c.

11. Get elevation angle if terrain processing is used.

12. Get aircraft physical parameters (altitude, speed, & thrust) at either one of the end points of the segment or at the CPA of the segment, depending on the relative position of observer and segment. Also get sideline distance to the observer.

13. Get the speed correction. In addition, get the elevation angle if terrain processing is not used, and using the angle get the lateral attenuation correction. Add these together to get the total noise correction.

14. Get the uncorrected single event noise level from the noise table for the aircraft, by using linear interpolation of thrust from part 12. and logarithmic interpolation of slant range distance from part 10.

15. Get the corrected single event noise level SENL by adding the noise correction from part 13 to the uncorrected interpolated noise level from part 14.

16. Get the weighted fractional noise energy level WFNL using the following expression:

    $WFNL = WHTOPS \times NOISFR \times 10^{(SENL/10)}$

    where WHTOPS are the equivalent daytime operations for the flight from part 5, NOISFR is the noise fraction from part 10, and SENL is the corrected single event noise level from part 15.

17. Convert the value WFNL to decibels by subtracting 49.37, the base 10 logarithm of 86,400 seconds per day, from the result in part 16.

18. For irregular grid significance testing, the regular grid diagonal for track significance testing is equal to the diagonal length of a regular grid rectangle.

19. The formula for average noise for noise significance testing is:

    $\text{Average noise} = (1-10^{-(\text{tolerance}/10)}) \times \text{total noise/number of flights}$