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Fitchburg Municipal Airport Noise Measurement Study:
Summary of Measurements, Data and Analysis

Maule M-7-235C
Piper Twin Comanche PA-30
Piper Navajo Chieftain PA-31-350
Piper Warrior PA-28-161
Beech 1900D
Eurocopter EC-130 Helicopter
Robinson R-22 Helicopter

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Research and Innovative Technology Administration
John A. Volpe National Transportation Systems Center
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Cambridge, MA 02142

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13. ABSTRACT (Maximum 200 words)

The U.S. Department of Transportation, John A. Volpe National Transportation Systems Center (Volpe Center), Environmental Measurement and Modeling Division, is providing technical support to the Federal Aviation Administration (FAA), with the cooperation of the National Park Service (NPS), toward the development of Air Tour Management Plans (ATMPs) for all National Parks with commercial air tours. In April, May, and August 2002, the Volpe Center measured noise for seven aircraft, six of which have been identified as participating in commercial air tour operations over units of the NPS, including the Maule M-7-235C, the Piper Twin Comanche PA-30, the Piper Navajo Chieftain PA-31-350, the Piper Warrior PA-28-161, the Eurocopter EC-130 helicopter, and the Robinson R-22 helicopter. The Beech 1900D was measured as a target of opportunity for the Volpe Center's Project supporting the development of FAA's Integrated Noise Model. This document describes the planning and execution of the study at Fitchburg Municipal Airport in Fitchburg, Massachusetts. Additionally, the data reduction procedures and data adjusted to standard conditions are presented.

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Aircraft noise, air tours, helicopters, noise measurements, noise, propeller aircraft, Integrated Noise Model, INM, Air Tour Management Plan

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS – WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup ©	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS – WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

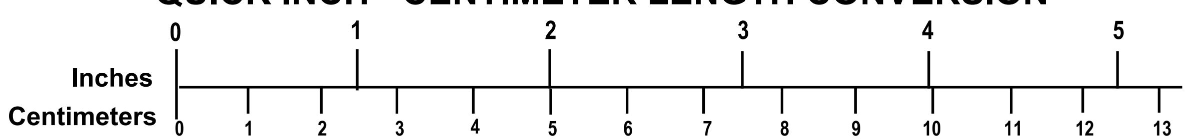
VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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The authors of this report wish to express their sincere gratitude to all who helped make this a successful study, including Volpe National Transportation Systems Center employees Michael Lau, Eric Boeker, Jose Mantilla, Amishi Joshi, Chris Scarpone, and George Noel. Pilot John Payson should also be thanked for donating both his personal time and the use of his Maule M-7-235C aircraft in the study. Without the extensive Beech 1900D documentation lent to the authors of this report by Henry Wurster of Commutair, the pilot of the 1900D during the study, the inclusion of this aircraft in the study would not have been possible. The staff at Fitchburg Municipal Airport was also instrumental in the successful completion of this study. In particular, the efforts of Richard Walsh, Airport Manager, and David Bouvier, Airport Assistant Manager, were invaluable.

The authors wish to offer their deepest condolences to the family of Alan Emerson of Emerson Aviation, the pilot of the Piper Twin Comanche PA-30, who was killed when his airplane went down some months after the measurement program.

Table of Contents

Table of Contents (continued)

Table of Contents (continued)

Table of Contents (continued)

Section **Page**

i

List of Figures

Figure **Page**

List of Figures (continued)

Figure **Page**

List of Figures (continued)

Figure **Page**

List of Tables

Table **Page**

List of Tables (continued)

1.0 INTRODUCTION

The National Parks Air Tour Management Act of 2000 (The Act) calls for the regulation of commercial air tour operations over units of the National Park System, and directs the Federal Aviation Administration (FAA), with the cooperation of the National Park Service (NPS), to develop Air Tour Management Plans (ATMPs) for all National Parks with commercial air tours. The Volpe Center Environmental Measurement and Modeling Division's Acoustics Facility (VCAF) is providing technical support to the FAA. An important element of this support is the computer modeling of potential noise impacts of air tours which take place over the National Parks, currently estimated at over 100 affected Park units, using the FAA's Integrated Noise Model (INM).

The first two Parks for which ATMPs will be developed are Hawaii Volcanoes National Park and Haleakala National Park. In order to undertake the supporting computer modeling, noise data for the specific aircraft currently flying over these Parks is required. The determination of aircraft noise data needs was based on queries by VCAF personnel of operators advertising air tours on the islands of Hawaii and Maui. Eleven operators provided information on twelve different aircraft types. Of those, six were determined by VCAF personnel not to have adequate noise data within the existing INM aircraft database, Version 6.0c at the time: Maule M-7-235C, Piper Twin Comanche PA-30, Piper Navajo Chieftain PA-31-350, Piper Warrior PA-28-161, Eurocopter EC-130, and Robinson R-22. It is expected that these six aircraft types will be found at other Park units for which ATMPs will be developed. In that regard, these data were not collected just for the Hawaii Parks, but for ATMPs in general.

The Beech 1900D was also measured as a target of opportunity for supporting the development and maintenance of the INM. The 1900D is a common commuter airliner modeled in prior versions of the INM with a substitution aircraft. Where possible, the FAA seeks to replace substitution aircraft with actual aircraft data.

This document summarizes the measurement study, which took place in April, May, and August 2002, at Fitchburg Municipal Airport (FIT) in Fitchburg, Massachusetts. Section 1.0 provides a brief introduction to the FIT Noise Measurement Study. Section 2.0 describes the test aircraft. Section 3.0 discusses the setup and instrumentation. Section 4.0 lists the test series performed. Section 5.0 describes the data reduction and analysis. Section 6.0 presents the results of the study, including the helicopter directivity data in polar plot form. Appendix A provides aircraft performance data along with completed INM Database Request Forms useful in assembling the database files necessary to run the aircraft data in the INM. Appendix B provides a list of contacts involved with the measurement study, including the airport office and aircraft charter companies. Appendix C summarizes the meteorological data used in the data processing. Appendix D summarizes the tracking or time-space-position information (TSPI) data used in the data processing. Appendix E provides complete aircraft noise-power-distance data tables and helicopter hover noise-power-distance data tables, as well as plots of the aircraft L_{AE} NPD curves. Appendix F provides the spectral data used to assign the propeller-driven aircraft to spectral classes in the INM, along with the specific INM spectral class assignments. Appendix G provides the complete database files to be included in an upcoming release of the INM. Appendix H provides a list of acronyms and abbreviations and their meanings.

1.1 Objective

The objective of the study was to collect a noise data set suitable for modeling both the many flight configurations flown by air tour aircraft in the Hawaii (and likely other) Parks and fulfill the INM's standard data input requirements. The flight configurations described in Section 4.0 of this document include level flight (LFO), approach (APP), departure (DEP), hover and idle events (the last two configurations for helicopters only). All data were collected and processed in accordance with the basic procedures defined in Federal Aviation Regulation (FAR) Part 36 (Reference 1).

1.2 Schedule

An aircraft measurement schedule for the study is presented in Table 1.

Table 1. Study aircraft measurement schedule.

Date	Time Slot	Aircraft
March 29, 2002	13:00 – 15:30	Piper Warrior PA-28-161 (#1)
March 30, 2002	09:00 – 12:00 13:00 – 17:00	Piper Twin Comanche PA-30 Piper Navajo Chieftain PA-31-350
May 1, 2002	08:00 – 09:30 12:00 – 14:30	Beech 1900D Robinson R-22
May 6, 2002	07:30 – 09:30 11:00 – 13:30	Piper Warrior PA-28-161 (#1) Robinson R-22
May 7, 2002	09:00 – 13:00	Eurocopter EC-130
August 30, 2002	10:00 – 12:00 15:00 – 16:00	Maule M-7-235C Piper Warrior PA-28-161 (#2)[1]

[1] Two different PA-28-161 aircraft were utilized for the flight test. This was done for several reasons, the most important of which was to assess measurement repeatability. A comparison of the data for the two PA-28-161 aircraft is presented in Section 6.1.2 below. While only PA-28 #1 was used to collect events for basic INM requirements, some events were collected with PA-28 #2 as a supplement to INM requirements specific to the objectives of the ATMP program.

2.0 TEST AIRCRAFT DESCRIPTIONS

Six of the seven aircraft documented in this report have been identified as participating in commercial air tour operations over Hawaii Volcanoes National Park and/or Haleakala National Park. Brief descriptions of all the aircraft are provided below. More detailed, INM-specific performance data for the Piper Twin Comanche PA-30, Piper Navajo Chieftain PA-31-350, Piper Warrior PA-28-161, and Maule M-7-235C are provided in Appendix A, along with data for the Beech 1900D,[2] which was measured as a target of opportunity in support of VCAF's INM Project. A list of contacts for all of the service providers involved in the measurement study, including aircraft charter companies and the airport, is provided in Appendix B.

2.1 Maule M-7-235C

The M-7-235C is a single-engine propeller-driven aircraft marketed and supported by Maule Air Inc. of Moultrie, Georgia (see Figure 1, Table 2). The airplane is designed to carry 1 pilot and 3 passengers.

Table 2. Airplane characteristics, Maule M-7-235C.

Airplane Manufacturer	**Maule Air Inc.**
Airplane Model	M-7-235C
Airplane Type	Single Propeller
Maximum Gross Takeoff Weight (lb)	2,500
Number and Type of Engine(s)	1 Lycoming IO-540-W1A5

Figure 1. Maule M-7-235C aircraft

2.2 Piper Twin Comanche PA-30

The PA-30 is a twin-engine propeller-driven aircraft marketed and supported by New Piper Aircraft Company (New Piper) of Vero Beach, Florida (see Figure 2, Table 3). The airplane is designed to carry 1 pilot and 3 passengers.

---

[2] Note that performance data for the R-22 and EC-130 helicopters are presented in Tables 7 through 10.

Table 3. Airplane characteristics, Piper Twin Comanche PA-30.

Airplane Manufacturer	New Piper Aircraft Co.
Airplane Model	PA-30
Airplane Type	Twin Propeller
Maximum Gross Takeoff Weight (lb)	3,600
Number and Type of Engine(s)	2 Lycoming IO-320-B1A

Figure 2. Piper Twin Comanche PA-30 aircraft

2.3 Piper Navajo Chieftain PA-31-350

The PA-31 is a twin-engine propeller-driven aircraft marketed and supported by New Piper (see Figure 3, Table 4). The airplane is designed to carry 1 pilot and 9 passengers.

Table 4. Airplane characteristics, Piper Navajo Chieftain PA-31-350.

Airplane Manufacturer	New Piper Aircraft Co.
Airplane Model	PA-31-350
Airplane Type	Twin Propeller
Maximum Gross Takeoff Weight (lb)	7,000
Number and Type of Engine(s)	2 Lycoming TIO-540-J2BD

Figure 3. Piper Navajo Chieftain PA-31-350 aircraft

2.4 Piper Warrior PA-28-161

The PA-28-161 is a single-engine propeller-driven aircraft marketed and supported by New Piper (see Figure 4, Table 5). The airplane is designed to carry 1 pilot and 3 passengers.

Table 5. Airplane characteristics, Piper Warrior PA-28-161.

Airplane Manufacturer	**New Piper Aircraft Co.**
Airplane Model	PA-28-161
Airplane Type	Single Propeller
Maximum Gross Takeoff Weight (lb)	2,325
Number and Type of Engine(s)	1 Lycoming O-320-D3G

Figure 4. Piper Warrior PA-28-161 aircraft

2.5 Beech 1900D

The 1900D is a twin-engine propeller-driven commuter aircraft marketed and supported by Raytheon Aircraft of Wichita, Kansas (see Figure 5, Table 6). The airplane is designed to carry 1 pilot, 1 copilot, and 19 passengers.

Table 6. Airplane characteristics, Beech 1900D.

Airplane Manufacturer	**Raytheon Aircraft**
Airplane Model	1900D
Airplane Type	Twin Propeller
Maximum Gross Takeoff Weight (lb)	17,120
Number and Type of Engine(s)	2 Pratt and Whitney Canada PT6A-67D

Figure 5. Beech 1900D aircraft

2.6 Eurocopter EC-130

The EC-130 is a helicopter marketed and supported by Eurocopter of the European Aeronautic Defense and Space company (see Figure 6, Tables 7 and 8). It is designed to carry 1 pilot and 6 passengers. Eurocopter designed the EC-130 specifically for the air tour market. The EC-130 uses a Fenestron tail rotor to reduce community noise levels.

Selected operational characteristics, obtained from the helicopter manufacturer, are presented in Tables 7 and 8.

Table 7. Helicopter characteristics, Eurocopter EC-130.

Helicopter Manufacturer	Eurocopter
Helicopter Model	EC130 B4
Helicopter Type	Single Rotor
Max Gross Takeoff Weight [MGTW] (lb)	5,291
Number and Type of Engine(s)	1 Arriel 2 B1
Shaft Horsepower (hp)	847
Max Continuous Power (hp)	728
Specific Fuel Consumption at Max Power (lb/hr/hp)	0.56
Never Exceed Speed [V_{NE}] (kts)	155
Max Speed in Level Flight with Max Continuous Power [V_H] (kts)	126
Speed for Best Rate of Climb [V_Y] (kts)	65
Best Rate of Climb [ROC] (FPM)	2,290

Table 8. Main and tail rotor specifications, Eurocopter EC-130.

Characteristic	**Main**	**Tail**
Rotor Speed (max RPM)	394	3,568
Diameter (in)	421	39
Chord (in)	14	2
Number of Blades	3	10
Fundamental Blade Passage Frequency (Hz)	20	595

Figure 6. Eurocopter EC-130 helicopter

2.7 Robinson R-22

The R-22 is a light helicopter marketed and supported by Robinson of Torrance, California (see Figure 7, Tables 9 and 10). The helicopter is designed to carry 1 pilot and 1 passenger.

Selected operational characteristics, obtained from the helicopter manufacturer, are presented in Tables 9 and 10.

Table 9. Helicopter characteristics, Robinson R-22.

Helicopter Manufacturer	Robinson
Helicopter Model	R22 B
Helicopter Type	Single Rotor
Max Gross Takeoff Weight [MGTW] (lb)	1,370
Number and Type of Engine(s)	1 Lycoming 0-320
Shaft Horsepower (hp)	160
Max Continuous Power (hp)	124
Specific Fuel Consumption at Max Power (lb/hr/hp)	0.44
Never Exceed Speed [V_{NE}] (kts)	102
Max Speed in Level Flight with Max Continuous Power [V_H] (kts)	102
Speed for Best Rate of Climb [V_Y] (kts)	53
Best Rate of Climb [ROC] (FPM)	500

Table 10. Main and tail rotor specifications, Robinson R-22.

Characteristic	Main	Tail
Rotor Speed (max RPM)	520	324
Diameter (in)	302	42
Chord (in)	7	4
Number of Blades	2	2
Fundamental Blade Passage Frequency (Hz)	17	11

Figure 7. Robinson R-22 helicopter

3.0 SETUP

3.1 Measurement Facility

Located between the Massachusetts cities of Fitchburg and Leominster, Fitchburg Municipal Airport (FIT) maintains two runways (14-32 and 02-20). The airport maintains an automated surface weather observation system, which reports weather by radio, telephone, and Internet. An aerial view of FIT overlaid with the microphone array is provided in Figure 8.

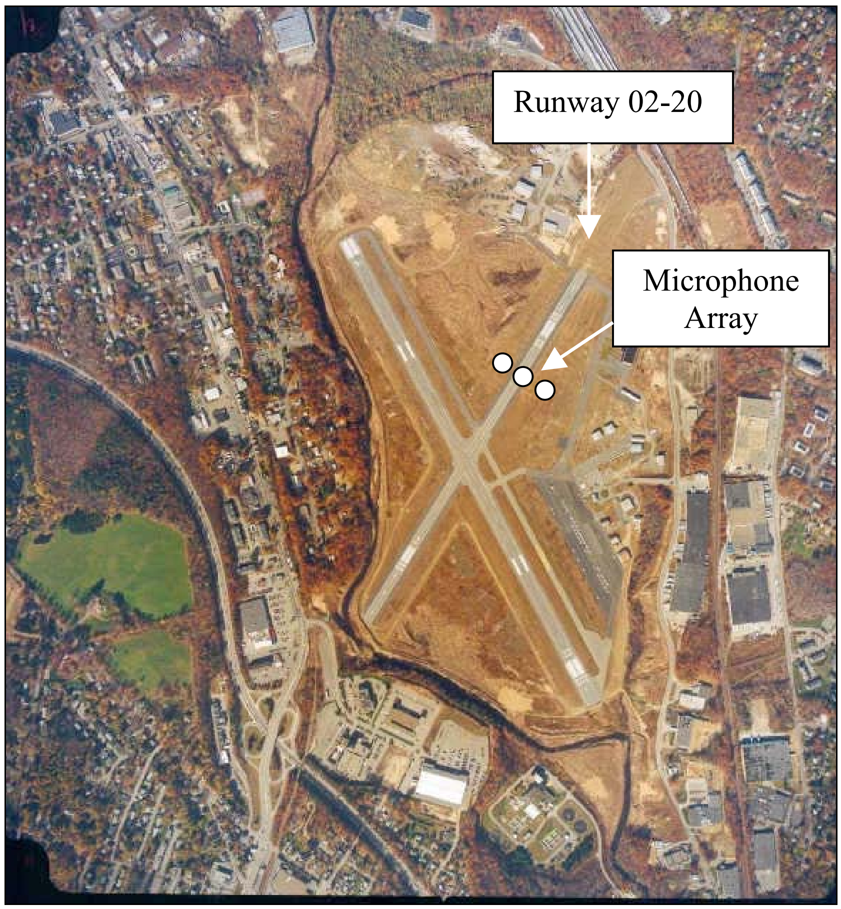

Figure 8. Aerial view of FIT

Figures 9 and 10 show the layout of the two setups for the study and the instrumentation used to collect tracking or TSPI data, acoustical data, and meteorological data. The two setups used were as follows: (1) The Dynamic Operations measurement setup, used for LFO, DEP, and APP flight configurations, is illustrated in Figure 9; and (2) the Static Operations measurement setup, used for helicopter hover and idle configurations, is illustrated in Figure 10. TSPI data were collected using a differential global positioning system (dGPS) (primary system, see Section 3.2.1) on the aircraft and a digital video tracking system (backup system, see Section 3.2.2) on the ground. Acoustical data (see Section 3.3) were collected separately for Dynamic Operations measurements and Static Operations measurements. Meteorological data (see Section 3.4) were collected both on the ground and on top of the FIT control tower, at heights of 4 and 34 ft, respectively, throughout the study.

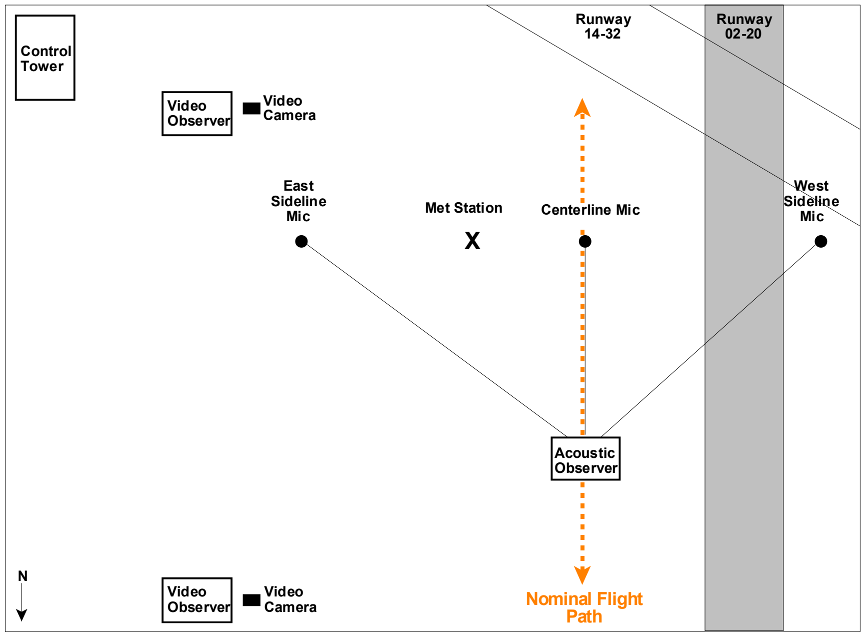

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Figure 9. Dynamic Operations instrumentation layout

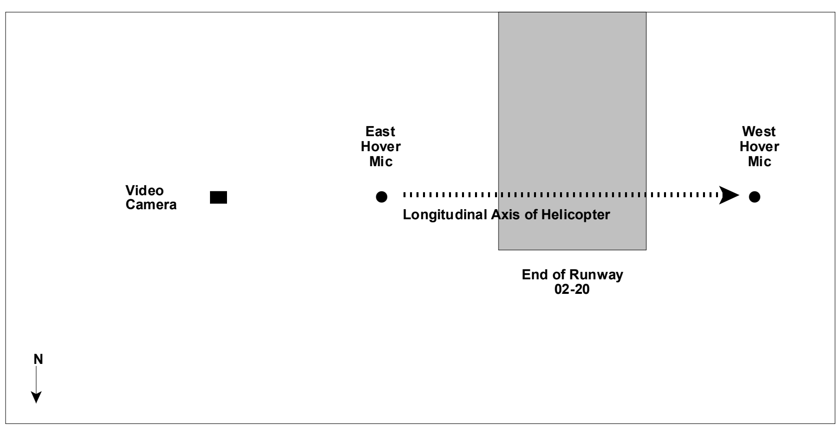

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Figure 10. Static Operations instrumentation layout

3.2 Aircraft Positioning Instrumentation

3.2.1 Differential Global Positioning System

The VCAF dGPS, which provides TSPI data accurate to within approximately ± 20 cm, was utilized for both the initial site survey at FIT, as well as for the primary, real-time tracking of each aircraft during the study. It consists of base station and rover units, each of which receives GPS satellite signals via a NovAtel receiver and transmits or receives differential corrections via a GLB transceiver. VCAF's dGPS collects data continuously at a rate of twice per second (Reference 2).

- **Base Station** - The dGPS base station, including NovAtel receiver, GLB transceiver, GPS antenna, and radio antenna, was located in the airport control tower.

- **Rover Unit** - The dGPS rover unit was maintained aboard the test aircraft. The GPS and radio antennae were sent to the aircraft operators for installation aboard the aircraft prior to the study. The NovAtel receiver, GLB transceiver, gel cell batteries for system DC power, and a laptop containing VCAF's TSPI software, were installed aboard the aircraft just prior to the start of the test and operated by VCAF personnel throughout the study.

3.2.2 Video Tracking

A multi-camera, digital video tracking system was used for documentation purposes and as a backup TSPI system in the event of any dGPS system malfunctions.

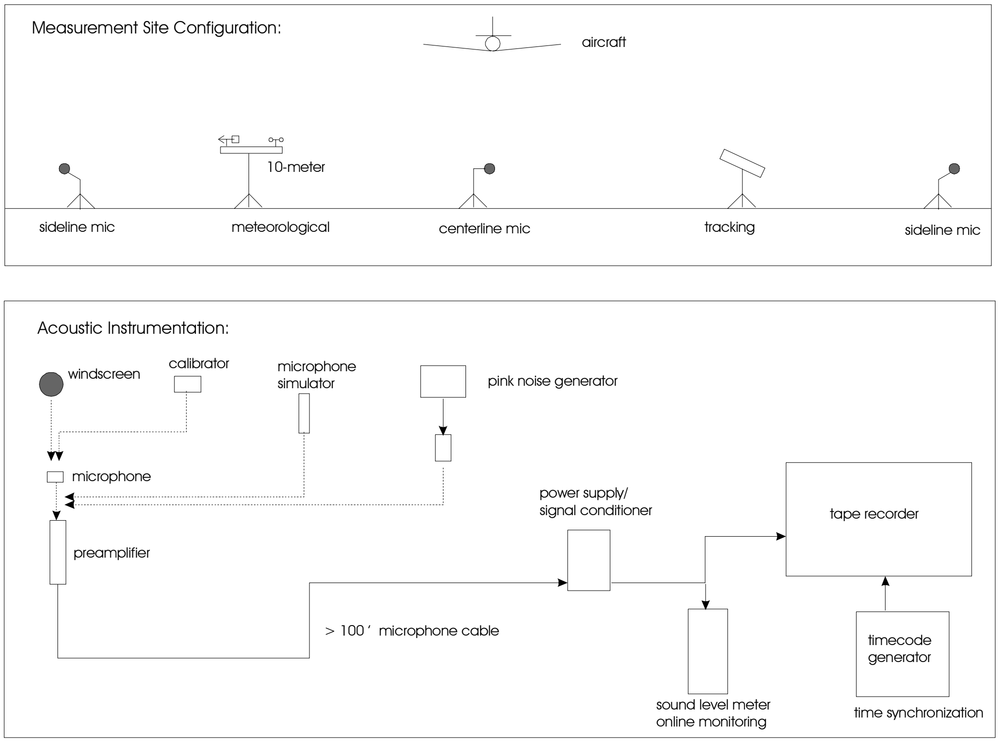
- **Dynamic Operations** - A system consisting of two Canon Optura digital video cameras was used to record aircraft operations. The system utilizes calibrated lenses, field-of-view targets, and triangulation algorithms to determine a target's TSPI data.

- **Static Operations** - A Sony TR818 8 mm camcorder was used to document aircraft orientation during Static Operations.

3.3 Acoustic Instrumentation

This Section provides an overview of the acoustic instrumentation.

- **Dynamic Operations** – For measurement of Dynamic Operations, three microphones (one 4-ft centerline and two 4-ft sideline microphones at approximately 400 ft from the centerline) were used for sound level measurements. Data from these microphones were collected using sound level meters and a digital audiotape (DAT) recorder (see Figure 11) at an acoustic observer table located approximately 100 ft from the centerline microphone. Sideline microphones were set at the appropriate vertical angle (relative to the local ground surface), while the centerline microphone was set at a 90-degree vertical angle, in order to maintain normal grazing incidence to the aircraft throughout the study. Table 11 below provides the coordinates of each microphone position.



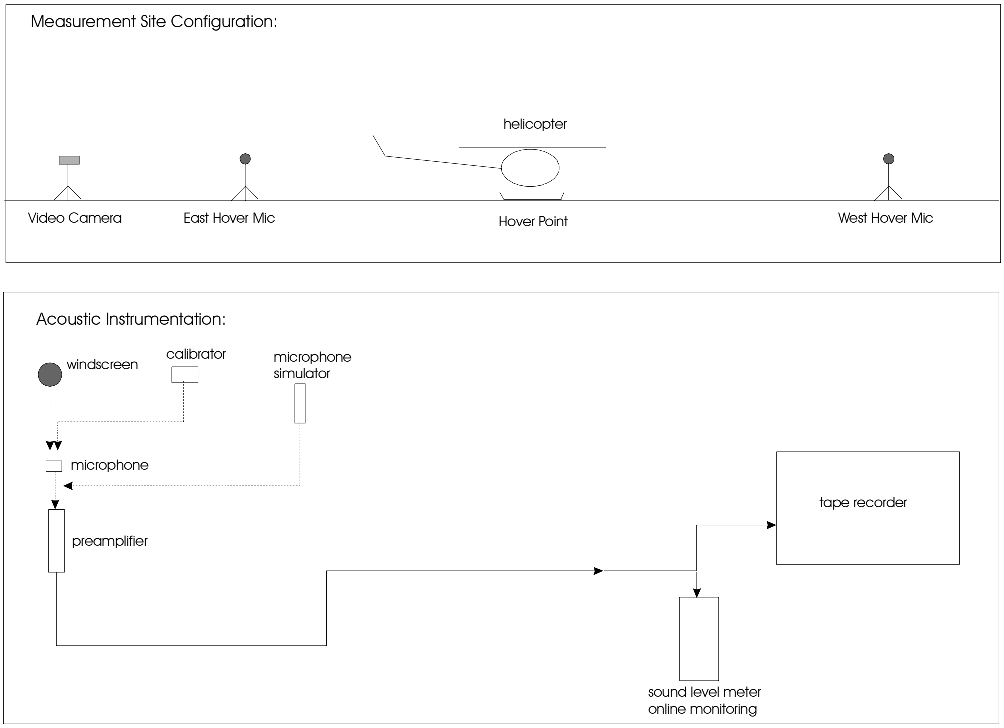
(not to scale)

Figure 11. Measurement site configuration and instrumentation layout for Dynamic Operations

Table 11. Dynamic Operations microphone locations, as measured with dGPS.

Microphone	X-coordinate (ft)	Y-coordinate (ft)	Z-coordinate (ft)	Microphone Height (ft)
East Sideline	0	-400	2	4
Centerline	0	0	0	4
West Sideline	0	400	0	4

- **<u>Static Operations</u>** – For Static Operations measurements, two 4-ft microphones were used for sound level measurements. Data from these microphones were collected using sound level meters and mini-DAT recorders, as shown in Figure 12. Table 12 below provides the coordinates of each microphone position.



(not to scale)

Figure 12. Measurement site configuration and instrumentation layout for Static Operations

Table 12. Static Operations microphone locations, as measured with dGPS.

Microphone	X-coordinate (ft)	Y-coordinate (ft)	Z-coordinate (ft)	Microphone Height (ft)
East Hover	500	-100	3	4
West Hover	500	350	3	4

3.4 Meteorological Instrumentation

Two Transportable Automated Meteorological Stations (TAMS) manufactured by Qualimetrics were deployed at the test facility. The primary TAMS was located near the centerline microphone (see Figure 9). A backup TAMS was placed atop the FIT airport control tower. The backup station was also utilized by the Test Director for real-time feedback related to meteorological conditions. Each TAMS system was configured to measure temperature, relative humidity, wind speed, wind direction, and barometric pressure, continuously at 1-second intervals throughout the study. Representative temperature and relative humidity data for each event are presented in Appendix C.

4.0 DATA COLLECTION AND TEST SERIES DESCRIPTION

The modeling methodology provided in the INM is based on relationships defined in an aircraft noise and performance database. Procedures for using and developing these databases are described in SAE-AIR-1845 (Reference 4), the INM Technical Manual (Reference 5) and the INM Database Request Form (Reference 5 and Appendix A). An aircraft noise and performance database will define the noise source for an aircraft state and be structured in a way that allows a model to reflect how noise source changes with aircraft state.

The test series described in this chapter are designed to capture the noise source as a function of aircraft state. Typically the state of the aircraft includes the aircraft operational mode (Level Flight, or LFO, Approach, or APP, and Departure, or DEP) and its power state. Advanced modeling will vary noise as a function of flap state and speed *independent* of operational mode and power setting, and this capability is available in the INM 7.0[3] series. For INM modeling using the INM 6.0 series, speed/velocity effects are included in the power state and there is no variation of noise source *directly* related to the speed of the aircraft. The only adjustments directly related to speed that are accounted for in later sections are *duration corrections* applied to exposure based metrics.

The SAE guidance document (Reference 4) is primarily a jet noise model that is adapted to handle aircraft such as propeller-driven aircraft and helicopters. SAE is examining the refinement of these methods to support more advanced modeling related to helicopters. This data collection effort includes test series that support additional source data for noise models, including: 1) accounting for directivity through left, right and center NPD curves, 2) 360-degree directivity patterns for hover and idle static operations, and 3) effects of speed on noise beyond simple duration corrections. The speed effects in the latter are referred to as blade tip mach number corrections, as this is believed to be the dominant source for this speed adjustment. SAE will peer review these and other issues related to helicopters. As this type of data has been collected across other projects and is considered a better practice than the simpler methodology in SAE-AIR-1845, FAA will provide this data in INM 7.0 to assist SAE and modelers in helicopter-related projects.

Test series descriptions for each aircraft are outlined in Tables 13, 14, and 15. Dynamic Operations events included LFO, APP, and DEP flight configurations.

4.1 Propeller-Driven Aircraft

Table 13 describes the different test series for propeller-driven aircraft, varied by:

- Flight Configuration (Operational Mode, Flap Setting, Descent)
- Reference Altitude
- Reference Speed
- Power

Flight configuration varied among LFO, APP, and DEP. The reference altitude was 500 ft for most events, except for the 1100 and 1200 measurement series flown with the PA-

[3] At the time of publication, INM 7.0 has yet to be publicly released.

28 #2, in which the reference altitudes were 100 and 200 ft, respectively. The flap settings were appropriate to the aircraft configuration. The reference speed refers to the aircraft groundspeed, in kts. Aircraft power is expressed in either RPM, manifold pressure (MAP, in inches of Mercury [in-Hg]), or torque (ft-lb).

- In the last two columns of Table 13, test series noise data collected to meet basic INM requirements are distinguished from test series noise data collected as a supplement to INM requirements, specific to the anticipated needs of the ATMP program.

- Maule M-7-235C 500 Series, 600 Series, 700 Series, 800 Series, and 900 Series noise data were not collected due to inclement weather conditions. A more detailed discussion of the Maule test series is presented in Section 6.1.3.

- Piper Warrior PA-28-161 1100 and 1200 Series noise data were collected in order to investigate the relationship between right-side and left-side noise (i.e., Does this aircraft possess a noticeably different noise signature on the left versus right side of the craft?); the results of an investigation into this directivity relationship and the possible effects of the ground surface need to be addressed in the future.

- The PA-28 (#2) 2000 Series noise data were collected in order to compare runs performed with two different PA-28 aircraft and to ensure the noise characteristics for the two aircraft were similar. A comparison of the data for these two aircraft is presented in Section 6.1.2.

Table 13. Propeller-driven aircraft test series descriptions.

Series	Conf.	Operational Mode	Flap Settings	Descent (ft/min)[4]	Ref. Alt. (ft)	Aircraft	# Events Used	Ref. Speed (kts)	Power			INM Stand.	Supp.
									RPM	MAP (in-Hg)	Torq. (ft-lb)		
300	LFO	Level flight	Up	NA	500	PA-28 (#1)	6	105	2467	NA	NA	✓	
						PA-30	2	165	2400	26	NA		
						PA-31	5	156	2380	34	NA		
						M-7-235C	3	87	2300	23	NA		
						1900D	5	220	1450	NA	3000		
400	LFO	Level flight	Up	NA	500	PA-28 (#1)	3	95	2150	NA	NA		✓
						PA-30	1	135	2200	22	NA		
						PA-31	2	155	2190	27	NA		
						M-7-235C	1	70	2000	15	NA		
500	DEP	Departure	Up	NA	500	PA-28 (#1)	6	79	2442	NA	NA	✓	
						PA-30	5	97	2600	24	NA		
						PA-31	6	105	2500	40	NA		
						1900D	3	160	1700	NA	3200		
600	APP	Approach	Up	500	500	PA-28 (#1)	2	100	1800	NA	NA	✓	
						PA-30	3	100	2300	15	NA		
						PA-31	3	160	2400	NA	NA		
						1900D	3	160	1450	NA	800		
700	APP	Approach	10	500	500	PA-28 (#1)	1	80	1600	NA	NA	✓	
						PA-30	3	96	2300	13	NA		
						PA-31	3	150	2380	NA	NA		
						1900D	2	130	1450	NA	700		
800	APP	Approach	25	500	500	PA-28 (#1)	1	70	1500	NA	NA	✓	
						PA-30	3	87	2300	14	NA		
						PA-31	2	120	2350	20	NA		
						1900D	2	115	1550	NA	1000		
900	LFO	Accel.	Up	NA	500	PA-28 (#1)	3	87	2600	NA	NA		✓
						PA-30	3	97	2650	29	NA		
						PA-31	3	105	2480	40	NA		
						1900D	3	160	1550	NA	3200		
1100	LFO	Level flight	Up	NA	100	PA-28 (#2)	2	105	2467	NA	NA		✓
1200	LFO	Level flight	Up	NA	200	PA-28 (#2)	4	105	2467	NA	NA		✓
2000	LFO	Level flight	Up	NA	500	PA-28 (#2)	3	105	2467	NA	NA		✓

Meteorological and TSPI data are presented for each of these events in Appendices C and D, respectively.

4.2 Helicopter - Dynamic Operations

Table 14 describes the Dynamic Operations test series for helicopter aircraft, varied by:

- Flight Configuration (Operational Mode, Descent Angle)
- Reference Altitude
- Reference Speed
- Power

NPDs for the above conditions are developed for left, right, and center of the helicopter to account for special directivity effects.

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[4] Note that the rate of descent parameter for propeller aircraft is presented in units of feet-per-minute, while for helicopters (Table 14) it is described in terms of a descent angle, in degrees.

Flight configuration varied among LFO, APP, and DEP. The reference altitude was 500 ft for all events, except for the 180 measurement series, in which the reference altitude was 100 ft. The descent angle (degrees) varied among 0, -3, -6, -9, and -12. The reference speed (kts) refers to the helicopter groundspeed. Helicopter power is expressed in either MAP, percent engine speed (%), or percent torque (%).

- In the last two columns, test series noise data collected to meet basic INM requirements are distinguished from noise data collected as a supplement to INM requirements specific to the anticipated needs of the ATMP program. As indicated in Table 14, the ATMP program anticipates the need for an expanded set of APP data at -3-, -9-, and -12-degree descent angles.

Table 14. Helicopter test series descriptions.

Series	Conf.	Operational Mode	Descent angle[5]	Ref. Alt. (ft)	Aircraft	# Events Used	Ref. Speed (kts)	Power			INM Stand.	Supp.
								MAP (in-Hg)	Torq. (ft-lb)	Engine Speed (%)		
120	LFO	Level flight	0	500	R-22	3	90	22	NA	NA	✓	
					EC-130	3	115	NA	75	93		
130	LFO	Level flight	0	500	R-22	3	81	22	NA	NA	✓	
					EC-130	2	125	NA	88	96		
140	LFO	Level flight	0	500	R-22	1	72	20	NA	NA	✓	
					EC-130	3	101	NA	53	90		
150	LFO	Level flight	0	500	R-22	3	63	18	NA	NA	✓	
					EC-130	3	88	NA	53	89		
160	LFO	Level flight	0	500	R-22	2	54	18	NA	NA	✓	
					EC-130	3	76	NA	48	89		
180	LFO	Level flight	0	100	R-22	3	72	17	NA	NA	✓	
					EC-130	3	101	NA	70	93		
210	DEP	Departure	NA	500	R-22	3	53	23	NA	NA	✓	
					EC-130	6	65	NA	85	95		
310	APP	Approach	-3	500	R-22	1	53	19	NA	NA		✓
					EC-130	3	65	NA	35	83		
320	APP	Approach	-6	500	R-22	2	53	15	NA	NA	✓	
					EC-130	3	65	NA	18	78		
330	APP	Approach	-9	500	R-22	3	53	15	NA	NA		✓
					EC-130	3	65	NA	10	76		
340	APP	Approach	-12	500	R-22	2	53	17	NA	NA		✓
					EC-130	4	80	NA	10	79		
350	APP	Constant Decel.	-6	500	R-22	3	50	14	NA	NA		✓
					EC-130	3	60	NA	12	78		

Meteorological and TSPI data are presented for each of these events in Appendices C and D, respectively.

4.3 Helicopter - Static Operations

Table 15 describes the Static Operations test series for helicopters, varied by:

- Flight Configuration
- Reference Altitude

[5] Note that the rate of descent parameter for helicopters is presented in terms of a descent angle, in degrees, while for propeller aircraft it is presented in units of feet-per-minute.

– Power

The test series for these conditions are used to develop a single NPD accompanied by a full 360-degree directivity pattern to model flight configuration varied by hover in-ground effect (HIGE), hover out-of-ground effect (HOGE), Ground Idle, and Flight Idle. The reference altitude depended on helicopter position (Reference 3), but in all cases was measured from the bottom of the helicopter skids. Helicopter power is expressed in either MAP, percent engine speed, or percent torque.

- Event 410 was designed to measure HIGE, and Event 420 was designed to measure HOGE. The HIGE reference altitude is 5 ft, and the HOGE reference altitude is the main rotor diameter multiplied by 2.5 (Reference 3), or 63 ft for the R-22 and 88 ft for the EC-130. These events were performed directly over the hover point illustrated in Figure 10.

- Note that rotation of the helicopters through 180 degrees simulated a full 360-degree rotation, based on the use of two microphones on opposite sides of the craft (see Section 6.2).

Table 15. Helicopter Static Operations test series descriptions.

Series	Config.	Operational Mode	Ref. Speed (kts)	R-22 Ref. Altitude (ft)[6]	EC-130 Ref. Altitude (ft)[5]	R-22 MAP (in-Hg)	EC-130 Power		INM Stand.	Supp.
							Engine Speed (%)	Torq. (%)		
410	HIGE	Hover	0	5	5	25	93	66	✓	
420	HOGE	Hover	0	63	88	25	93	70	✓	
510	Flight Idle	Idle	0	0	0	15	90	11	✓	
520	Ground Idle	Idle	0	0	0	11	68	9	✓	

Meteorological and TSPI data are presented for each of these events in Appendices C and D, respectively.

4.4 Helicopter – Source Noise Speed Effects

The fundamental SAE-AIR-1845 modeling methodology does not directly account for speed effects on source noise; there are only duration corrections that are applied to exposure-based metrics, such as SEL and EPNL. However, it is recognized that these speed effects do exist. For example, data collection efforts and research projects can identify airframe noise effects for commercial jet aircraft, and to account for these effects, special adaptations to SAE-AIR-1845 must be employed.

Helicopter measurement programs have also quantified a speed effect (Reference 8). Across test series of level flight conditions (LFO), power and aircraft state may be constant with aircraft speed varying about the reference speed. Aircraft noise will be seen to vary with speed and this effect may be captured through a regression of noise on

[6] HIGE and HOGE altitude are measured from the bottom of the helicopter skids.

speed. There may be several sources for this effect, but the dominant source is believed to be attributable to blade tip mach number. Previous measurement programs for noise models (Reference 8) have reported this effect as a blade tip mach number correction. The flight tests of this study sought to observe and quantify this effect to check consistency with past measurement programs and modeling efforts.

5.0 TEST SERIES DATA ANALYSIS/NOISE MODEL DATA DEVELOPMENT

Section 4.0 of this report details the test series of this data collection and describes the noise source data that is produced to support current noise models. This section describes the analysis undertaken to process the collected data and the procedures used to transform this data into a form suitable for noise models. This section overviews the data reduction and analysis procedures. Noise-Power-Distance (NPD) data were generated for four different noise metrics: sound exposure level (SEL), denoted by the symbol L_{AE}; maximum, slow-scale, A-weighted sound level (MXSA), denoted by the symbol L_{ASmx}; effective perceived noise level (EPNL), denoted by the symbol L_{EPN}; and tone-adjusted, maximum, slow-scale, perceived noise level (MXSPNT), denoted by the symbol L_{PNTSmx}. Hover data consist of time-period, equivalent, continuous, A-weighted sound pressure levels (TAEQ), denoted by the symbol L_{Aeqt}, and time-period, equivalent, continuous, perceived noise levels (TPEQ), denoted by the symbol L_{PNTt}.[7] For the EC-130 HIGE and HOGE events and the R-22 HIGE event, the averaging time-period (t) is 10 seconds; for the R-22 HOGE event, the averaging time-period is 6 seconds.

See Appendix E for aircraft Dynamic Operations L_{AE}, L_{ASmx}, L_{EPN}, and L_{PNTSmx} NPD data in tabular form, helicopter hover and idle configuration L_{Aeqt} and L_{PNTt} NPD and directivity data in tabular form, and aircraft L_{AE} NPD data in plotted form.

Developing noise model data from data collected in a particular test series requires that analysis procedures verify and determine that the acoustic state captured by an NPD correctly represents the intended reference conditions. This involves a three-step process, including: 1) Verify that an individual event adhered to the test series reference parameters (i.e altitude, power, speed) to produce a final event set; 2) Obtain the statistical average of the final event set to produce representative noise model data (i.e. spectral class, NPD, blade tip mach number); and 3) Perform an analysis that quantifies the relation between the average model data and the final event set for the test series.

5.1 Test Series Event Verification

Field data are collected in various formats, including DAT (acoustic data), ASCII files (TSPI and Met data), digital video tape (video tracking data), and paper annotation (multiple field logs). This information was converted to a uniform digital format for processing by VCAF's analysis software.

5.2 Noise Model Data Development

Noise model data development included the production of: 1) Spectral Classes; 2) Noise-Power-Distance-Curves; 3) Helicopter Static Operation Directivity Patterns; and 4) Blade tip mach number corrections. Field data were reduced to a form usable by VCAF's analysis software, and the procedures discussed in FAR Part 36 (Reference 1) were followed.

[7] From this point forward, noise metrics will be referred to by their symbol (L_{AE}, L_{ASmx}, L_{EPN}, L_{PNTSmx}, L_{Aeqt}, or L_{PNTt}).

- **FAR 36** The as-measured sound pressure level (SPL) data, meteorological data, and tracking data were used by VCAF's processing suite to generate a set of sound level metrics. These metrics were derived for the three, 4-ft microphones for each aircraft event. A general processing flow diagram is presented in Figure 13.

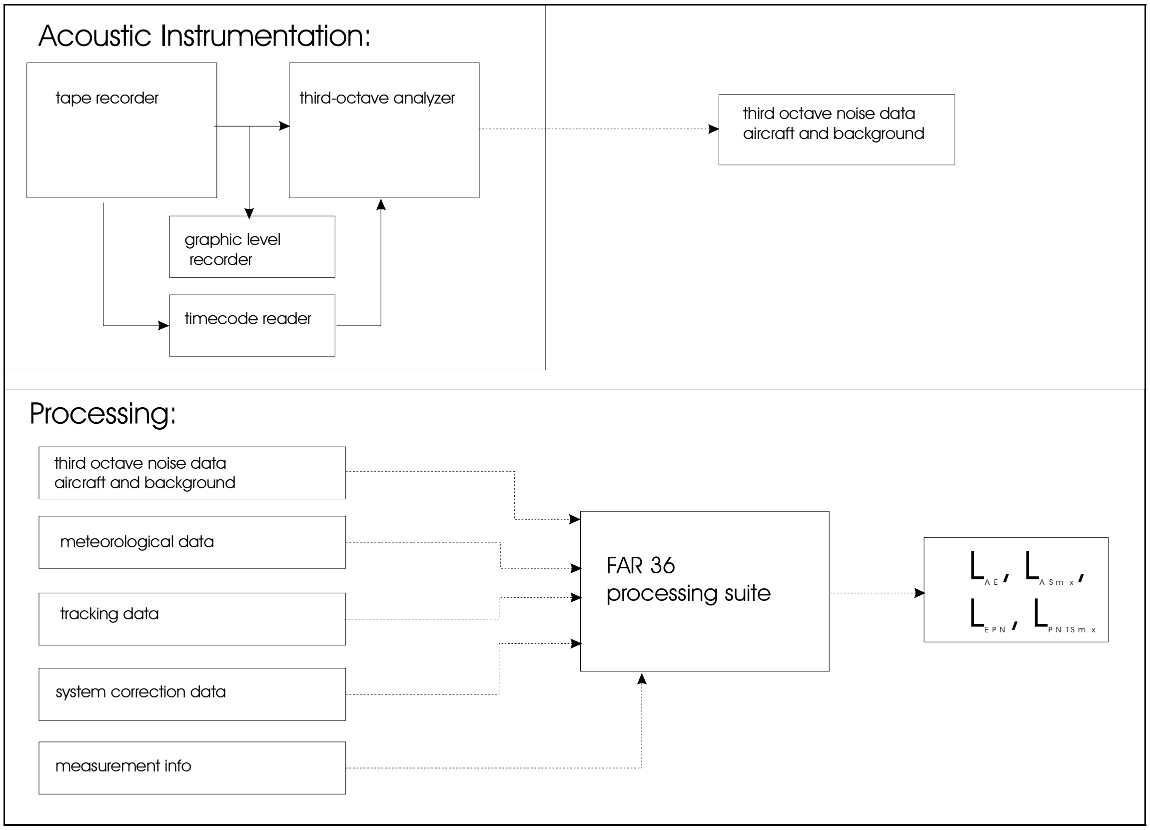


Figure 13. Data processing flow diagram

- Four programs in the VCAF FAR 36 processing suite apply the necessary sound level adjustments:
  - First, system correction data files are generated, including combined system frequency response, combined microphone pressure and free-field response, and valid average pre-detection background noise.
  - Second, initial acoustic data processing is performed, including the calculation of a timestamp for each record, the testing of data validity vs. pre-detection and post-detection background noise, and the calculation of preliminary metrics for each acoustic data record, including tone-correction factors. Using meteorological and tracking data, this second program also reconstructs masked sound pressure levels via frequency-extrapolation and/or time-extrapolation methods.
  - Third, aircraft tracking data is processed, including the calculation of single-point track data from the TSPI time-history data, the determination of the speed of sound, and the calculation of propagation distance,

acoustic emission angle, elevation angle, and reference condition propagation distance for each acoustic data record.
  - Fourth, spherical spreading and atmospheric absorption are accounted for via both the simplified and integrated procedures.

- Sound level metrics were derived using both simplified and integrated procedures:

  - **Simplified Metrics** Simplified L_{AE}, L_{ASmx}, L_{EPN}, and L_{PNTSmx} metrics were generated using as-measured spectral and tracking data taken at aircraft overhead time. These metrics were strictly used for diagnostic purposes only and will not be discussed further in this document.

  - **Integrated Metrics** Integrated L_{AE}, L_{ASmx}, L_{EPN}, and L_{PNTSmx} metrics were generated using the full, spectral, meteorological and tracking time-history data representative of aircraft sound levels within ten decibels of the maximum sound level. The integrated procedure adjusts the as-measured, one-half second spectral data for atmospheric and off-reference conditions to a single, reference condition. These integrated metrics have been assembled into NPDs and are presented in the noise data tables in Appendix E.

A test was performed to compare the variance of the Volpe software processing methodologies. In Figure 14, as-measured and FAR 36-generated L_{AE} and L_{ASmx} values are compared. This plot features data from the EC-130 helicopter and compares as-measured, simplified FAR 36, and integrated FAR 36 L_{AE} and L_{ASmx} values from individual 120 Series events plus the average and standard deviation of the events.

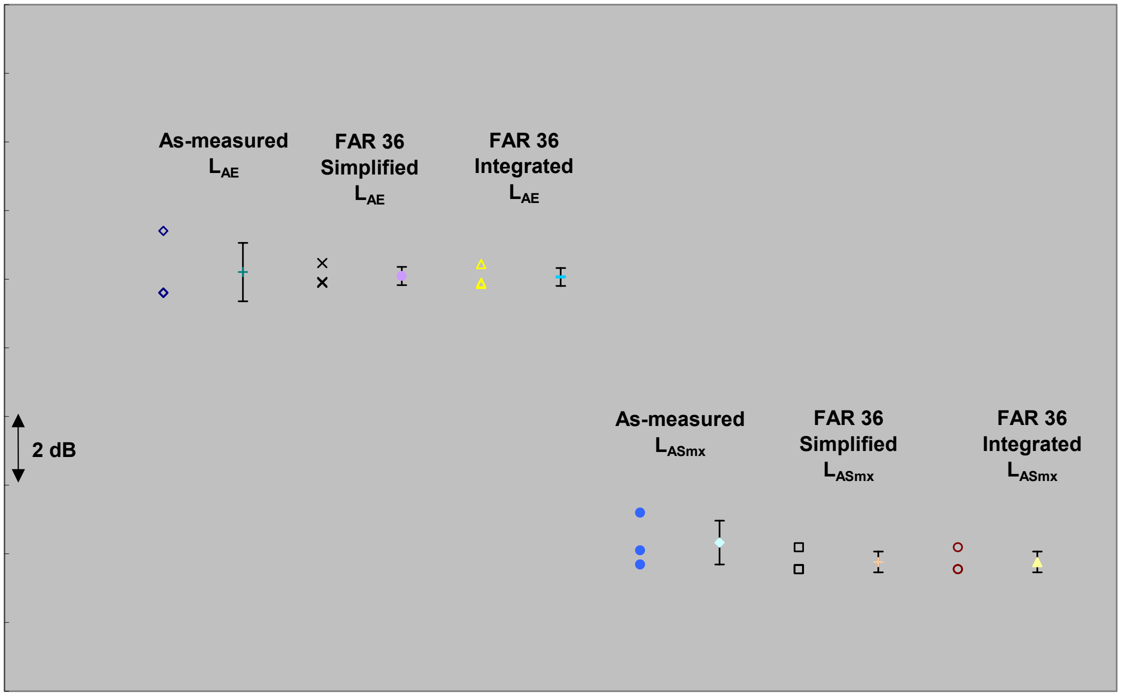


Figure 14. Processing methodology comparison of individual EC-130 120 Series event L_{AE} and L_{ASmx} values with average and standard deviation

6.0 RESULTS

Results from the Fitchburg Noise Measurement Study are presented in this section. Section 6.1 discusses Dynamic Operations NPDs. Refer to Tables 13 and 14 in Sections 4.1 and 4.2, respectively, for specifics on the operational characteristics associated with each Dynamic Operations measurement series. Directivity plots for the helicopter HIGE and HOGE events are presented in Section 6.2. Refer to Table 15 in Section 4.3 for specifics on the operational characteristics associated with each hover event.

Each measurement series NPD was generated from Dynamic Operations noise data collected during one to six DEP, APP, or LFO events which were adjusted in VCAF's FAR 36 processing software, grouped by configuration and power settings, and arithmetically averaged together.

Though the INM currently uses only centerline NPDs to calculate noise for propeller-driven aircraft, the sideline NPDs are discussed for completeness and in the event a future release of the INM may utilize sideline NPDs in its calculations. The helicopter noise calculation methodology to be included in INM 7.0 is expected to utilize centerline and sideline NPDs, as is the case with the Heliport Noise Model (HNM).

6.1 Noise-Power-Distance Curves

The Dynamic Operations NPDs from the Fitchburg noise study are discussed in Section 6.1. Left-side, center, and right-side (relative to the direction of flight) noise data were collected for the Maule M-7-235C, Piper Twin Comanche PA-30, Piper Navajo Chieftain PA-31-350, Piper Warrior PA-28-161, and Beech 1900D propeller-driven aircraft as well as the Eurocopter EC-130 and Robinson R-22 helicopters. The NPDs generated from these noise data, adjusted for reference speed, reference distance, reference temperature, and reference relative humidity and grouped into measurement series according to power settings, are presented in tabular form in Appendix E. The L_{AE} Dynamic Operations NPDs are plotted in Figures E-1 through E-56.

6.1.1 Reference Speed Duration Adjustment for Exposure-Based Metrics

All of the exposure-based NPD data in Section 6.0 and Appendix E were developed (according to the procedures documented in Section 5.0) using each aircraft's reference speed. Consistent with SAE-AIR-1845 ([Reference 4] which, along with FAR 36, is the foundation for processing data for inclusion in the INM [Reference 5]), NPDs for exposure-based aircraft noise metrics were adjusted to a reference speed of 160 kts. This was performed by applying a duration adjustment to the propeller-driven aircraft NPDs to account for the effect of time-varying aircraft speed. Since the L_{ASmx} and L_{PNTSmx} metrics are assumed to be independent of speed, no duration adjustment is applied to these metrics. The L_{AE} and L_{EPN} values in Appendix E of this report were adjusted prior to entering them into the INM's NPD_CURV.DBF database table, which is included in Appendix G. This duration adjustment is made using the following equation from Section 3.7 of the INM Technical Manual (Reference 6):

$$DUR_{ADJ} = 10 \log_{10}[160/AS_{seg}] \qquad \text{[Eq. 1]}$$

where AS_{seg} is the aircraft reference speed at the closest point of approach between the flight segment and the receiver.

All aircraft-specific reference speeds and the corresponding INM duration adjustments to 160 kts are provided in the TSPI data tables in Appendix D of this report. The aircraft NPD noise metric information contained in the NPD_CURV.DBF file described in Appendix G and found on the included CD-ROM have been adjusted to a reference speed of 160 kts. No other data presented in this report have been adjusted to 160 kts. Data reference speed information is summarized in Table 16.

Table 16. Propeller-driven aircraft data reference speed information.

Data Set	Reference Speed
Section 6.0	Aircraft specific
Appendix D	Aircraft specific
Appendix E	Aircraft specific
Appendix G	160 kts

6.1.2 Two Fitchburg PA-28 Aircraft

As noted in Section 1.0, two different PA-28 aircraft were utilized for the study, one on April 29 and May 6, 2002 (PA-28 #1), and the other on August 30, 2002 (PA-28 #2). While only PA-28 #1 was used to collect events for basic INM requirements, some events were collected with PA-28 #2 as a supplement to INM requirements specific to the ATMP program. The noise collected from both the PA-28 #1 and the PA-28 #2 during a 500-ft reference altitude LFO at 105 kts reference speed and 2,467 RPM reference power were compared in order to measure repeatability, and to determine the degree of acoustic equivalency of the two aircraft. Table 17 presents a comparison of the noise collected from PA-28 #1 and PA-28 #2 in level flight. The PA-28 #1 left-side, centerline, and right-side NPDs were generated from the noise collected during six LFO events which have been adjusted in VCAF's FAR 36 processing software, and arithmetically averaged together. The PA-28 #2 NPDs were generated from the noise collected during three LFO events, similarly adjusted and averaged.

Table 17. An L_{AE} comparison of two Warrior PA-28 aircraft at 500-ft, 105-kts.

Dist. (ft)	Average Left Δ (dB(A))	Average Center Δ (dB(A))	Average Right Δ (dB(A))
200	0.0	-1.4	-0.8
400	-0.2	-1.6	-0.9
630	-0.3	-1.8	-1.0
1000	-0.4	-1.9	-1.1
2000	-0.5	-2.1	-1.2
4000	-0.4	-2.2	-1.0
6300	-0.1	-2.1	-0.7
10000	0.2	-2.0	-0.3
16000	0.7	-1.8	0.4
25000	1.0	-1.5	0.8
max	1.0	-1.4	0.8
min	-0.5	-2.2	-1.2
average	0.0	-1.8	-0.6

It was found that the L_{AE} results from the two aircraft are very similar at the left and right sideline (generally within 1.0 dB), and were relatively similar at the centerline (generally within 2.0 dB). The similarity between the noise of the two aircraft is further demonstrated in a comparison of the centerline maximum adjusted noise spectra generated by each aircraft during 500-ft, 105-knot LFO events collected over three different days. These spectra, which have been adjusted to a 500-ft reference altitude, are presented in Figure 15.

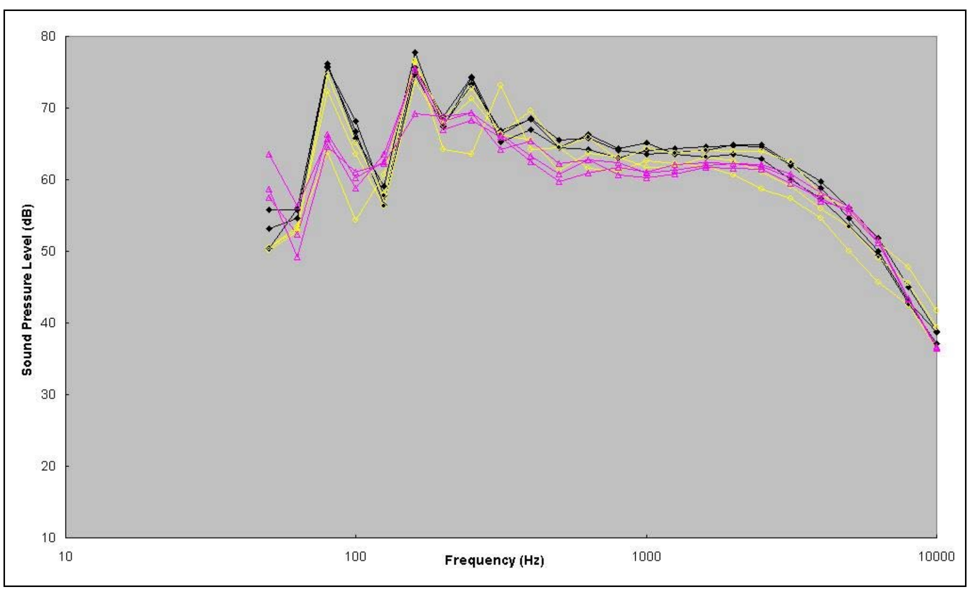


Figure 15. Comparison of PA-28 aircraft adjusted centerline maximum spectra

The three black spectra represent data for the PA-28 #1 flown on April 29, 2002. The three yellow spectra are from PA-28 #1 flown on May 6, 2002. The three pink spectra are from PA-28 #2 flown on August 30, 2002. Based on the above comparisons, it was concluded that comparable data collected for the two aircraft were sufficiently similar.

6.1.3 Maule M-7-235C Data

Weather conditions during the Maule study were below Visual Flight Rules (VFR) minimum requirements for operation in controlled airspace; cloud ceilings were at approximately 2,000 ft mean sea level (MSL). In order to obtain the minimum necessary acoustic data, study events were performed at the end of "missed approaches" on the Fitchburg GPS RWY 20 instrument APP procedure. The flight time required for each of these events was approximately 20 to 25 minutes, as opposed to the typical 5 - 7 minutes for normal VFR condition events. The additional time required resulted in only two measurement series being completed for this aircraft. Accordingly, data are only presented for the Maule 300 and 400 Series in Appendix E and Appendix G.

6.2 Helicopter Directivity Data

Polar plots of the helicopter directivity noise data are presented in Figures 17 through 20 of Section 6.2. These data are presented in tabular form in Appendix E. Table 15 presents the Static Operations test events for helicopters, varied by configuration and altitude. Note: Event 410 was designed to measure the HIGE, and Event 420 was designed to measure the HOGE. These events were performed directly over the hover point illustrated in Figure 10 at different reference altitudes measured from the bottom of the helicopter skids: The HIGE reference altitude is 5 ft, and the HOGE reference altitude is the main rotor diameter multiplied by 2.5 (Reference 3).

The R-22 began the HIGE event in line with the longitudinal axis, with the nose facing the West Hover Microphone and the tail facing the East Hover Microphone (see Figure 10 above for a diagram of the helicopter hover event placement). The pilot then rotated the helicopter counterclockwise in 45-degree increments approximately every 30 seconds through a sweep of 180 degrees at a reference altitude of 5 ft. Figure 16 below presents a diagram of the helicopter sweep pattern. For the HOGE event, the pilot rotated the R-22 clockwise back to its original position at an altitude of 63 ft. EC-130 measurements were conducted in a similar manner, with reference altitudes of 5 and 88 ft, respectively, for the HIGE and HOGE events.

Data in increments of 15 degrees were interpolated from the 45-degree data in order to meet anticipated requirements for future releases of the INM. Note that rotation through 180 degrees simulated a full 360-degree rotation, based on the use of two microphones on opposite sides of the craft. The plots below present the time-period equivalent continuous A-weighted sound pressure level (TAEQ) difference, denoted by the symbol ΔL_{Aeqt}, produced as the helicopter nose sweeps 180 degrees away from the longitudinal axis (position L_0, where the Rotational Angle and ΔL_{Aeqt} are both zero), with the right side facing one microphone and the left side facing the other microphone. For the EC-130 HIGE and HOGE events, and the R-22 HIGE event, the time-period is 10 seconds; for the R-22 HOGE event, the time-period is 6 seconds. Average wind direction and wind speed are noted on each plot. Note that a wind direction of zero degrees indicates a wind blowing exactly north.

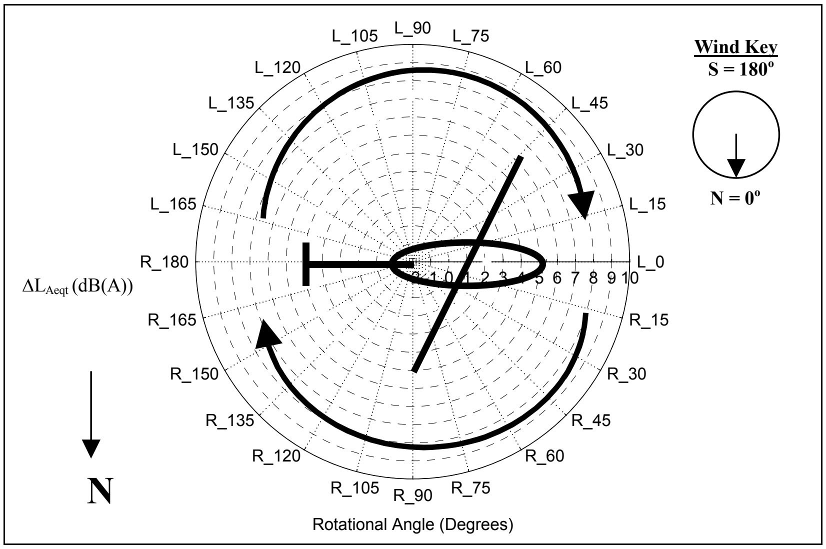


Figure 16. Helicopter sweep pattern through HIGE and HOGE events

6.2.1 Hover In-Ground Effect

Some asymmetry is noted in the R-22 and EC-130 HIGE data, plotted in Figures 17 and 18. Asymmetry is not uncommon in hover noise directivity data and has been noted in HNM data (Reference 3). However, it is important to know that this asymmetry is not due to the effects of wind. A cursory analysis of the correlation between wind speed and direction and the hover noise directivity sound levels in Figures 17 and 18 indicates that asymmetry in the directivity data is not the effect of wind speed and direction but rather a real characteristic of the source.

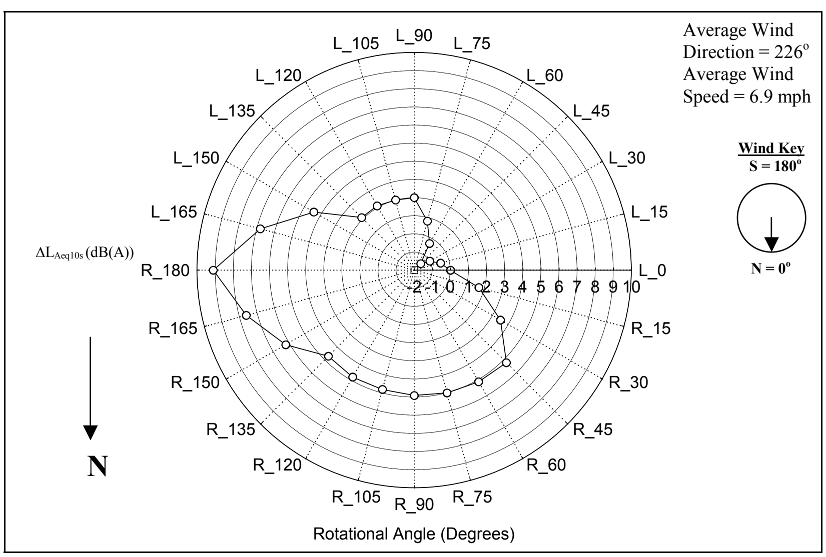


Figure 17. EC-130 HIGE directivity

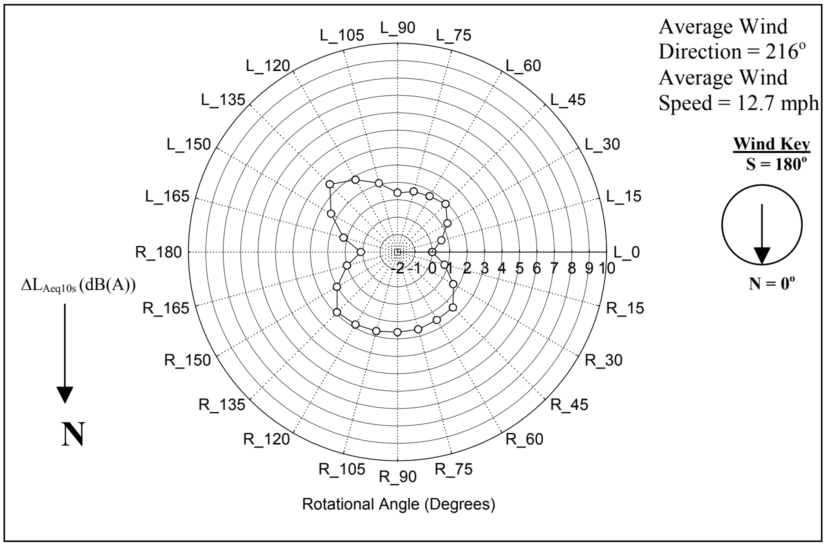


Figure 18. R-22 HIGE directivity

6.2.2 Hover Out-of-Ground Effect

Some asymmetry is noted in the R-22 and EC-130 HOGE data, plotted in Figures 19 and 20. Again, a cursory analysis of the correlation between wind speed and direction and the hover noise directivity sound levels in Figures 19 and 20 indicates that asymmetry in the directivity data is not the effect of wind speed and direction but rather a real characteristic of the source.

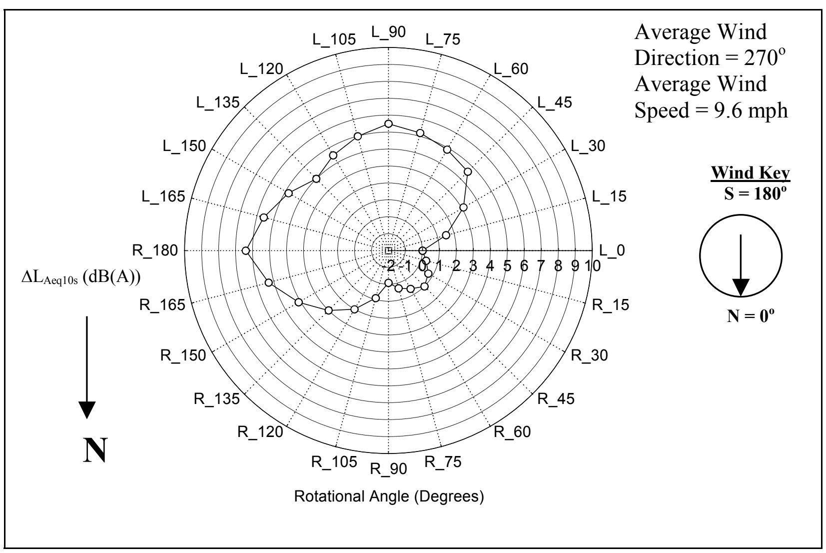


Figure 19. EC-130 HOGE directivity

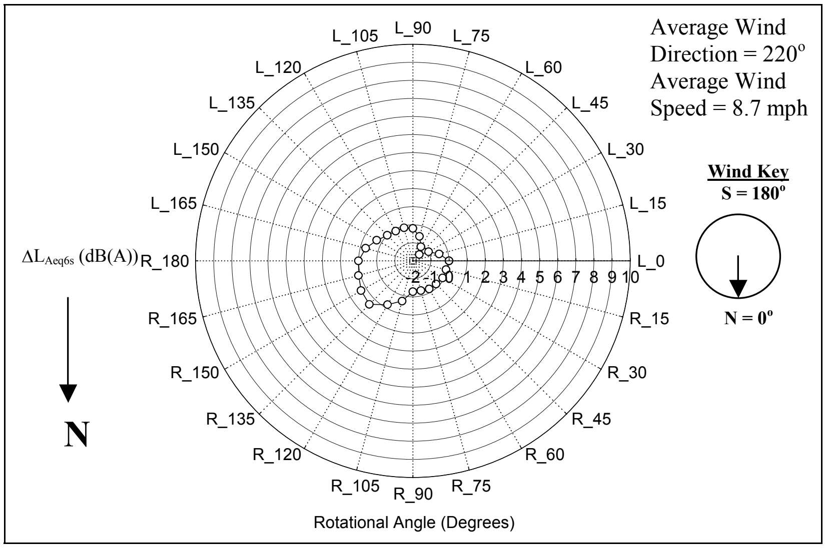


Figure 20. R-22 HOGE directivity

7.0 REFERENCES

1. Federal Aviation Regulations, Part 36, Noise Standards: Aircraft Type and Airworthiness Certification, Federal Aviation Administration: Washington, DC, September 1992.

2. Differential Global Positioning System User's Guide Version 1.2, John A. Volpe National Transportation Systems Center Acoustics Facility: Cambridge, MA, July 2000.

3. Fleming, Gregg G., Rickley, Edward J., HNM, Heliport Noise Model Version 2.2, User's Guide, DOT Report No. DOT-VNTSC-FAA-94-3, US Department of Transportation: Washington, DC, February 1994.

4. Society of Automotive Engineers, Committee A-21, Aircraft Noise, Procedure for the Calculation of Airplane Noise in the Vicinity of Airports, Aerospace Information Report No. 1845, Society of Automotive Engineers, Inc.: Warrendale, PA, March 1986.

5. Fleming, et al., Integrated Noise Model (INM) Version 6.0 User's Guide, FAA Report No. FAA-AEE-99-03, Federal Aviation Administration: Washington, DC, September 1999.

6. Fleming, et al., Integrated Noise Model (INM) Version 6.0 Technical Manual, FAA Report No. FAA-AEE-02-01, Federal Aviation Administration: Washington, DC, January 2002.

7. Spectral Classes for FAA's Integrated Noise Model Version 6.0, John A. Volpe National Transportation Systems Center Acoustics Facility: Cambridge, MA, December 1999.

8. Noise Measurement Flight Test for Aerospatiale SA 354N Dauphin 2 Twin Jet Helicopter: Data and Analyses, FAA Report No. FAA-EE-84-2, Federal Aviation Administration: Washington, DC, April 1984.

APPENDIX A: INM DATA

Appendix A presents the aircraft performance data necessary to build INM database tables for the Piper Twin Comanche PA-30, Piper Navajo Chieftain PA-31-350, Piper Warrior PA-28-161, and Beech 1900D.

As discussed in Section 6.1.3, weather conditions during the Maule M-7-235C study resulted in only two measurement series being completed for this aircraft. Therefore, instead of a performance data report, options for including the Maule as a user-defined aircraft in the INM are presented.

Performance data for the EC-130 and R-22 helicopters are presented in Sections 2.6 and 2.7, respectively. Options for including the EC-130 and R-22 as user-defined aircraft in the INM are also presented.

A.1 INM Database Request Form

The aircraft performance data are presented in the form of letter reports prepared by Senzig Engineering for the VCAF. Each letter report details the derivation of performance parameters for each propeller-driven aircraft and provides a completed INM Database Request Form (Reference 6). Because the letter reports are considered stand-alone documents, the tables and figures presented in these letter reports are not listed in the List of Figures and the List of Tables.

A.1.1 Piper Twin Comanche PA-30

June 2, 2003

Gregg Fleming
Division Chief, Environmental Measurement and Modeling

John A. Volpe National Transportation Systems Center
55 Broadway
Cambridge, Massachusetts

Re: Piper Twin Comanche data for the Integrated Noise Model

Dear Mr. Fleming,

On April 30, 2002, the Volpe National Transportation Systems Center (Volpe) and the Federal Aviation Administration (FAA) conducted a study with a Piper PA-30 Twin Comanche (PA-30) at Fitchburg Municipal Airport in Massachusetts. The study was conducted with the goal of determining reference noise and performance data for the FAA's Integrated Noise Model (INM). This letter report describes the methods and documents the information sources used to generate the INM performance data. As part of the same test, four other propeller-driven aircraft were tested: a Piper PA-28 Warrior, a Piper PA-31-350 Navajo Chieftain, a Raytheon Beech 1900D, and a Maule M-7-235C. The INM performance data developed for these aircraft are contained in separate letter reports.

INM performance data are divided into thrust parameters and aerodynamic parameters. The first Section of this report discusses the PA-30 thrust parameters and their sources. The second Section discusses the PA-30 aerodynamic parameters and their sources. The report concludes with a discussion of how these parameters are used in the INM to model DEP and APP performance of the PA-30.

The basic characteristics of the PA-30 are listed in the table below:

Table 1. PA-30 characteristics.

Piper Twin Comanche PA-30	
Max Takeoff weight	3,600 lb
Engines (2)	Lycoming IO-320-B1A
Propellers (2)	Hartzell HC-E2YL-2

Thrust Performance INM performance coefficients are based on the equations found in SAE-AIR-1845[1]. A primary parameter in the calculation of aircraft noise and performance in the INM is thrust. The INM uses the following equation to calculate thrust from horsepower and flight speed. This equation is the equivalent of SAE-AIR-1845 equation A4:

$$\frac{F}{\delta} = \frac{K\eta HP}{V\delta} \qquad (1)$$

where

F	is the net thrust in pounds
δ	is the non-dimensional pressure ratio
K	is a constant to convert to dimensionally consistent units
η	is the non-dimensional propeller efficiency
HP	is Horsepower
and V	is true airspeed in kts

The Horsepower is found from the study conditions, the engine performance data recorded during the study, and Lycoming engine performance charts. A computer program called LycNA[2] was written to automate the determination of Horsepower. Hartzell Propeller Inc. provided a copy of their MAPINTRP computer code and the data files for the PA-30 propeller so that propeller efficiencies could be calculated. True airspeed in knots (KTAS) is found from the calibrated airspeed in knots (KCAS) and the density ratio σ at the study condition using the following equation:

$$KTAS = KCAS \big/ \sqrt{\sigma} \qquad (2)$$

Table 2 below shows the engine parameters for each of the flight conditions used in the test. These values represent averages over the particular study series. Horsepower, the only derived value, was found from the average of the horsepower values calculated for each run, not the horsepower that one could calculate from the average values of the other operational parameters listed in Table 2. Note that the altitudes listed in Table 2 are Mean Sea Level (MSL), not Above Ground Level (AGL), since MSL altitudes are required for the performance calculations that follow.

Table 2. Study conditions.

Flight Condition	Altitude (ft, MSL)	OAT (°F)	RPM	HP	KTAS	η	F/δ
Normal LFO 3000 ft (100 Series)	3257	35	2380	118	172	.80	232.7
DEP 3000 ft (200)	3545	33	2650	150	115	.82	456.8
Normal LFO 500 ft (300)	838	48	2375	112	160	.83	214.0
Tour LFO 500 ft (400)	825	46	2200	89	137	.82	201.3
DEP 500 ft (500)	808	45	2607	118	107	.81	339.3
Flaps and gear up APP 500 ft (600)	642	46	2300	38	126	.49	55.4
Flaps and gear down APP 500 ft (800)	675	46	2283	43	105	.69	107.3
Acceleration 500 ft (900)	848	47	2650	159	163	.82	297.8

For calculating the INM thrust, which doesn't account for power degradation with increasing altitude, a two-step engine power process was used. In the first step, the atmospheric conditions at 1,500 ft MSL were used for the INM's "MaxTakeoff" power setting; this was taken as the average condition between the runway at Sea Level and the end of the first step at 3,000 ft MSL. The Manifold Pressure (MAP) was found by using the standard procedure of operating normally aspirated aircraft at "square" conditions; the MAP is set to the RPM divided by 100, or 26 inches (i.e., the take-off power condition is "26-square", 2,600 RPM and 26 inches of manifold pressure). For these conditions, LycNA calculated 139.4 hp.

For the second step, an altitude of 5,000 ft MSL was used as the nominal condition for the INM's "MaxClimb" power setting; this altitude was meant to provide a bias toward the lower range of the altitude (3,000 ft to 10,000 ft) to provide a conservative estimate of the noise on the ground. At this altitude, the Manifold Pressure drop with increasing altitude must be considered. To calculate the nominal manifold pressure, the standard pressure ratio at 5,000 ft is 0.8321, or 24.90 inches in the units used by Lycoming for MAP. To account for losses in the aircraft's induction system, 1 inch was subtracted from the standard pressure, for a final manifold pressure of 23.90 inches at 5,000 ft. This Manifold Pressure at a constant engine speed of 2,600 RPM yields an engine power of 130.0 hp.

Aerodynamic Parameters

The INM uses the coefficient of drag divided by lift (R) in the calculation of aircraft DEP and APP performance. The equation used to find the value of R for the various flight conditions is based on equation A12 in SAE-AIR-1845:

$$R = \frac{F/\delta}{W/\delta} - \frac{\sin(\gamma)}{1.01} \qquad (3)$$

where

R is the non-dimensional coefficient of drag divided by lift
F is the net thrust in pounds
W is the aircraft weight in pounds

δ is the non-dimensional pressure ratio
γ is the climb angle in degrees
and 1.01 is a factor used to adjust the climb angle for flight into an assumed headwind.

To calculate R used in the first segment of the climb, a modified version of the above equation was used. This modified version, found on page 30 of the INM Technical Manual[3] , accounts for acceleration during a climb segment. The equation is:

$$S_a = 0.95k(v_{T2}^2 - v_{T1}^2)/(G_m - G) \qquad (4)$$

where

S_a is the horizontal distance in ft
k is a constant to convert to dimensionally consistent units
v_{T1} is the initial true airspeed in kts
v_{T2} is the final true airspeed in kts
G_m is an acceleration factor; $G_m = N\left(F/\delta\right)/\left(W/\delta\right) - R$ (non-dimensional)
N is the number of engines
and G is the climb gradient (non-dimensional)

The equation is re-ordered to solve for the R parameter. The horizontal distance S_a is found in the PA-30 Owner's Handbook[4] in Section IV, pages 56 and 57. The horizontal distance is the difference between the "take-off distance over 50 ft obstacle at various altitudes, temperatures, weights, and winds" found in the chart on page 57 and the "take-off ground run distance at various altitudes, temperatures, weights, and winds" found in the chart on page 56. For International Standard Atmosphere (ISA) conditions at Sea Level (SL), the distance from the start of the take-off roll to the end of the ground roll is 1250 ft, at which point the aircraft is moving at a true airspeed of 70 kts. The distance to the point where a 50 ft obstacle is cleared in 2,160 ft, at which point the aircraft is moving at a true airspeed of 79 kts. For these conditions, the climb gradient G is the 50 ft altitude gain divided by the 910 ft horizontal distance.

The only unknown in the above equation is the adjusted net thrust term. The thrust is found from using the take-off RPM and MAP settings found during the study. This was nominally 2,600 RPM and 26 inches as described above. Note that the study aircraft used this manifold pressure and RPM during the 200 series Events due to the colder (and hence denser) air of the study compared to ISA conditions. The thrust equation gives an adjusted net thrust per engine of 488 lb. This, in turn, gives an R value for take-off conditions of 0.154071.

The enroute climb flap coefficient (R_{zero}) is found from the "Multi-engine Climb rate and speed vs. density altitude and weight" chart found on page 59 of the Owner's handbook. The enroute climb is non-accelerated, so the first equation in this Section is valid. For the best rate of climb speed (V_y) of 97 kts and the climb rate of 1,400 ft per minute, the climb angle is 8.2 degrees. The thrust is 375 lb/engine and the corresponding R value is 0.067504.

$$\gamma = \sin^{-1}\left(\frac{1400\,fpm/60\sec/\min}{97\,knots \times 1.6878\,ft/\sec/knot}\right) = 8.2° \tag{5}$$

$$R_{zero} = \frac{F/\delta}{W/\delta} - \frac{\sin\gamma}{1.01} = \frac{2\times 375}{3600} - \frac{\sin(8.2)}{1.01} = 0.067504 \tag{6}$$

For APP conditions, a standard glide slope angle of three degrees was assumed. The engine powers and propeller efficiencies of the two APP conditions were used to calculate thrusts of 49 lb/engine for the flaps and gear up (clean) condition and 98 lb/engine for the flaps 27 and gear down (dirty) condition. These were entered into the thrust equation with R as the unknown. For the clean configuration, a flap coefficient of 0.078131 was calculated; for the dirty configuration, a flap coefficient of 0.104586 was calculated.

In addition to the standard INM coefficients, the R coefficients for normal LFO and tour LFO conditions can be calculated from the above equation when γ is zero. For the normal LFO configuration R_{fast} is 0.104607 and for the tour configuration R_{slow} is 0.096913.

Modeling Departures and Approaches in the INM

Using the performance coefficients in the previous Sections, we can develop DEP and APP procedure steps in the INM. The DEP procedures are taken from Reference 5, pages 31, 56, and 57. The first step in the DEP is to accelerate down the runway at full power. The PA-30 Owner's Manual lists a V_{mc} airspeed of 79 kts (V_{mc} is the minimum airspeed at which a twin engine aircraft can be controlled if one engine is not working). For this reason, the aircraft should not begin the DEP climb until this speed is attained. We assume that during the acceleration from the rotation speed of 70 kts to the V_{mc} speed, the aircraft gains minimal altitude, then, once 79 kts is reached, the aircraft is pitched up to climb attitude until 50 ft above the ground. At this point, the aircraft is allowed to accelerate to the en route airspeed of 113 kts. The DEP is modeled with a change in thrust setting at 3,000 ft AGL; this is used to approximate the decrease in engine performance with increasing altitude. The climb then continues up to the INM's cutoff altitude of 10,000 ft AGL, with steps at 5,500 and 7,500 ft to improve the true airspeed adjustment.

For the APP, we assume that the aircraft starts at the INM standard altitude of 6,000 ft at the study APP speed of 120 kts. This speed is held until an altitude of 3,000 ft where the flaps extension speed of 109 kts is reached and the flaps and gear are extended. The aircraft further decelerates until the recommended pattern airspeed of 96 kts at 1,500 ft. The aircraft then slows to the APP speed of 87 kts at 1,000 ft above the field. This airspeed is held until touchdown. The landing roll distance of 700 ft is found from the

"Landing ground run distance at various altitudes, temperatures, weights, and winds" chart on page 64 of the Owner's Handbook.

If you have any questions on the information in this report, please contact me via telephone at 781.721.4824 or via e-mail at dsenzig@senzig.com.

Sincerely,

SENZIG ENGINEERING

David Senzig, PE

References

1. "Procedure for Calculation of Airplane Noise in the Vicinity of Airports," Society of Automotive Engineers, Aerospace Information Report 1845, Warrendale, Pennsylvania, March 1986
2. "Converting Piston Engine Operating Parameters to Power Output," Volpe National Transportation Systems Center, Environmental Measurement and Modeling Division, Cambridge, Massachusetts, September 2002
3. "Integrated Noise Model (INM) Version 6.0 Technical Manual," Olmstead, J.R., Fleming, G.G., Gulding, J.M., et al., FAA report FAA-AEE-02-01, Washington, D.C., January 2002
4. "Twin Comanche C Owner's Handbook," Piper Aircraft Corporation, part number 753 773, Lock Haven, Pennsylvania, November 1973

INM Database Request Form

The following describes the performance and noise data required for aircraft to be included in the FAA's INM database.

1. REFERENCE CONDITIONS FOR PERFORMANCE DATA

Table A-1. INM PA-30 reference conditions.

Wind	4 m/s (8 kt) headwind, constant with height above ground
Runway elevation	Mean Sea Level (MSL)
Runway gradient	None
Air temperature	15ºC (59ºF)
Aircraft takeoff gross weight	3,060 lb
Aircraft landing weight	3,240 lb
Number of engines supplying thrust	All
Atmosphere	International Standard Atmosphere (ISA)

2. AIRCRAFT AND ENGINE DATA

Where there are variations in certification weights and engine thrusts for a given model, provide data for the heaviest aircraft in terms of maximum gross takeoff weight in the model classification.

Table A-2. INM PA-30 aircraft and engine characteristics.

Aircraft model	Piper PA-30 Twin Comanche
Engine model	Lycoming IO-320-B1A
Number of engines	2
Engine type (jet, turboprop, piston)	piston
Noise stage number (2, 3, 4)	-
Maximum static thrust (lb/engine)	777
Automated thrust restoration (yes, no)	no
Weight class (small, large, heavy)	small
Maximum gross takeoff weight (lb)	3,600
Maximum gross landing weight (lb)	3,600
Maximum landing distance (ft)	700

Table A-3. PA-30 INM DEP weights.

Stage number	Trip length (nmi)	Weight (lb)
1	0-500	3,600

Takeoff weights should be developed so as to increase with an increase in mission trip length. Weight assumptions should use industry planning assumptions for load factor, average passenger weight, excess cargo beyond passenger weight, and fuel required to complete mission trip length.

3. AERODYNAMIC COEFFICIENTS

Aerodynamic coefficients for use with the SAE AIR 1845 equations are required for available flap settings. The flap settings may be identified in degrees and abbreviations. Please provide data for all flap settings specified in Sections 5 and 6.

Table A-4. PA-30 INM aerodynamic and flap coefficients.

Flap Configuration Identifier	Operation (A, D)[1]	Gear	Takeoff B (ft/lb)	Takeoff C (kt/√lb)	Land D (kt/√lb)	Drag/Lift R
15-D	D	down	0.100146	1.166667		0.154071
Zero-D	D	up	[2]			0.067504
Zero-A	A	up				0.078131
27-A	A	down			1.316667	0.104586

[1] A = Approach, D = Depart
[2] Not applicable

4. ENGINE COEFFICIENTS

For jet aircraft, engine coefficients in accordance with SAE AIR 1845 equations are required for maximum takeoff, maximum climb, and general thrust in terms of EPR or N1. The Max-Takeoff coefficients should be valid to 6,000 ft MSL, the Max-Climb and General Thrust coefficients should be valid to 16,000 ft MSL. This is necessary so that the INM accurately models operations at high altitude airports such as Denver and Salt Lake City.

In addition, high temperature coefficients are required for operations above the thrust break temperature. INM uses the Max-Takeoff and Max-Climb coefficients below the breakpoint temperature and uses the Hi-Temp coefficients above the breakpoint temperature. The breakpoint temperature is at the intersection of the two curves. An example of Max-Takeoff and Hi-Temp Max-Takeoff curves is shown in Figure 1.

For propeller-driven aircraft, engine coefficients in accordance with SAE AIR 1845 equations are required for propeller efficiency and installed net propulsive power.

Table A-5. INM PA-30 thrust coefficients.

Thrust Type	Propeller Efficiency	Installed net propulsive horsepower (hp)
Max-Takeoff	.80	139.4
Max-Climb	.80	130.5

5. DEP PROCEDURES

DEP procedures consist of a takeoff segment, and a combination of climb and acceleration segments up to an altitude of 10,000 ft AFE. The endpoint altitude defines a climb segment. An acceleration segment is defined by its rate-of-climb and the calibrated airspeed at its endpoint. The flap settings are indicated for endpoints of segments. These flap settings should coincide with those given in Section 3 above. Please provide procedural data for each stage length given in Section 2.

Stage Number	1

Repeat table for each takeoff stage number (takeoff weight) listed in Section 2.

Table A-6. PA-30 INM DEP procedure.

Segment Type[1]	Thrust Type[2] (T/C)	Flap Configuration Identifier[3]	Endpoint Altitude (ft AFE)	Rate-of-Climb (ft/min)	Endpoint Speed (KCAS)	Start Thrust[4] (lb)
Takeoff	T	15-D				777
Accelerate	T	15-D		415	79	520
Accelerate	T	15-D		500	113	320
Climb	T	Zero-D	1500			330
Climb	T	Zero-D	3000			340
Climb	C	Zero-D	5500			340
Climb	C	Zero-D	7500			350
Climb	C	Zero-D	10000			380

[1] Add, delete, and sequence the segments as necessary to represent a takeoff procedure
[2] T = Max-Takeoff, C = Max-Climb, as defined in Section 4
[3] Use the identifiers in Section 3
[4] These data are used to compare to INM-computed thrust values

6. APP PROCEDURES

A landing profile should be calculated for a starting altitude of 6,000 ft above field elevation (AFE). The flap settings should coincide with those given in Section 3 above.

Landing weight (lb)	3,600
Stopping distance (ft)	700

Table A-7. PA-30 INM APP procedure.

Profile Point	Operation	Altitude (ft AFE)	Distance from Touchdown[1] (ft)	Start Speed (KTAS)	Flap Configuration[2]	Start Thrust[3] (lb)
1	Descend	6000	−114487	120	Zero-A	50
2	Descend	3000	−57243	109	27-A	100
3	Descend	1500	−28622	96	27-A	100
4	Descend	1000	−19081	87	27-A	100
5	Land	0	30	79	27-A	78
6	Decelerate	0	670	70	27-A	78
7	Start Taxi	0	0	10	27-A	78

[1] Glide slope is 3.0 degrees
[2] Use identifiers in Section 3
[3] These data are used to compare to INM-computed thrust values
[4] Landing speed is for reference only; INM calculates landing speed using the D coefficient (Section 3) and landing weight

A.1.2 Piper Navajo Chieftain PA-31-350

June 3, 2003

Gregg Fleming
Division Chief, Environmental Measurement and Modeling

John A. Volpe National Transportation Systems Center
55 Broadway
Cambridge, Massachusetts

Re: Piper Chieftain data for the Integrated Noise Model

Dear Mr. Fleming,

On April 30, 2002 the Volpe National Transportation Systems Center (Volpe) and the Federal Aviation Administration (FAA) conducted a study with a Piper PA-31-350 Navajo Chieftain (PA-31) at Fitchburg Municipal Airport in Massachusetts. These organizations conducted the study with the goal of determining reference noise and performance data for the FAA's Integrated Noise Model (INM) in support of the Air Tour Management Plan (ATMP). This letter report describes the methods and documents the information sources used to generate the INM performance data. As part of the same test, Volpe and FAA tested four other propeller-driven aircraft: a Piper PA-28 Warrior, a Piper PA-30 Twin Comanche, a Raytheon Beech 1900D, and a Maule M-7-235C. Separate letter reports contain the INM performance data developed for these aircraft.

Developers of INM performance data can use either procedure steps or profile points to define the performance of the aircraft. Procedure steps allow the modeled aircraft performance to account for variations in weather, particularly temperature, or field elevation. SAE-AIR-1845[1] defines the relationship of weather and field elevation to aircraft performance. With profile points, the developer provides the exact altitude, airspeeds and thrust settings for a given track distance; these do not change as weather and airport elevation changes. Both the method of generating these profile points and the method of determining the coefficients in the procedure steps rely on well known aerodynamic and aircraft performance relationships[2].

For propeller-driven aircraft using procedure steps, the INM calculates the net adjusted thrust at each segment from the following equation:

$$\frac{F}{\delta} = \frac{K\eta HP}{V\delta} \qquad (1)$$

where

F is the net thrust in pounds
δ is the non-dimensional pressure ratio
K is a constant to convert to dimensionally consistent units

η is the non-dimensional propeller efficiency
HP is Horsepower
and V is true airspeed in kts

Empirical data has shown that net adjusted thrust as well as other power parameters (e.g. horsepower, or propeller speed) may not correlate with the noise produced by the aircraft. In the case of the Piper PA-31, engine RPM may better predict noise than thrust (or horsepower). The following two figures show the Sound Exposure Levels (SEL) recorded during the study as a function of RPM (Figure 1) and thrust (Figure 2). Note that the 600 and 800 series data represent APPs and so will comprise a different family of curve than the other series, which represent either DEPs or LFOs.

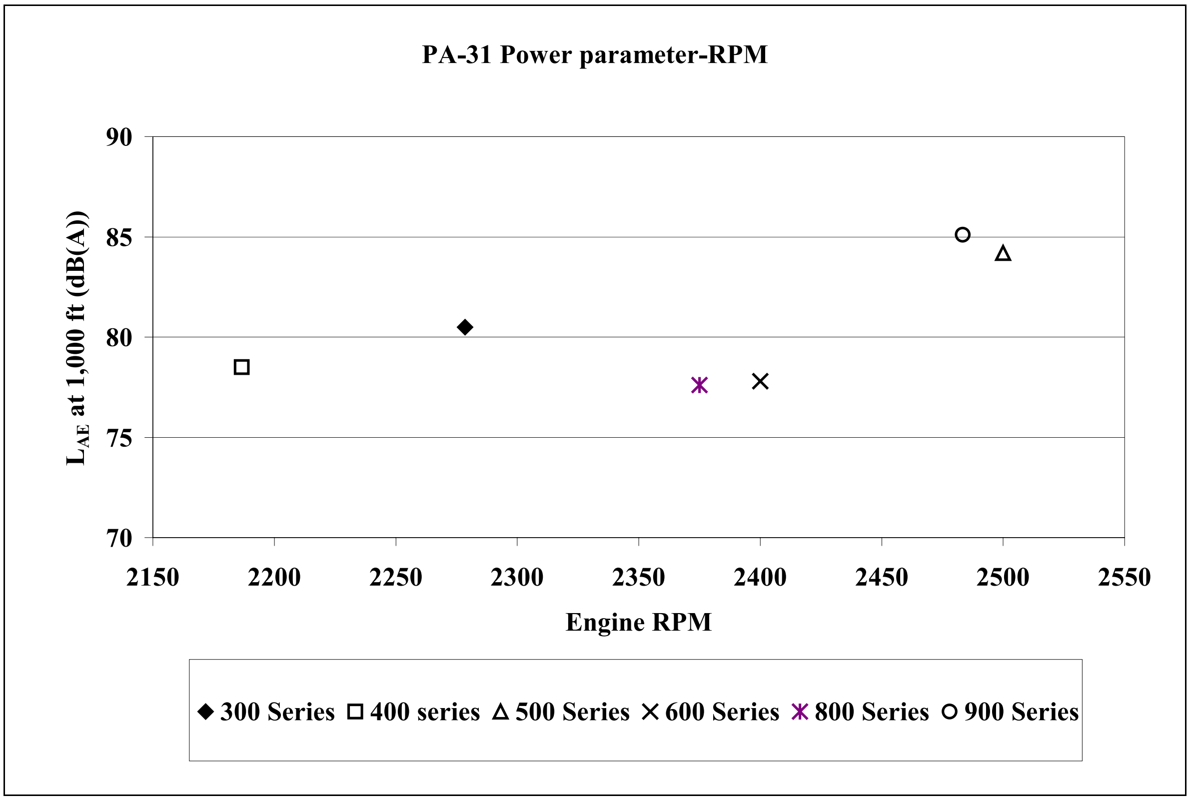


Figure 1. PA-31 noise as a function of RPM

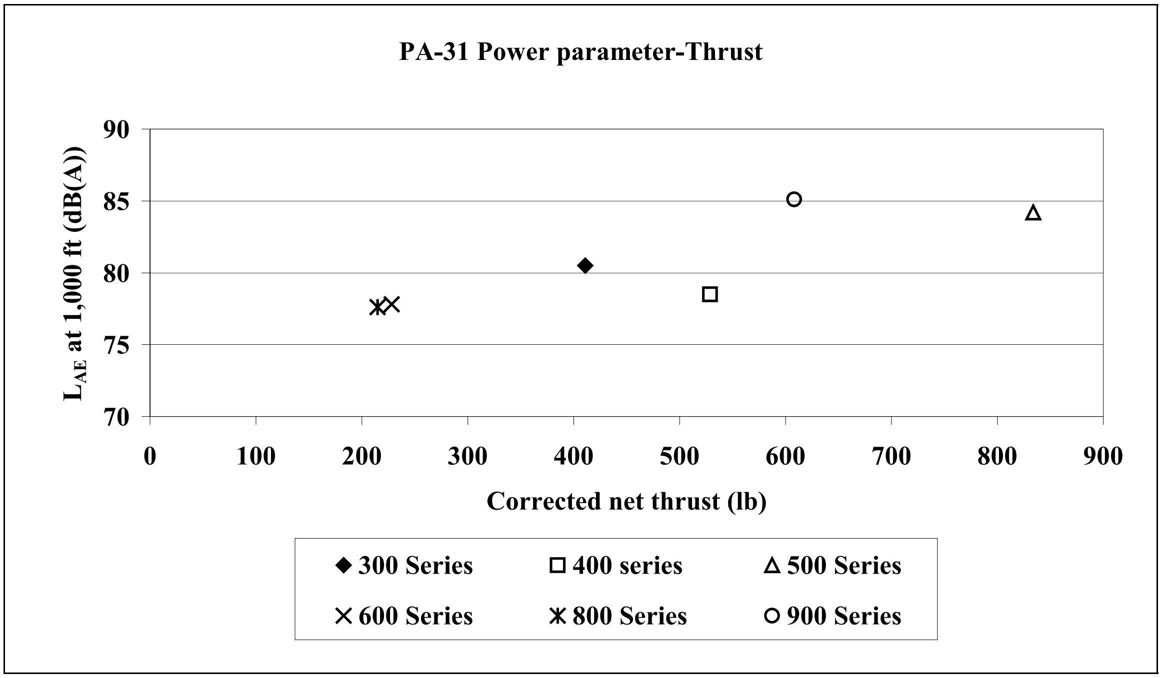


Figure 2. PA-31 noise as a function of thrust

When calculating aircraft performance with procedure steps, the INM uses thrust both as an independent variable to perform a table look-up of the noise in the Noise-Power-Distance (NPD) database and as a component of the physical equations that calculate the position and speed of the aircraft. If the thrust doesn't correlate well with noise, then a better predictor of noise should be used, even if this means that without thrust information procedure steps cannot be used. Because the noise appears to correlate better with RPM than thrust for the PA-31, I have elected to model the PA-31 performance with profile points, rather than procedure steps.

This letter report contains the information sources and data used to determine the profile points of the PA-31 for DEPs and APPs. The report contains enough information so that later developers can create additional points profiles, both DEPs and APPs, as required.

The basic characteristics of the PA-31 are listed in the table below:

Table 1. PA-31 aircraft characteristics.

Piper Navajo Chieftain PA-31-350	
Max Takeoff weight	7,000 lb
Engines (2)	Lycoming TIO-540-J2BD
Propellers (2)	Hartzell FC8468-6R(Left) & FJC8468-6R (Right)

In addition, Table 2 below lists the study conditions and operational parameters recorded during the study. These values represent averages over the particular study series. Horsepower, the only derived value in the table, was found from the average of the horsepower values calculated at each run, not the horsepower that one could calculated from the averaged values of the operational parameters listed in Table 2. Note that the altitudes listed in Table 2 are Mean Sea Level (MSL), not Above Ground Level (AGL), since MSL altitudes are required for the performance calculations that follow.

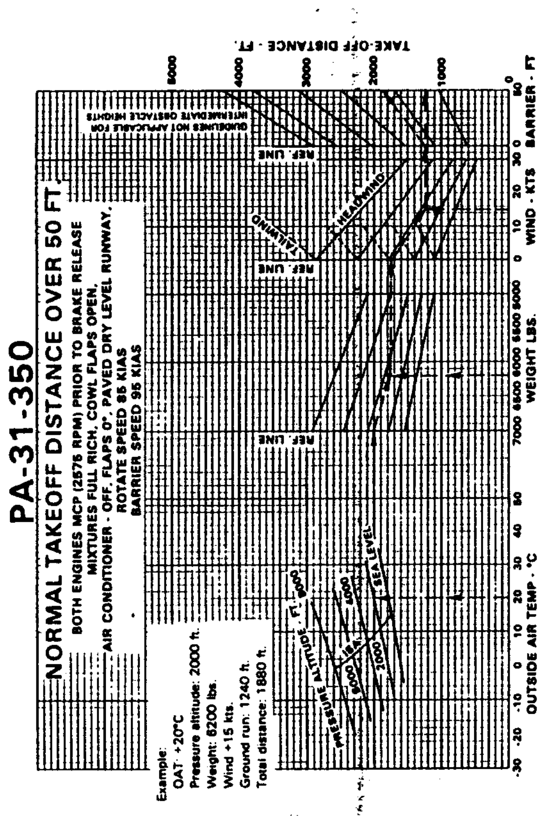
Table 2. PA-31 Fitchburg study conditions.

Flight Condition	Altitude (ft, MSL)	OAT (°F)	RPM	HP	KTAS
Normal LFO 3000 ft (100 Series)	3017	36	2300	235	188
Normal LFO 500 ft (300)	888	40	2279	230	185
Tour LFO 500 ft (400)	909	38	2187	193	124
DEP 500 ft (500)	691	37	2500	310	124
Flaps and gear up APP 500 ft (600)	758	49	2400	103	117
Flaps and gear down APP 500 ft (800)	703	45	2375	134	165
Acceleration 500 ft (900)	907	43	2483	310	167

DEP Points

The Pilot's Operating Handbook[3] (the Handbook) contains the majority of the information required to generate the profile points. The Handbook contains performance charts and operational descriptions to aid in calculating all the information needed by the INM.

Figure 3 below shows the takeoff ground roll and the track distance required to reach 50 ft above ground level (AGL). For the maximum gross aircraft weight, 7,000 lb, the ground roll is 1,750 ft and the track distance to 50 ft AGL is 2,800 ft.



NORMAL TAKEOFF DISTANCE OVER 50 FEET
Figure 5-15

Figure 3. Ground roll and distance to 50-ft obstacle clearance chart

After the aircraft reaches 50 ft AGL, the aircraft accelerates from the 50 ft obstacle clearance speed of 95 kts to the best rate of climb speed of 111 kts (from pages 4-9 and 5-20 of the Handbook). For this acceleration, the INM's acceleration equation is used to calculate both the track distance and altitude gained. Note Figure 4 gives a Sea Level Rate of climb of 1,125 ft per minute at the en route climb speed of 111 kts.

$$S_a = k(v_{T2}^2 - v_{T1}^2)/2g(G_m - G) \tag{2}$$

where

S_a	is the horizontal distance
k	is a constant to convert to dimensionally consistent units
v_{T1}	is the initial true airspeed in kts
v_{T2}	is the final true airspeed in kts
g	is the acceleration of gravity
G_m	is an acceleration factor; $G_m = \sin(\gamma)/0.95$
ROC	is the climb gradient in ft per minute
and G	is the climb gradient; $G = (ROC/2kv_{T2})$ [non-dimensional]

The factor of 2 in the climb gradient term accounts for the assumption that half of the energy available for acceleration is used for increasing the altitude of the aircraft. Applying the actual parameters to the above equation gives a segment acceleration distance of 2,638 ft:

$$S_a = \frac{(1.6878 \times 111)^2 - (1.6878 \times 95)^2}{2 \times 32.17\left(\frac{(1125/60 \times 1.6778 \times 111)}{0.95} - \frac{1125}{(2 \times 60 \times 1.6878 \times 111)}\right)} = 2638$$

The altitude gain is calculated from the climb gradient term:

$$Y = S_a \times TAN(ASIN(G)) = 123.2$$

Note that the track distance and altitude gain above are *added* to the previous step, these numbers by themselves are not the cumulative distance and altitude.

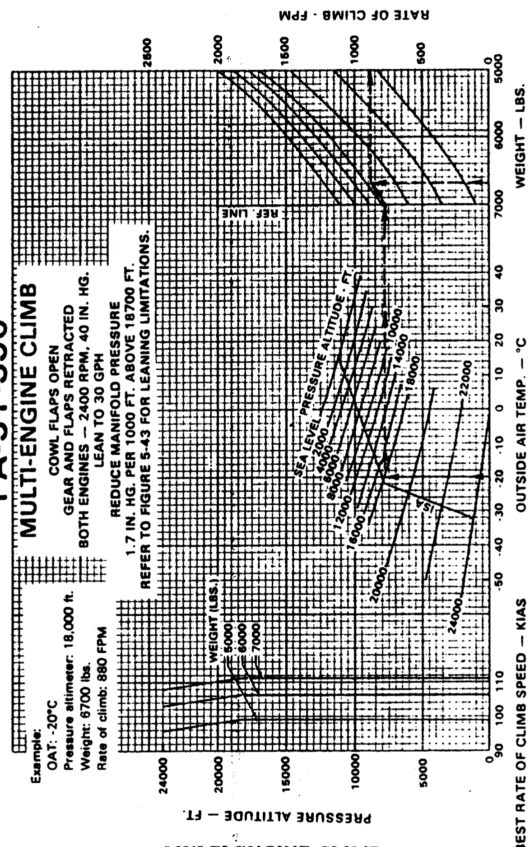
For the remainder of the climb up to 10,000 ft MSL, the airspeed is held constant at 111 indicated kts, but the true airspeed increases as the relationship:

$$KTAS = KCAS/\sqrt{\sigma} \tag{3}$$

where σ is the density ratio at the particular altitude. Tables of density ratios can be found in most aeronautical textbooks, or in manufacturers' data[4]. Figure 5, the time and distance to climb chart, shows the actual track distance and altitude relationship for the remainder of the climb up to the standard INM end-of-track altitude of 10,000 ft AGL.

SECTION 5
PERFORMANCE

PIPER AIRCRAFT CORPORATION
PA-31-350, CHIEFTAIN



MULTI-ENGINE CLIMB
(Maximum Normal Operating Power)
Figure 5-19

REPORT: LK-1208
5-20

ISSUED: SEPTEMBER 14, 1979

Figure 4. PA-31 climb configuration chart

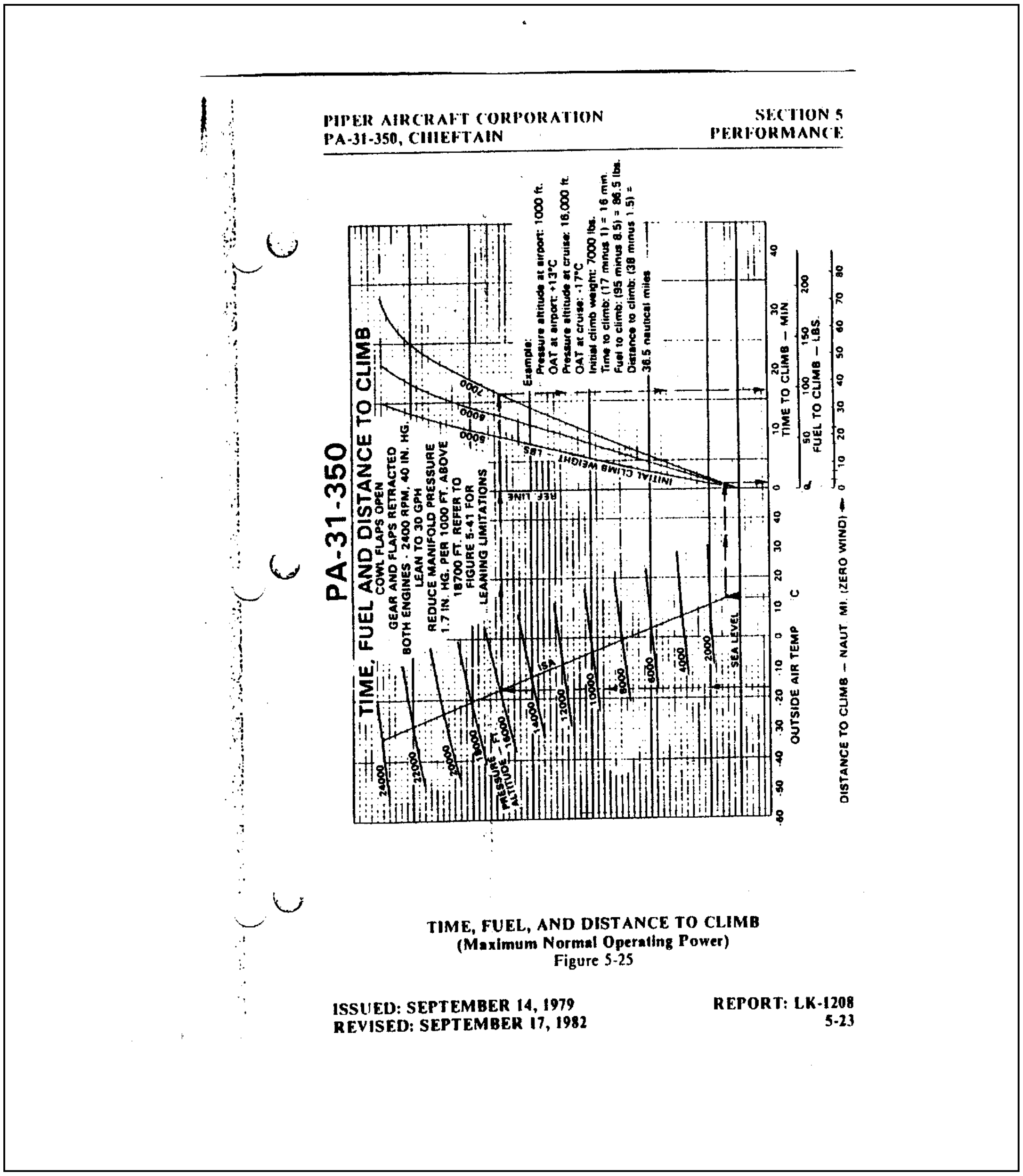


Figure 5. PA-31 time and distance to climb chart

APP Points

The APP data starts at the INM standard APP altitude of 6,000 ft AGL, and assumes a standard three-degree glideslope. The glideslope determines the track distance from the touchdown point, with the touchdown point given by the chart shown in Figure 6.

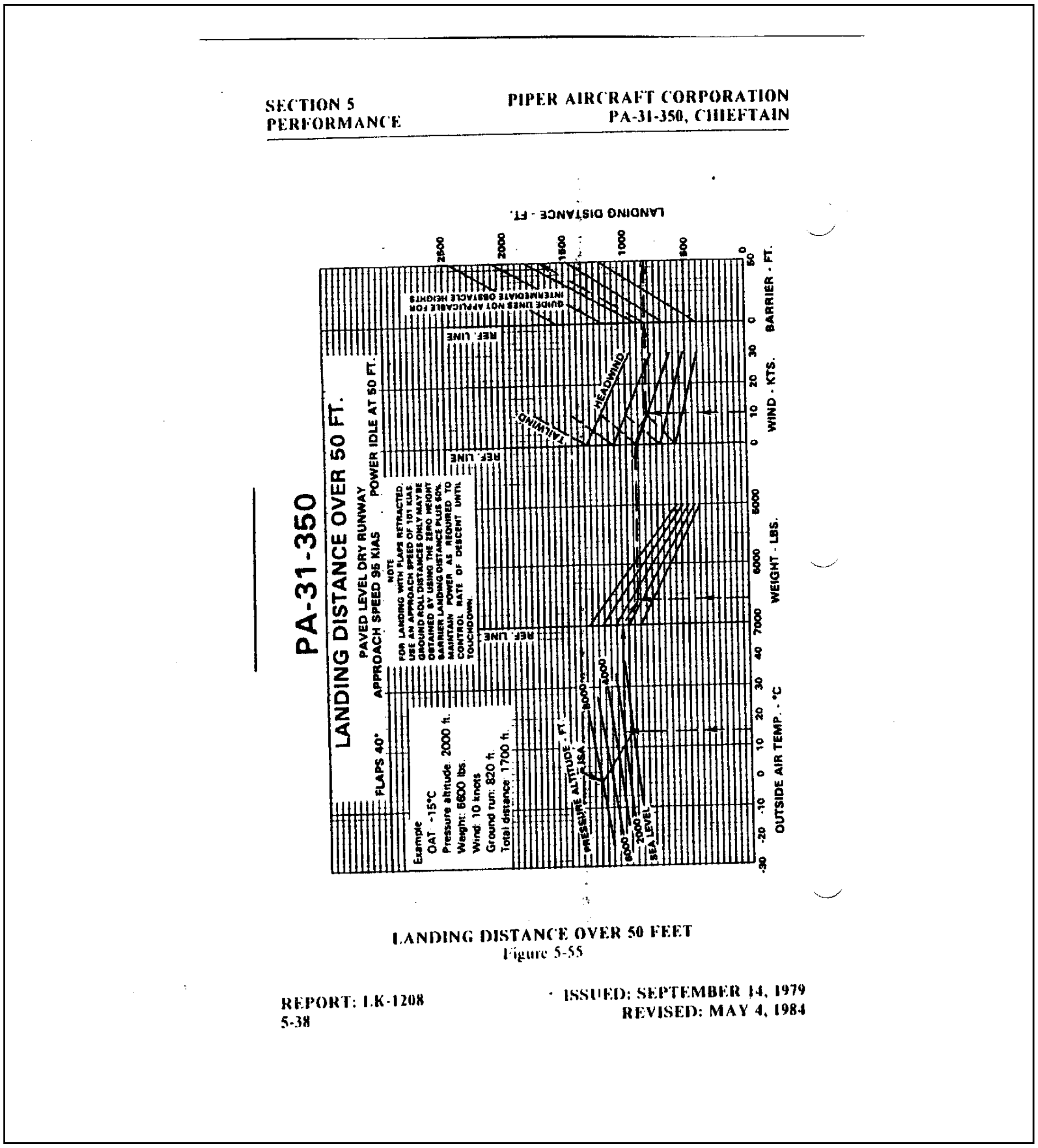


Figure 6. PA-31 landing distances

The airspeeds used in the APP come from the Handbook. The APP procedure starts at 173 kts indicated airspeed; this corresponds to a transition from LFO, at a 'best economy' 65 percent power setting at ISA conditions at 5,000 ft MSL, as found on page 5-28 of the Handbook. At 1,500 ft AGL, the aircraft slows to the flap extension speed of 162 kts. At 1,000 ft AGL, the aircraft's airspeed is 147 KIAS, which is the average of the Flaps 25 and Flaps 40 airspeed. At 500 ft AGL, the aircraft carries full flaps (Flaps 40) and has slowed to 132 KIAS. Over the threshold at 50 ft, the PA-31 flies at 95 KIAS down to the touchdown point.

Modeling DEPs and APPs in the INM

Appendix A contains the aircraft characteristic page from the INM data request form and the profile points based on the procedures described above. Note that the Handbook gives all airspeeds in indicated kts, but the INM uses true airspeed; the speeds listed in Appendix A are true airspeed.

If you have any questions on the information in this report, please contact me via telephone at 781.721.4824 or via e-mail at dsenzig@senzig.com.

Sincerely,

Senzig Engineering

David Senzig

David Senzig, PE

References

1. "Procedure for Calculation of Airplane Noise in the Vicinity of Airports," Society of Automotive Engineers, Aerospace Information Report 1845, Warrendale, Pennsylvania, March 1986
2. "Airplane Aerodynamics and Performance," Lan and Roskam, Roskam Aviation and Engineering, Ottawa, Kansas, 1981.
3. "Chieftain PA-31-350 Pilot's Operating Handbook," Piper Aircraft Corporation, Report LK-1208, Lakeland, Florida, September 1979.
4. "Aeronautical Vestpocket Handbook," United Technologies, Pratt & Whitney, East Hartford, Connecticut, September 1991.

INM Data Request form with Piper Navajo information

Below are the profile points that can be entered into the INM's *pro_pts.dbf* file. The following sheet contains the first page of the INM data request form. This page has information that can be translated directly to the *aircraft.dbf* file in the INM. The other pages of the data request form are specific to procedure step data and so are not included here.

Table A-1. Standard PA-31 DEP profile points
(maximum gross takeoff weight = 7,000 lb).

Step	distance (ft)	Alt (ft)	Speed (kts)	Power (RPM)
1	0.0	0.0	32.0	2500
2	1750.0	0.0	85.0	2500
3	2800.0	50.0	95.1	2500
4	5438.5	182.2	111.3	2500
5	18228.3	1500.0	113.5	2400
6	36456.7	3000.0	116.0	2400
7	60761.2	5500.0	120.5	2400
8	97217.8	7500.0	124.2	2400
9	136712.6	10000.0	129.2	2400

Table A-2. Standard PA-31APP profile points
(maximum gross landing weight = 7,000 lb).

Step	distance (ft)	Alt (ft)	Speed (kts)	Power (RPM)
1	-113611.8	6000.0	189.2	2400
2	-27746.7	1500.0	165.6	2400
3	-18206.1	1000.0	149.2	2350
4	-8665.6	500.0	133.0	2350
5	0.0	0.0	95.1	2350
6	875.0	0.0	95.0	2350
7	1850.0	0.0	10.0	1000

INM Database Request Form

The following describes the performance and noise data required for aircraft to be included in the FAA's INM database.

1. REFERENCE CONDITIONS FOR PERFORMANCE DATA

Table A-3. INM PA-31 Fitchburg study reference conditions.

Wind	4 m/s (8 kt) headwind, constant with height above ground
Runway elevation	Mean Sea Level (MSL)
Runway gradient	None
Air temperature	15ºC (59ºF)
Aircraft gross takeoff weight	5,950 lb
Aircraft landing weight	6,300 lb
Number of engines supplying thrust	All
Atmosphere	International Standard Atmosphere (ISA)

2. AIRCRAFT AND ENGINE DATA

Where there are variations in certification weights and engine thrusts for a given model, provide data for the heaviest aircraft in terms of maximum gross takeoff weight in the model classification.

Table A-4. PA-31 INM aircraft characteristics.

Aircraft model	Piper Navajo Chieftain PA-31-350
Engine model	Lycoming TIO-540-J2BD
Number of engines	2
Engine type (jet, turboprop, piston)	piston
Noise stage number (2, 3, 4)	-
Maximum static thrust (lb/engine)	1481
Automated thrust restoration (yes, no)	no
Weight class (small, large, heavy)	small
Maximum gross takeoff weight (lb)	7,000
Maximum gross landing weight (lb)	7,000
Maximum landing distance (ft)	1,850

A.1.3 Piper Warrior PA-28-161

June 2, 2003

Gregg Fleming

John A. Volpe National Transportation Systems Center
55 Broadway
Kendall Square
Cambridge, Massachusetts

Re: Piper Warrior data for the Integrated Noise Model

Dear Mr. Fleming,

On April 29 and May 6, 2002 the Volpe National Transportation Systems Center (Volpe) and the Federal Aviation Administration (FAA) conducted a series of studies with a Piper PA-28 Warrior (PA-28) at Fitchburg Municipal Airport in Massachusetts. The study was conducted with the goal of determining reference noise and performance data for the FAA's Integrated Noise Model (INM) in support of the Air Tour Management Plan (ATMP). This letter report describes the methods and documents the information sources used to generate the INM performance data. As part of the same test, four other propeller-driven aircraft were tested: a Piper PA-30 Twin Comanche, a Piper PA-31-350 Navajo Chieftain, a Raytheon Beech 1900D, and a Maule M-7-235C. The INM performance data developed for these aircraft are contained in separate letter reports.

Developers of INM performance data can use either procedure steps or profile points to define the performance of the aircraft. Procedure steps allow the modeled aircraft performance to account for variations in weather, particularly temperature, or field elevation. SAE-AIR-1845[1] defines the relationship of weather and field elevation to aircraft performance. With profile points, the developer provides the exact altitude, airspeeds and thrust settings for a given track distance; these do not change as weather and airport elevation changes. Both the method of generating these profile points and the method of determining the coefficients in the procedure steps rely on well-known aerodynamic and aircraft performance relationships[2].

Empirical data has shown that net adjusted thrust may not correlate with the noise produced by the aircraft as well as other power parameters (e.g. horsepower, or propeller speed). In the case of the PA-28, engine RPM may better predict noise than thrust (or horsepower). Figure 1 below shows the Sound Exposure Levels (SEL) recorded during the study as a function of RPM. Note that the 600, 700, and 800 series represent APPs and therefore comprise a different family of curves than the other series, which represent either takeoffs or LFOs. While Figure 1 below shows that RPM appears to correlate well with SEL, this report does not present similar graphics for thrust and horsepower, which may also correlate with noise. Horsepower for the PA-28 can be approximated from the Piper engine performance chart shown in Figure 2 from The Piper Warrior II Pilot's

Information Manual (the Manual)[3]. While not explicitly stated on the chart itself, Figure 2 best represents LFO conditions, not DEPs or arrivals. For example, an aircraft in a shallow dive can easily operate at the highest RPM given on the chart (2,700 RPM) with a partially closed throttle. The partially closed throttle translates to a lower-than-standard manifold pressure in the engine induction system, and therefore a lower-than-rated horsepower, but the chart indicates, incorrectly, that the engine is operating at the rated horsepower. For this reason, horsepower was not used. Similarly, because the INM's thrust calculation contains horsepower as an independent variable, thrust also cannot be accurately calculated from the data available. Given that thrust could not be accurately calculated, procedure steps could not be used, and the PA-28 performance was therefore modeled with profile points.

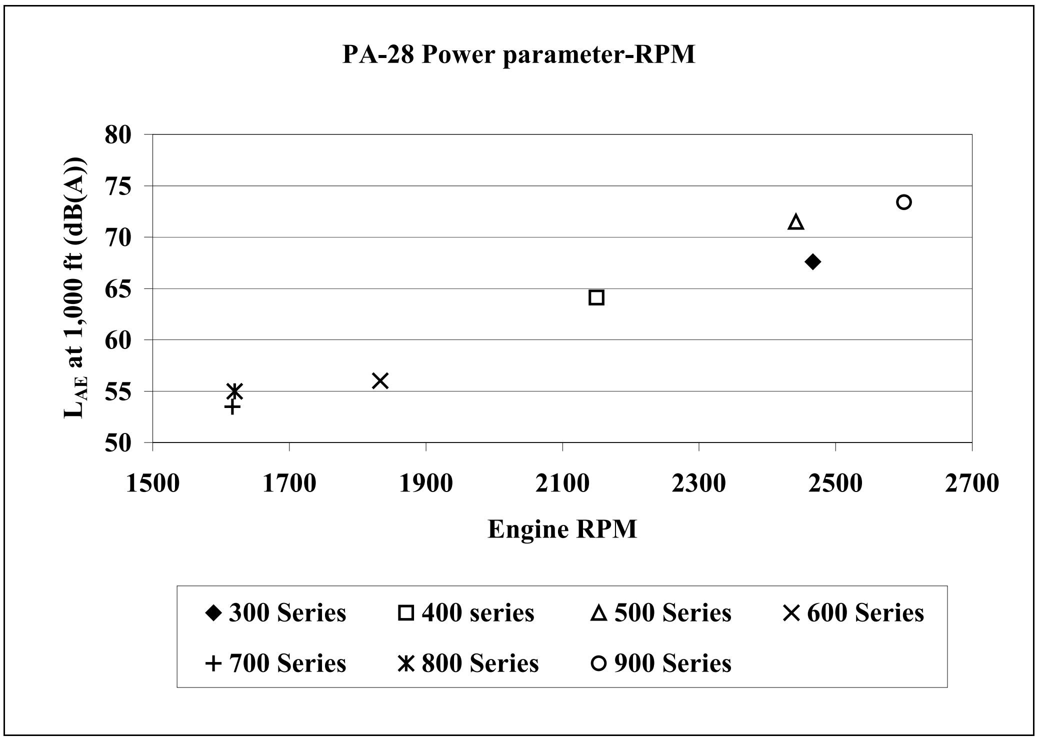


Figure 1. PA-28 noise as a function of engine RPM

The remainder of this letter report contains the information sources and data used to determine the profile points of the PA-28 for DEPs and APPs. The report contains sufficient information and references to the original sources so that future developers can create additional points profiles, both DEPs and APPs, as required. The profile points and INM aircraft characteristics are presented in Appendix A.

The basic characteristics of the PA-28 are listed in Table 1.

Table 1. PA-28 aircraft characteristics.

Piper Warrior PA-28-161	
Max Takeoff weight	2,325 lb
Engine (1)	Lycoming O-320-D3G
Propeller (1)	Sensenich 74DM6-0-60

The actual study conditions are given in Table 2 below. Note that the altitudes listed in Table 2 are Mean Sea Level (MSL), not Above Ground Level (AGL).

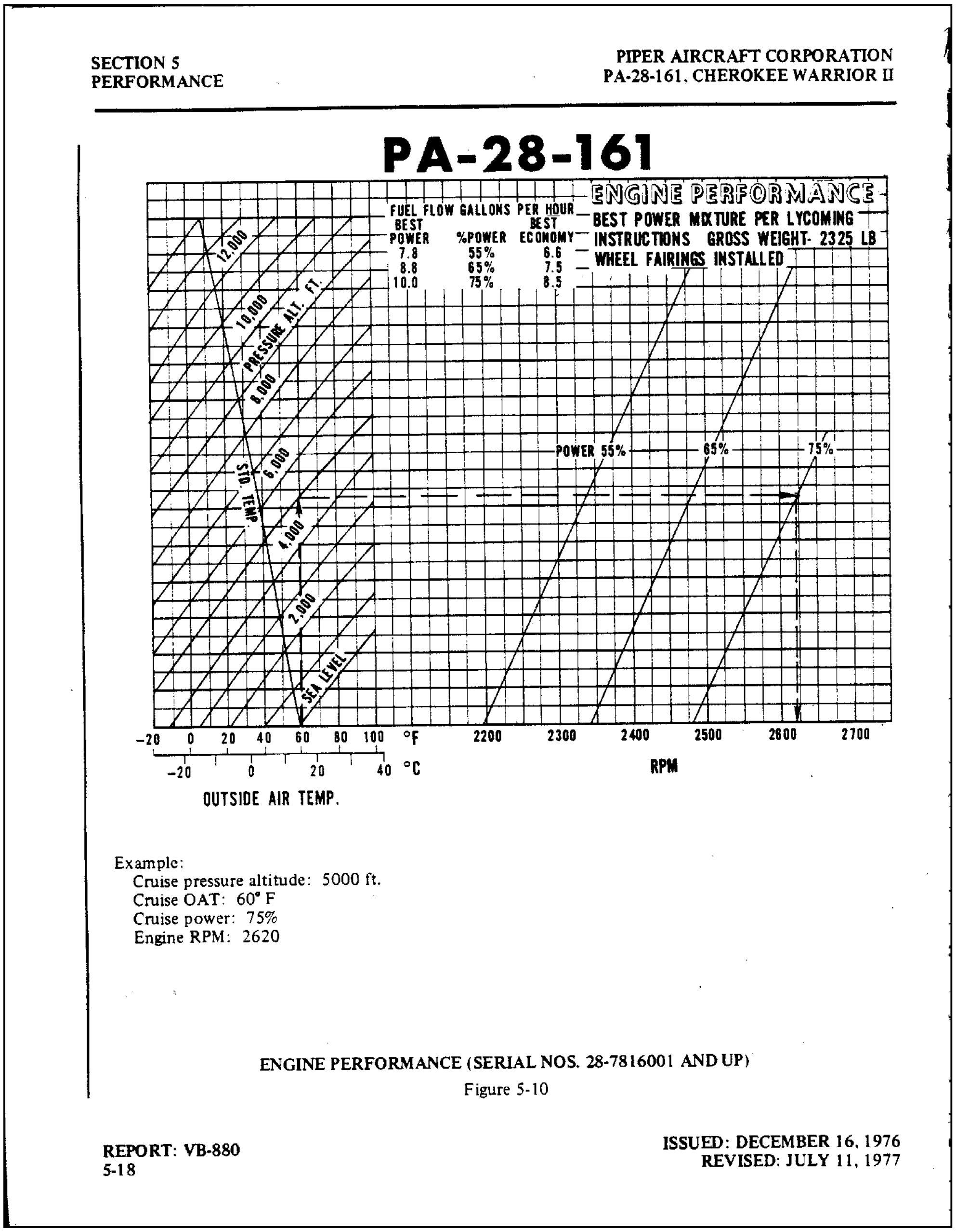


Figure 2. PA-28 engine performance chart

Table 2. PA-28 Fitchburg study conditions.

Flight Condition	Altitude (ft, MSL)	OAT (°F)	RPM	KTAS
Normal LFO 3000 ft (100 Series)	3288	57	2500	104
DEP 3000 ft (200)	3020	58	2550	89
Normal LFO 500 ft (300)	785	50	2467	107
Tour LFO 500 ft (400)	883	36	2150	91
DEP 500 ft (500)	771	36	2442	80
Flaps up APP 500 ft (600)	892	45	1800	95
Flaps 10 APP 500 ft (700)	837	35	1600	85
Flaps 25 APP 500 ft (800)	924	34	1500	75
Acceleration 500 ft (900)	819	65	2600	100

DEP Points

The PA-28 standard DEP profile points are based on the information found in the Manual. The takeoff ground roll of 1,000 ft and the rotation airspeed of 50 kts are given in the Manual on page 5-13. The initial rate of climb is given on page 5-19 as 710 ft per minute. The speed at the 50 ft obstacle clearance point is 55 kts at a distance from brake release of 1,750 ft, according to the Manual chart on page 5-14.

The best climb speed (V_y) is established after takeoff up to an altitude of 1,500 ft AGL. After this, the en route climb speed of 87 kts is used for the remainder of the climb to 10,000 ft AGL. The track distance for the climb is given by the data found in the "Fuel, Time and Distance to Climb" chart found on page 5-20 of the Manual.

The usage of the above charts is presented in more detail in the PA-31 letter report that is part of the Fitchburg study documentation.

APP Points

The APP data starts at the INM standard APP altitude of 6,000 ft AGL, and assumes a standard three-degree glideslope. The glideslope determines the track distance from the touchdown point.

The airspeeds used in the APP come from the Manual. The APP procedure starts at 126 kts indicated airspeed (page 4-5); this corresponds to a transition from LFO. At 1,500 ft the aircraft slows past the flap extension speed of 103 KIAS to 95 KIAS; this speed was confirmed in the study. At 1,000 ft AGL, the aircraft's airspeed is 85 KIAS, which is the Flaps 10 airspeed of the study. At 500 ft AGL, the aircraft carries Flaps 40 and has slowed to 70 KIAS as recommended on page 4-14 of the Manual. Over the threshold at 50 ft, the PA-28 flies at 63 KIAS down to the touchdown point. Ground roll is given in the chart on page 5-32 of the Manual.

Modeling DEPs and APPs in the INM

Appendix A contains the aircraft characteristic page from the INM data request form and the profile points based on the procedures described above. Note that the Handbook gives all airspeeds in indicated kts, but the INM uses true airspeed; the speeds listed in Appendix A are true airspeed.

If you have any questions on the information in this report, please contact me via telephone at 781.721.4824 or via e-mail at dsenzig@senzig.com.

Sincerely,

SENZIG ENGINEERING

David Senzig, PE

References

5. "Procedure for Calculation of Airplane Noise in the Vicinity of Airports," Society of Automotive Engineers, Aerospace Information Report 1845, Warrendale, Pennsylvania, March 1986
6. "Airplane Aerodynamics and Performance," Lan and Roskam, Roskam Aviation and Engineering, Ottawa, Kansas, 1981.
7. "Warrior II Pilot's Information Manual," Piper Aircraft Corporation, Handbook Part No. 761 649, Lakeland, Florida, December 1976.
8. "Aeronautical Vestpocket Handbook," United Technologies, Pratt & Whitney, East Hartford, Connecticut, September 1991.

INM Data Request form with Piper Warrior information

Below are the profile points that can be entered into the INM's `pro_pts.dbf` file. The following sheet contains the first page of the INM data request form. This page has information that can be translated directly to the `aircraft.dbf` file in the INM. The other pages of the data request form are specific to procedure step data and so are not included here.

Table A-1. Standard PA-28 DEP profile points
(maximum gross takeoff weight = 2,325 lb).

Step	Distance (ft)	Alt (ft)	Speed (kts)	Power (RPM)
1	0.0	0.0	32.0	2500
2	1000.0	0.0	50.0	2500
3	1750.0	50.0	55.0	2500
4	4653.2	179.0	79.2	2500
5	21266.4	1500.0	80.8	2500
6	41317.6	3000.0	82.6	2500
7	88103.7	5500.0	85.8	2500
8	127598.4	7500.0	88.4	2500
9	203549.9	10000.0	91.9	2500

Table A-2. Standard PA-28 APP profile points
(maximum gross landing weight = 2,325 lb).

Step	Distance (ft)	Alt (ft)	Speed (kts)	Power (RPM)
1	-114486.8	6000.0	137.8	1800
2	-28621.7	1500.0	97.1	1800
3	-19081.1	1000.0	86.3	1600
4	-9540.6	500.0	70.5	1600
5	0.0	0.0	63.0	1500
6	520.0	0.0	63.0	1500
7	1110.0	0.0	10.0	1000

INM Database Request Form

The following describes the performance and noise data required for aircraft to be included in the FAA's INM database.

1. REFERENCE CONDITIONS FOR PERFORMANCE DATA

Table A-3. PA-28 INM reference conditions.

Wind	4 m/s (8 kt) headwind, constant with height above ground
Runway elevation	Mean Sea Level (MSL)
Runway gradient	None
Air temperature	15ºC (59ºF)
Aircraft gross takeoff weight	1,976 lb
Aircraft landing weight	2,093 lb
Number of engines supplying thrust	All
Atmosphere	International Standard Atmosphere (ISA)

2. AIRCRAFT AND ENGINE DATA

Where there are variations in certification weights and engine thrusts for a given model, provide data for the heaviest aircraft in terms of maximum gross takeoff weight in the model classification.

Table A-4. PA-28 INM aircraft and engine characteristics.

Aircraft model	Piper Warrior PA-28-161
Engine model	Lycoming O-320-D3G
Number of engines	1
Engine type (jet, turboprop, piston)	piston
Noise stage number (2, 3, 4)	-
Maximum static thrust (lb/engine)	400
Automated thrust restoration (yes, no)	no
Weight class (small, large, heavy)	small
Maximum gross takeoff weight (lb)	2,325
Maximum gross landing weight (lb)	2,325
Maximum landing distance (ft)	1,695

A.1.4 Beech 1900D

June 3, 2003

Gregg Fleming
Division Chief, Environmental Measurement and Modeling

John A. Volpe National Transportation Systems Center
55 Broadway
Cambridge, Massachusetts

Re: Raytheon Beech 1900D data for the Integrated Noise Model

Dear Mr. Fleming,

On April 30, 2002 the Volpe National Transportation Systems Center (Volpe) and the Federal Aviation Administration (FAA) conducted a study with a Raytheon Beech 1900D Airliner (1900D) at Fitchburg Municipal Airport in Massachusetts. These organizations conducted the study with the goal of determining reference noise and performance data for the FAA's Integrated Noise Model (INM). This letter report describes the methods and documents the information sources used to generate the INM performance data. As part of the same test, Volpe and FAA tested four other propeller-driven aircraft: a Piper PA-28 Warrior, a Piper PA-30 Twin Comanche, a Piper PA-31-350 Navajo Chieftain, and a Maule M-7-235C. Separate letter reports contain the INM performance data developed for these aircraft.

INM performance data are divided into thrust parameters and aerodynamic parameters[1]. The first Section of this report discusses the 1900D thrust parameters and their sources. The second Section discusses the 1900D aerodynamic parameters and their sources. The report concludes with a discussion of how these parameters are used in the INM to model DEP and APP performance of the 1900D. The method of determining the coefficients in the procedure steps rely on well known aerodynamic and aircraft performance relationships[2].

The basic characteristics of the 1900D are listed in Table 1 below:

Table 1. 1900D aircraft characteristics.

Raytheon Beech 1900D Airliner	
Max Takeoff weight	17,120 lb
Engines (2)	Pratt & Whitney Canada PT6A-67D
Propellers (2)	Hartzell E10950PK

Thrust Coefficients

For turboprop aircraft using procedure steps, the INM calculates the net adjusted thrust at each segment from the following equation:

$$\frac{F}{\delta} = E + F\,V + G_A\,h + G_B\,h^2 + H\,T_C \qquad (1)$$

where

F	is the net thrust in pounds
δ	is the non-dimensional pressure ratio
E	is a coefficient representing static thrust
F	is a coefficient representing change in thrust as a function of airspeed
G_A, G_B	are coefficients representing change in thrust as a second order function of altitude
H	is a coefficient representing change in thrust as a function of temperature
V	is the calibrated airspeed in kts
h	is the pressure altitude in ft above Mean Sea Level
	and T_C is the temperature in degrees Centigrade at the aircraft's altitude

Staff at Raytheon Aircraft Company provided the following tabular data to assist in the determination of the thrust coefficients. The numerical series data found in the upper half of half of Table 2 represent conditions at the Fitchburg study, the INMT*X* and INMC*X* data in the lower half of Table 2 represent conditions used to calculate the INM thrust coefficients.

In addition, Table 2 below lists the study conditions and operational parameters recorded during the study. These values represent averages over the particular study series. Note that the altitudes listed in Table 2 are Mean Sea Level (MSL), not Above Ground Level (AGL), since MSL altitudes are required for the performance calculations that follow.

Table 2. 1900D thrust and study performance data.

Series	Power	Alt. (ft)	IOAT (F)	KIAS	Propeller RPM (per input)	Torque per Engine (ft-lb)	Power per Engine (HP)	Prop Thrust Per Engine (lbf)	Jet Thrust per Engine (lbf)	Total Thrust per Engine (lbf)
100	LFO	3109	40	221	1467	3100	866	1075	32	1107
300	LFO	962	50	225	1470	3033	849	1067	29	1096
500	Climb	1073	48	178	1550	3167	935	1448	56	1504
600	Descent	834	48	160	1557	800	237	351	8	359
800	Descent	918	46	117	1550	800	236	483	20	503

Table 2. 1900D thrust and study performance data (cont.).

Series	Power	Alt. (ft)	TOAT (F)	KTAS	Prop RPM	Torque (ft-lb)	HP	Prop Thrust	Jet Thrust	Total Thrust
INMT1	Takeoff	0	59	0	1700	3200	1036	3219	148	3367
INMT2	Takeoff	0	59	160	1700	3200	1036	1744	73	1817
INMT3	Takeoff	0	69	160	1700	3200	1036	1741	73	1814
INMT4	Takeoff	1000	55	160	1700	3200	1036	1740	74	1814
INMC1	Climb	1000	55	160	1470	3100	868	1468	59	1526
INMC2	Climb	1000	65	160	1470	3100	868	1464	59	1522
INMC3	Climb	1000	55	200	1470	3100	868	1217	41	1258
INMC4	Climb	3000	48	160	1470	3100	868	1453	60	1513
INMC5	Climb	5000	41	160	1470	3100	868	1437	61	1498

The data in the lower half of Table 2 provides enough information to calculate the INM thrust coefficients; with the INMT*X* series used for the MaxTakeoff thrust coefficients and the INMC*X* series used for the MaxClimb thrust coefficients.

Thrust coefficients for *MaxTakeoff* conditions

We first calculate the *H* coefficient in the INM thrust equation from the INMT3 and INMT2 series data. The difference in temperature is 10 degrees Fahrenheit or 5.6 degrees Centigrade. The difference in thrust for these two series is 1,814 lb – 1,817 lb or –3 lb of thrust. The H coefficient is therefore $H = -3/5.6 = -0.504\, lb/C$.

Given that we know H, we can now calculate the static thrust coefficient E. The thrust equation reduces to the following during static conditions at Sea Level:

$$F = E + H(15°C) \quad (2)$$

For the conditions of the first equation, the static equation can be solved for E, the only unknown, with the thrust from the INMT1 series data.

$$E = F - H(15°C) = 3367 + 0.504(15) = 3375\, lb$$

By similar means of substitution from the INMT2 and INMT4 series, the values *F* and G_A can be found to be –9.687 lb/knot and –0.00462 lb/foot, respectively. Note that G_B is zero, since the second order effects of altitude are small between zero and 1,500 ft AGL, where the aircraft operates under MaxTakeoff conditions.

Thrust coefficients for *MaxClimb* conditions

The coefficients of MaxClimb condition are found using a slightly different APP for some of the coefficients. We first determine the temperature coefficient *H* in the same manner as we did with the MaxTakeoff condition. We use the INMC1 and INMC2 series; the difference in thrust for these two series is 1,522 lb – 1,526 lb or –4 lb of thrust, and the change in temperature is again 5.6 degrees Centigrade. The H coefficient is therefore

$$H = -4/5.6 = -0.720\, lb/C.$$

The velocity coefficient is found in a similar manner using the INMC1 and INMC3 series; the difference in thrust for these two series is 1,258 lb – 1,526 lb or –268 lb of thrust, and the change in true airspeed is 40 kts. The H coefficient is therefore

$$F = -268 \;\; lb / 40 \;\; knot = -6.7075 lb / knot$$

Unlike the MaxTakeoff condition, the MaxClimb *E* coefficient can't be calculated at a static condition, since the aircraft would not normally be at climb power on the ground. The data provided by Raytheon is sufficient to simultaneously calculate a solution of three unknowns, *E*, G_A, and G_B, given the three independent equations from INMC1, INMC4 and INMC5. The form of the system of equations is

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} E \\ G_A \\ G_B \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} \quad (3)$$

Where the *a* and *b* elements of the matrices are determined from the independent equations. The actual values used in solving for the three unknowns are:

$$\begin{bmatrix} 1 & 1\times10^3 & 1\times10^6 \\ 1 & 3\times10^3 & 9\times10^6 \\ 1 & 1\times10^4 & 1\times10^8 \end{bmatrix} \begin{bmatrix} E \\ G_A \\ G_B \end{bmatrix} = \begin{bmatrix} 2539 \\ 2523 \\ 2505 \end{bmatrix}$$

Solving for the three unknowns yields:

E = 2548.8 lb
G_A = -0.0104 lb/ft
$G_B = 6.03\times10^{-7}$ lb/ft^2

Aerodynamic Coefficients
This letter report contains the information sources and data used to determine the procedure steps of the 1900D for DEPs and APPs. The report contains enough information so that later developers can create additional points profiles, both DEPs and APPs, as required.

DEP Points
The Pilot's Operating Handbook[3] (the Handbook) contains the majority of the information required to generate the profile points. The Handbook contains performance charts and operational descriptions to aid in calculating all the information needed by the INM.

The calculation of the flap coefficients are similar to that described in the other letter reports, and so is not repeated here. Unlike those aircraft, however, the B1900D routinely flies farther than the 500 nautical mile stage length 1 used for the Piper Warrior, Twin

Comanche, and Navajo. This Section describes the process of establishing the stage lengths and their corresponding weights.

Determining stage length
The maximum take-off weight, maximum usable fuel, fuel burn rates, and cruising speeds determine the maximum distance the aircraft can fly. The maximum usable fuel is the initial maximum usage fuel in the tanks at push-back from the gate (4,458 lb), less the following amounts:

- fuel required for taxi and take-off (110 lb)
- fuel required to reach cruise altitude (200 lb)
- fuel required to descend from cruise altitude (200 lb)
- fuel required to meet FAA 45 minute IFR reserve requirements (572 lb)

Accounting for these four requirements leaves 3,376 pounds of fuel to fly the mission. The aircraft cruises at 256 kts true airspeed while burning 381 lb/hour/engine at 20,000 MSL at an intermediate power setting of 1,550 RPM. The aircraft can cruise for 3,376/(2*381) = 4.43 hours and travel 256 kts*4.43 hours = 1,134 nautical miles (nmi). This approximately 1,000 nautical mile range corresponds to an INM stage length of 2, and assumes the aircraft is operating at its maximum take-off weight of 16,950 lb.

For the INM stage length of 1, or 500 nmi, we note that the aircraft flies 500 nmi less than in its stage length 2 configuration. Flying these 500 nmi takes 500 nmi/256 kts= 1.95 hours, during which time the aircraft burns 1.95*2*381 = 1,488 pounds of fuel. The stage length 1 weight is therefore 16,950 – 1,488 ≅ 15,500 lb.

APP Points
The APP data starts at the INM standard APP altitude of 6,000 ft AGL, and assumes a standard three degree glideslope. The glideslope determines the track distance from the touchdown point, with the touchdown point given by the chart shown in Figure 6.

The airspeeds used in the APP come from the Manual. The APP procedure starts at 160 kts indicated airspeed; this corresponds to the average of the flaps-up/gear-up indicated airspeeds during the 600 series descent study. This speed and configuration is maintained from 6,000 ft AGL to 1,500 ft, where the study in the intermediate configuration had an indicated airspeed of 146 kts. At 1,000 ft AGL, the flaps are set to 35 degrees and the landing gear are extended. The airspeed at this point is 118 kts. The landing rollout speed of 84 kts comes from the landing configuration stall speed listed in Jane's[13]. The landing distance is calculated from information in the Manual.

Modeling DEPs and APPs in the INM
Appendix A contains the INM data request form and the procedure steps based on the operational methods described above.

If you have any questions on the information in this report, please contact me via telephone at 781.721.4824 or via e-mail at dsenzig@senzig.com. I gratefully acknowledge the assistance of Henry Wurster of Champlain Enterprises for the help he provided on this Project, both his airmanship during the study and his support of this analysis.

Sincerely,

SENZIG ENGINEERING

David Senzig, PE

References

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10. “Airplane Aerodynamics and Performance,” Lan and Roskam, Roskam Aviation and Engineering, Ottawa, Kansas, 1981.
11. “Beech 1900D Airliner Pilot’s Operating Manual,” Raytheon Aircraft Corporation, P/N 129-590000-73B2, Wichita, Kansas, November 2001.
12. “Aeronautical Vestpocket Handbook,” United Technologies, Pratt & Whitney, East Hartford, Connecticut, September 1991.
13. Jane’s All the World’s Aircraft 2002-2003, www.janes.com, 2002.

INM Data Request form with Beech 1900D information

The following describes the performance and noise data required for aircraft to be included in the FAA's INM database.

1. REFERENCE CONDITIONS FOR PERFORMANCE DATA

Table A-1. 1900D INM reference conditions.

Wind	4 m/s (8 kt) headwind, constant with height above ground
Runway elevation	Mean Sea Level (MSL)
Runway gradient	None
Air temperature	15ºC (59ºF)
Aircraft gross takeoff weight	14,408 lb
Aircraft landing weight	14,940 lb
Number of engines supplying thrust	All
Atmosphere	International Standard Atmosphere (ISA)

2. AIRCRAFT AND ENGINE DATA

Where there are variations in certification weights and engine thrusts for a given model, provide data for the heaviest aircraft in terms of maximum gross takeoff weight in the model classification.

Table A-2. 1900D INM aircraft and engine characteristics.

Aircraft model	Raytheon Beech 1900D
Engine model	Pratt & Whitney Canada PT6A-67D
Number of engines	2
Engine type (jet, turboprop, piston)	turboprop
Noise stage number (2, 3, 4)	-
Maximum static thrust (lb/engine)	3,367
Automated thrust restoration (yes, no)	no
Weight class (small, large, heavy)	small
Maximum gross takeoff weight (lb)	16,950
Maximum gross landing weight (lb)	16,600
Maximum landing distance (ft)	2,720

Takeoff Weights

Stage number	Trip length (nmi)	Weight (lb)
1	0-500	15,500
2	500-1000	16,950

Takeoff weights should be developed so as to increase with an increase in mission trip length. Weight assumptions should use industry planning assumptions for load factor, average passenger weight, excess cargo beyond passenger weight, and fuel required to complete mission trip length.

3. AERODYNAMIC COEFFICIENTS

Aerodynamic coefficients for use with the SAE AIR 1845 equations are required for available flap settings. The flap settings may be identified in degrees and abbreviations. Please provide data for all flap settings specified in Sections 5 and 6.

Table A-3. 1900D INM aerodynamic and flaps coefficients.

Flap Configuration Identifier	**Operation (A, D)**[1]	**Gear**	**Takeoff B (ft/lb)**	**Takeoff C (kt/√lb)**	**Land D (kt/√lb)**	**Drag/Lift R**
17-D	D	down	.060076	0.858496		0.072968
	D	down				
Zero-D	D	Up	[2]			0.094383
	D	up				
	D	up				
Zero-A	A	up				0.106643
	A	up				
35-A	A	down			0.915858	0.130495
	A	down				
	A	down				

[1] A = Approach, D = Depart
[2] Not applicable

4. ENGINE COEFFICIENTS

For jet aircraft, engine coefficients in accordance with SAE AIR 1845 equations are required for maximum takeoff, maximum climb, and general thrust in terms of EPR or N1. The Max-Takeoff coefficients should be valid to 6,000 ft MSL, the Max-Climb and General Thrust coefficients should be valid to 16,000 ft MSL. This is necessary so that the INM accurately models operations at high altitude airports such as Denver and Salt Lake City.

In addition, high temperature coefficients are required for operations above the thrust break temperature. INM uses the Max-Takeoff and Max-Climb coefficients below the breakpoint temperature and uses the Hi-Temp coefficients above the breakpoint temperature. The breakpoint temperature is at the intersection of the two curves. An example of Max-Takeoff and Hi-Temp Max-Takeoff curves is shown in Figure 1.

Table A-4. 1900D INM thrust coefficients.

Thrust Type	E (lb)	F (lb/kt)	Ga (lb/ft)	Gb (lb/ft^2)	H (lb/°C)
Max-Takeoff	3374.6	-9.6869	-0.0046	0	-0.504
Hi-Temp Max-Takeoff					
Max-Climb	2548.8	-6.7075	-0.0140	0	-0.720
Hi-Temp Max-Climb					
General Thrust					
Hi-Temp General Thrust					
	K1a (lb/EPR)	**K1b (lb/EPR^2)**	**or**	**K2 lb/(N1/$\sqrt{\theta}$)**	**K3 lb/(N1/$\sqrt{\theta}$)^2**
General Thrust					
Hi-Temp General Thrust					

5. DEP PROCEDURES

DEP procedures consist of a takeoff segment, and a combination of climb and acceleration segments up to an altitude of 10,000 ft AFE. A climb segment is defined by its endpoint altitude. An acceleration segment is defined by its rate-of-climb and the calibrated airspeed at its endpoint. The flap settings are indicated for endpoints of segments. These flap settings should coincide with those given in Section 3 above. Please provide procedural data for each stage length given in Section 2 above.

Stage Number	1

Repeat table for each takeoff stage number (takeoff weight) listed in Section 2.

Table A-5. 1900D Stage 1 INM DEP procedure.

Segment Type[1]	Thrust Type[2] (T/C)	Flap Configuration Identifier[3]	Endpoint Altitude (ft AFE)	Rate-of-Climb (ft/min)	Endpoint Speed (KCAS)	Start Thrust[4] (lb)
Takeoff	T	17-D				3400
Climb	T	17-D	400			2400
Accelerate	T	17-D		2750	128	2100
Accelerate	C	Zero-D		2950	138	1700
Climb	C	Zero-D	3000			1600
Accelerate	C	Zero-D		1500	160	1400
Climb	C	Zero-D	5500			1400
Climb	C	Zero-D	7500			1400
Climb	C	Zero-D	10000			1300

[1] Add, delete, and sequence the segments as necessary to represent a takeoff procedure
[2] T = Max-Takeoff, C = Max-Climb, as defined in Section 4
[3] Use the identifiers in Section 3
[4] These data are used to compare to INM-computed thrust values

Stage Number	2

Repeat table for each takeoff stage number (takeoff weight) listed in Section 2.

Table A-6. 1900D Stage 2 INM DEP procedure.

Segment Type[1]	Thrust Type[2] (T/C)	Flap Configuration Identifier[3]	Endpoint Altitude (ft AFE)	Rate-of-Climb (ft/min)	Endpoint Speed (KCAS)	Start Thrust[4] (lb)
Takeoff	T	17-D				3400
Climb	T	17-D	400			2300
Accelerate	T	17-D		2400	128	2100
Accelerate	C	Zero-D		2650	138	1600
Climb	C	Zero-D	3000			1600
Accelerate	C	Zero-D		1500	160	1400
Climb	C	Zero-D	5500			1400
Climb	C	Zero-D	7500			1400
Climb	C	Zero-D	10000			1300

[1] Add, delete, and sequence the segments as necessary to represent a takeoff procedure
[2] T = Max-Takeoff, C = Max-Climb, as defined in Section 4
[3] Use the identifiers in Section 3
[4] These data are used to compare to INM-computed thrust values

6. APP PROCEDURES

A landing profile should be calculated for a starting altitude of 6,000 ft above field elevation (AFE). The flap settings should coincide with those given in Section 3 above.

Landing weight (lb)	14,940
Stopping distance (ft)	1,696

Table A-7. 1900D INM APP procedure.

Profile Point	Operation	Altitude (ft AFE)	Distance from Touchdown[1] (ft)	Start Speed (KTAS)	Flap Configuration[2]	Start Thrust[3] (lb)
1	Descend	6000	−114487	160	Zero-A	520
2	Descend	3000	−57243	160	Zero-A	465
3	Descend	1500	−28622	146	Zero-A	440
4	Descend	1000	−19081	118	35-A	620
5	Land	0	300	118 [4]	35-A	590
6	Reverse Thrust	0	1696	84	35-A	340
7	Start Taxi	0	1706	10	35-A	340

[1] Glide slope is 3.0 degrees
[2] Use identifiers in Section 3
[3] These data are used to compare to INM-computed thrust values
[4] Landing speed is for reference only; INM calculates landing speed using the D coefficient (Section 3) and landing weight

A.2 Other Aircraft

A.2.1 Maule M-7-235C

As discussed in Section 6.1.3 above, weather conditions resulted in only two measurement series being completed for the Maule M-7-235C. Users may analyze the available Maule performance data by creating a user-defined aircraft in the INM and utilizing the 300 Series and 400 Series NPD data provided for the Maule in Appendix E. Only LFOs may be modeled with these data; accordingly, APP and DEP distance and altitude information are not presented. The user may choose the speed and power metric to associate with the NPDs. In the case of the Maule, the user may want to associate RPM with the 300 and 400 Series NPDs. Speed data for the Maule are presented in Appendix D. RPM data for the Maule are presented in Table A-1.

Table A-1. Maule M-7-235C RPM power metrics.

Event	RPM
310	2,300
320	2,300
330	2,300
411	2,000

A.2.2 Eurocopter EC-130

A database file containing helicopter NPD data was distributed with INM Version 6.0c to facilitate simplified, uniform modeling of helicopter operations in INM. Consistent with this approach, a database file containing NPD data has been developed for the EC-130 and included in Appendix G. EC-130 performance data in Section 2.6 may be used to model the helicopter in INM. Distance, altitude, and speed data for the EC-130 are presented in Appendix D.

A.2.3 Robinson R-22

Similar to the EC-130, a database file containing NPD data has been developed for the R-22 and included in Appendix G. R-22 performance data in Section 2.7 may be used to model the helicopter in INM. Distance, altitude, and speed data for the R-22 are presented in Appendix D.

APPENDIX B: FITCHBURG STUDY LIST OF SERVICE CONTACTS

Each of the service providers crucial to the success of the Fitchburg Study are listed with their contact information in Table B-1. John Payson, pilot of the Maule M-7-235C, volunteered the use of his craft and time; his contact information has been omitted.

Table B-1. Study list of contacts.

Service Provided	Company	Address	Contact	Telephone Number	Email	Website
Airport Runway	Fitchburg Municipal Airport	567 Airport Rd. Fitchburg, MA 01420	David Bouvier	(978) 345-9580	fitairport@wn.net	www.fitchburgairport.com
Study Design, INM Analysis	Senzig Engineering	269 Highland Ave. Winchester, MA 01890	David Senzig	(781) 721-4824	dsenzig@senzig.com	www.senzig.com
Maule M-7-235C airplane	NA	NA	John Payson	NA	NA	NA
Piper Twin Comanche PA-30 airplane	Alan Emerson Aviation Inc.	65 Aviation Dr. Gilford, NH 03246	David Emerson	(603) 293-7980	NA	www.emersonaviation.com
Piper Navajo Chieftain PA-31-350 airplane	Eagle Air Inc.	375 Airport Dr. Worcester, MA 01602	Doug Lord	(888) 993-2453	sales@eagleaircharter.com	www.eagleaircharter.com
Piper Warrior PA-28-161 airplane	Beverly Flight Center	Beverly Airport Westside Danvers, MA 01923	Arnie Nordheim	(978) 774-7755	info@beverlyflightcenter.com	www.beverlyflightcenter.com
Beech 1900D airplane	Commutair	518 Rugar St. Plattsburgh, NY 12901	Henry Wurster	(518) 562-2700	hwurster@commutair.com	www.commutair.com
Eurocopter EC-130 helicopter	Liberty Helicopter Inc	PO Box 1338 Linden, NJ 07036	Ken Testa	(908) 474-9300	testak@libertyhelicopters.com	www.libertyhelicopters.com
Robinson R-22 helicopter	Northern Lights	NA	Jenny Bruce	(781) 769-4720	NA	www.northernlightsheli.com

APPENDIX C: METEOROLOGICAL DATA

This appendix presents the test day meteorological data used in the processing of all acoustic data. As noted in Section 3.4, temperature, relative humidity, wind speed, wind direction, and barometric pressure data were collected. Temperature in degrees Fahrenheit and relative humidity in percent, taken at the aircraft's overhead time of day, are presented for each event in Tables C-1 through C-9.

Changes in outdoor temperature and relative humidity are assumed to be negligible over short periods of time; accordingly, for the purpose of data processing, temperature and relative humidity were assumed to be constant over the ten-dB down period of each aircraft event.

All acoustic data presented herein were analyzed in accordance with wind speed and direction criteria as specified in FAR 36 (Reference 1). In addition to the overhead temperature and relative humidity data presented for all measurement events, average wind speed and direction data are presented for the periods specific to each helicopter Static Operations event.

C.1 Maule M-7-235C

Table C-1. Maule event meteorological data.

Event #	Date	Time of Day	Air Temp (°F)	Humidity (%RH)
310	8/30/2002	10:45:03	67	76
320	8/30/2002	11:01:29	67	75
330	8/30/2002	11:18:26	69	74
411	8/30/2002	11:53:09	69	72

C.2 Piper Twin Comanche PA-30

Table C-2. PA-30 event meteorological data.

Event #	Date	Time of Day	Air Temp (°F)	Humidity (%RH)
310	4/30/2002	9:46:28	44	55
330	4/30/2002	9:56:36	45	54
410	4/30/2002	10:01:45	45	52
511	4/30/2002	10:21:03	47	50
530	4/30/2002	10:31:06	46	49
540	4/30/2002	10:35:30	47	47
550	4/30/2002	10:40:58	46	47
560	4/30/2002	10:46:08	47	46
610	4/30/2002	10:54:02	49	45
621	4/30/2002	11:03:23	49	40
630	4/30/2002	11:07:16	49	38
710	4/30/2002	11:11:51	47	38
721	4/30/2002	11:18:37	49	41
730	4/30/2002	11:23:00	52	40
811	4/30/2002	11:29:57	51	39
820	4/30/2002	11:33:13	49	38
830	4/30/2002	11:37:05	51	41
910	4/30/2002	11:41:05	49	40
920	4/30/2002	11:44:04	49	40
930	4/30/2002	11:47:25	49	39

C.3 Piper Navajo Chieftain PA-31-350

Table C-3. PA-31 event meteorological data.

Event #	Date	Time of Day	Air Temp (°F)	Humidity (%RH)
310	4/30/2002	13:16:27	51	34
321	4/30/2002	13:22:45	51	34
330	4/30/2002	13:26:55	51	36
350	4/30/2002	16:57:06	47	59
360	4/30/2002	16:59:46	47	59
410	4/30/2002	13:30:58	51	36
431	4/30/2002	13:45:36	50	36
510	4/30/2002	14:27:30	52	36
520	4/30/2002	14:32:40	51	35
530	4/30/2002	14:39:00	51	35
540	4/30/2002	14:44:05	52	34
550	4/30/2002	14:49:23	53	35
561	4/30/2002	14:58:41	51	35
610	4/30/2002	15:02:46	52	35
620	4/30/2002	15:06:57	52	36
631	4/30/2002	15:14:51	53	36
710	4/30/2002	15:19:07	51	36
721	4/30/2002	15:28:47	51	37
730	4/30/2002	15:33:38	52	37
810	4/30/2002	15:37:42	51	37
831	4/30/2002	16:39:45	47	57
910	4/30/2002	16:43:28	47	57
920	4/30/2002	16:47:05	47	58
930	4/30/2002	16:50:42	47	58

C.4 Piper Warrior PA-28-161

Table C-4. PA-28 event meteorological data.

Event #	Date	Time of Day	Air Temp (°F)	Humidity (%RH)
321	4/29/2002	13:06:04	40	81
331	4/29/2002	13:15:33	42	82
332	4/29/2002	13:20:13	42	81
333	5/6/2002	7:57:09	61	51
334	5/6/2002	8:00:42	63	49
360	5/6/2002	9:30:16	71	34
411	4/29/2002	13:32:49	42	80
421	4/29/2002	13:43:04	40	82
430	4/29/2002	13:48:04	40	82
510	4/29/2002	13:52:32	40	82
520	4/29/2002	13:57:22	40	84
530	4/29/2002	14:02:13	40	83
540	4/29/2002	14:06:55	40	83
550	4/29/2002	14:09:39	40	84
562	4/29/2002	14:21:17	40	84
611	4/29/2002	14:28:52	40	84
630	4/29/2002	14:35:49	40	85
710	4/29/2002	14:39:14	40	85
831	4/29/2002	15:04:50	40	85
911	5/6/2002	9:24:23	69	32
921	5/6/2002	9:27:44	71	32
930	4/29/2002	15:15:14	39	85
1110	8/30/2002	15:11:52	77	62
1120	8/30/2002	15:17:59	76	61
1210	8/30/2002	15:35:20	78	60
1220	8/30/2002	15:39:05	79	56
1230	8/30/2002	15:45:50	79	55
1240	8/30/2002	15:49:40	79	58
2100	8/30/2002	15:02:51	78	61
2200	8/30/2002	15:05:30	77	61
2300	8/30/2002	15:08:36	76	61

C.5 Beech 1900D

Table C-5. 1900D event meteorological data.

Event #	Date	Time of Day	Air Temp (°F)	Humidity (%RH)
310	5/1/2002	8:10:08	46	61
320	5/1/2002	8:16:26	46	61
330	5/1/2002	8:22:25	46	60
340	5/1/2002	8:26:18	47	60
350	5/1/2002	8:31:09	46	60
510	5/1/2002	8:45:21	46	59
521	5/1/2002	8:54:01	46	58
530	5/1/2002	9:02:17	48	57
610	5/1/2002	9:18:56	48	55
620	5/1/2002	9:25:01	47	54
630	5/1/2002	9:28:45	49	53
710	5/1/2002	9:32:25	48	52
730	5/1/2002	9:40:16	49	53
810	5/1/2002	9:45:14	48	52
830	5/1/2002	9:52:55	48	52
910	5/1/2002	9:57:13	49	51
930	5/1/2002	10:04:28	49	51
931	5/1/2002	10:08:11	50	50

C.6 Eurocopter EC-130

Table C-6. EC-130 meteorological data - Dynamic Operations events.

Event #	Date	Time of Day	Air Temp (°F)	Humidity (%RH)
120	5/7/2002	9:33:55	64	54
121	5/7/2002	9:36:47	64	54
122	5/7/2002	9:39:07	65	54
130	5/7/2002	9:41:18	65	54
132	5/7/2002	9:45:04	65	53
140	5/7/2002	9:47:15	66	53
141	5/7/2002	9:49:03	65	53
142	5/7/2002	9:50:27	66	53
150	5/7/2002	9:52:46	65	54
151	5/7/2002	9:54:13	65	54
152	5/7/2002	9:56:16	65	54
160	5/7/2002	9:57:54	65	54
162	5/7/2002	10:02:47	67	54
163	5/7/2002	10:06:01	67	53
180	5/7/2002	12:37:35	73	51
181	5/7/2002	12:39:02	73	51
183	5/7/2002	12:40:55	74	51
210	5/7/2002	10:09:38	68	53
211	5/7/2002	10:12:38	67	53
214	5/7/2002	10:19:15	68	52
215	5/7/2002	10:21:07	69	52
216	5/7/2002	10:22:36	68	52
217	5/7/2002	10:24:15	69	52
311	5/7/2002	10:34:43	69	55
313	5/7/2002	10:47:38	69	55
314	5/7/2002	10:52:10	69	54
320	5/7/2002	10:56:31	69	54
321	5/7/2002	11:01:01	70	55
323	5/7/2002	11:09:32	70	53
330	5/7/2002	11:58:14	71	52
331	5/7/2002	12:01:54	72	52
333	5/7/2002	12:09:07	72	52
341	5/7/2002	12:17:07	71	52
342	5/7/2002	12:20:04	72	52
343	5/7/2002	12:22:41	74	52
344	5/7/2002	12:25:35	74	51
350	5/7/2002	12:28:52	72	51
351	5/7/2002	12:32:26	73	51
352	5/7/2002	12:35:07	73	51

One-second wind speed and wind direction data over the course of the measured Static Operations HIGE, HOGE, Ground Idle and Flight Idle events have been arithmetically averaged and included in Tables C-7 and C-9. Average wind direction is measured in degrees from north (i.e., a wind direction of zero degrees indicates a wind blowing exactly north).

Table C-7. EC-130 hover and idle meteorological data - Static Operations events.

Event #	Config.	Date	Time of Day	Air Temp (°F)	Humidity (%RH)	Avg. Wind Speed (kts)	Avg. Wind Direction (degrees)
410	HIGE	5/7/2002	09:04:10	65	52	6.9	226
420	HOGE	5/7/2002	09:09:30	62	53	9.6	270
510	Flight Idle	5/7/2002	09:02:10	64	52	5.4	231
520	Ground Idle	5/7/2002	09:02:40	65	52	5.8	237

C.7 Robinson R-22

Table C-8. R-22 meteorological data - Dynamic Operations events.

Event #	Date	Time of Day	Air Temp (°F)	Humidity (%RH)
120	5/1/2002	12:07:18	53	45
121	5/1/2002	12:10:49	55	44
122	5/1/2002	12:14:24	53	42
132	5/1/2002	12:24:04	53	43
133	5/1/2002	12:28:50	54	42
134	5/1/2002	12:32:49	54	42
142	5/1/2002	12:44:49	55	41
150	5/1/2002	12:52:07	56	42
151	5/1/2002	12:56:13	55	41
154	5/1/2002	13:07:13	56	41
160	5/1/2002	13:10:21	56	41
162	5/1/2002	13:20:21	56	42
180	5/6/2002	13:01:20	80	25
183	5/6/2002	13:09:50	78	24
184	5/6/2002	13:12:33	79	24
213	5/1/2002	13:38:16	54	42
214	5/1/2002	13:41:58	55	41
217	5/1/2002	13:53:30	57	41
314	5/1/2002	14:30:03	56	41
322	5/6/2002	11:49:27	75	23
323	5/6/2002	11:54:30	75	23
330	5/6/2002	12:01:39	75	23
331	5/6/2002	12:07:58	76	25
332	5/6/2002	12:14:58	76	24
342	5/6/2002	12:42:41	78	25
344	5/6/2002	12:54:49	78	25
350	5/6/2002	13:18:50	79	25
351	5/6/2002	13:22:47	78	25
352	5/6/2002	13:27:34	77	24

Table C-9. R-22 hover and idle meteorological data - Static Operations events.

Event #	Config.	Date	Time of Day	Air Temp (°F)	Humidity (%RH)	Avg. Wind Speed (kts)	Avg. Wind Direction (degrees)
410	HIGE	5/6/2002	11:26:00	74	23	12.7	216
420	HOGE	5/6/2002	11:29:43	74	23	8.7	220
510	Flight Idle	5/6/2002	11:23:05	75	23	9.2	238
520	Ground Idle	5/6/2002	11:24:30	75	23	4.9	211

APPENDIX D: TIME-SPACE-POSITION INFORMATION (TSPI)

This appendix presents a summary of the TSPI data used in the processing of the acoustic data measured for each aircraft event, including overhead time, aircraft test altitude in ft, test speed in kts, descent angle in degrees, and reference speed in kts. Altitude data represent instantaneous altitude at the overhead time, whereas groundspeed and descent angle – the angle at which the aircraft approaches or departs from the ground – represent an average of data representing the sound level time history 10-dB-down duration. A diagram of descent angle geometry is presented in Figure D-1.

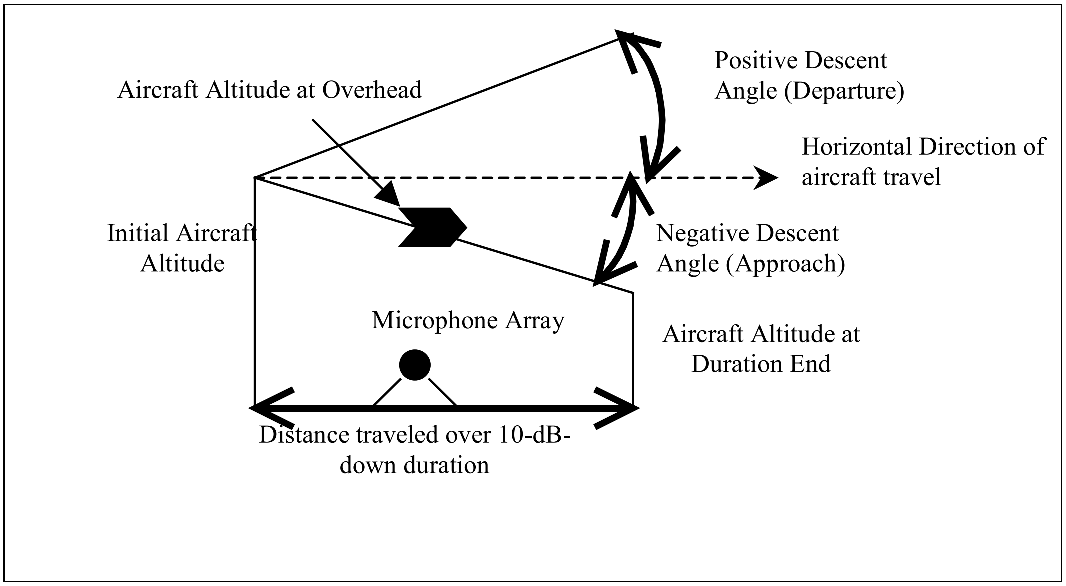

Figure D-1. Aircraft descent angle geometry

A DEP resulted in a positive descent angle, with the aircraft altitude at duration end higher than the initial aircraft altitude. An APP resulted in a negative descent angle, with the aircraft altitude at duration end lower than the initial aircraft altitude.

Data presented in Tables D-1 through D-7 include aircraft-specific test and reference conditions. For completeness, values of DUR_{ADJ}, used to adjust exposure-based metrics from these conditions to the 160-kts reference speed required for inclusion in the INM, are provided in the last column.

D.1 Maule M-7-235C

Table D-1. Maule event TSPI data.

Event #	Overhead Time	Test Altitude (ft)	Test Speed (kts)	Test Descent angle (degrees)	Reference Speed (kts)	DUR_{ADJ} (dB)
310	10:45:03	477	122	0.7	87	2.6
320	11:01:29	468	126	0.3	87	2.6
330	11:18:26	469	123	0.3	87	2.6
411	11:53:09	539	63	0.7	70	3.6

D.2 Piper Twin Comanche PA-30

Table D-2. PA-30 event TSPI data.

Event #	Overhead Time	Test Altitude (ft)	Test Speed (kts)	Test Descent angle (degrees)	Reference Speed (kts)	DUR_{ADJ} (dB)
310	9:46:28	579	134	0.9	165	-0.1
330	9:56:36	464	149	1.9	165	-0.1
410	10:01:45	492	140	0.7	135	0.7
511	10:21:03	353	83	12.7	97	2.2
530	10:31:06	386	89	9.0	97	2.2
540	10:35:30	424	97	11.2	97	2.2
550	10:40:58	568	88	11.7	97	2.2
560	10:46:08	464	92	13.2	97	2.2
610	10:54:02	269	113	0.3	100	2.0
621	11:03:23	268	119	0.3	100	2.0
630	11:07:16	347	108	-1.1	100	2.0
710	11:11:51	288	98	-1.2	96	2.2
721	11:18:37	268	110	-0.7	96	2.2
730	11:23:00	299	128	-0.9	96	2.2
811	11:29:57	371	93	-1.9	87	2.6
820	11:33:13	248	91	-2.3	87	2.6
830	11:37:05	282	96	-2.0	87	2.6
910	11:41:05	496	118	1.0	97	2.2
920	11:44:04	512	106	3.7	97	2.2
930	11:47:25	491	113	1.2	97	2.2

D.3 Piper Navajo Chieftain PA-31-350

Table D-3. PA-31-350 event TSPI data.

Event #	Overhead Time	Test Altitude (ft)	Test Speed (kts)	Test Descent angle (degrees)	Reference Speed (kts)	DUR_{ADJ} (dB)
310	13:16:27	570	179	-0.2	156	0.1
321	13:22:45	570	177	0.3	156	0.1
330	13:26:55	539	172	0.8	156	0.1
350	16:57:06	526	159	3.5	156	0.1
360	16:59:46	463	174	4.2	156	0.1
410	13:30:58	555	177	0.4	155	0.1
431	13:45:36	563	169	0.2	155	0.1
510	14:27:30	301	116	6.9	105	1.8
520	14:32:40	190	124	6.9	105	1.8
530	14:39:00	253	119	5.0	105	1.8
540	14:44:05	340	106	13.6	105	1.8
550	14:49:23	342	105	9.9	105	1.8
561	14:58:41	622	99	9.8	105	1.8
610	15:02:46	517	131	0.8	160	0.0
620	15:06:57	390	112	1.6	160	0.0
631	15:14:51	324	102	-1.1	160	0.0
710	15:19:07	236	100	-0.6	150	0.3
721	15:28:47	424	110	-3.1	150	0.3
730	15:33:38	466	96	-3.1	150	0.3
810	15:37:42	291	94	-3.3	120	1.2
831	16:39:45	420	100	-3.4	120	1.2
910	16:43:28	547	146	-0.2	105	1.8
920	16:47:05	573	136	0.0	105	1.8
930	16:50:42	556	134	3.5	105	1.8

D.4 Piper Warrior PA-28-161

Table D-4. PA-28-161 event TSPI data.

Event #	Overhead Time	Test Altitude (ft)	Test Speed (kts)	Test Descent angle (degrees)	Reference Speed (kts)	DUR_{ADJ} (dB)
321	13:06:04	432	101	1.3	105	1.8
331	13:15:33	494	100	1.0	105	1.8
332	13:20:13	505	100	-0.6	105	1.8
333	7:57:09	400	104	1.4	105	1.8
334	8:00:42	417	103	1.4	105	1.8
360	9:30:16	376	101	1.3	105	1.8
411	13:32:49	544	85	0.7	95	2.3
421	13:43:04	540	80	0.3	95	2.3
430	13:48:04	522	86	-0.9	95	2.3
510	13:52:32	367	74	6.8	79	3.1
520	13:57:22	297	75	4.6	79	3.1
530	14:02:13	511	72	3.3	79	3.1
540	14:06:55	387	72	5.2	79	3.1
550	14:09:39	591	84	4.6	79	3.1
562	14:21:17	395	82	3.1	79	3.1
611	14:28:52	501	102	-2.8	100	2.0
630	14:35:49	490	102	-3.4	100	2.0
710	14:39:14	468	89	-3.4	80	3.0
831	15:04:50	483	72	-2.7	70	3.6
911	9:24:23	443	99	1.8	87	2.6
921	9:27:44	500	95	2.1	87	2.6
930	15:15:14	490	96	0.2	87	2.6
1110	15:11:52	36	123	0.1	105	1.8
1120	15:17:59	67	109	0.9	105	1.8
1210	15:35:20	178	102	0.3	105	1.8
1220	15:39:05	181	113	0.9	105	1.8
1230	15:45:50	206	104	0.1	105	1.8
1240	15:49:40	194	111	0.3	105	1.8
2100	15:02:51	476	102	0.0	105	1.8
2200	15:05:30	445	117	0.0	105	1.8
2300	15:08:36	471	103	-1.2	105	1.8

D.5 Beech 1900D

Table D-5. 1900D event TSPI data.

Event #	Overhead Time	Test Altitude (ft)	Test Speed (kts)	Test Descent angle (degrees)	Reference Speed (kts)	DUR_{ADJ} (dB)
310	8:10:08	541	226	0.5	220	-1.4
320	8:16:26	534	225	-0.4	220	-1.4
330	8:22:25	482	225	0.4	220	-1.4
340	8:26:18	438	239	-0.4	220	-1.4
350	8:31:09	426	233	0.8	220	-1.4
510	8:45:21	536	179	1.6	160	0.0
521	8:54:01	600	171	6.2	160	0.0
530	9:02:17	638	168	6.0	160	0.0
610	9:18:56	307	148	-3.0	160	0.0
620	9:25:01	434	159	-1.7	160	0.0
630	9:28:45	306	139	-1.3	160	0.0
710	9:32:25	505	146	-2.0	130	0.9
730	9:40:16	449	136	-2.1	130	0.9
810	9:45:14	434	107	-3.4	115	1.4
830	9:52:55	463	110	-2.6	115	1.4
910	9:57:13	564	168	0.9	160	0.0
930	10:04:28	523	158	0.6	160	0.0
931	10:08:11	553	170	1.9	160	0.0

D.6 Eurocopter EC-130

Helicopter reference speeds are based on maximum speed in level flight with maximum continuous power (V_H) and speed for best rate of climb (V_Y). The adjustment factors used to calculate the helicopter reference speeds are included in Tables D-6 and D-7.

Table D-6. EC-130 event TSPI data.

Event #	Overhead Time	Test Altitude (ft)	Test Speed (kts)	Test Descent angle (degrees)	Ref. Speed (kts)	Ref. Speed Adj. Factor, with V_H = 126 kts, V_Y = 65 kts	DUR_{ADJ} (dB)
120	9:33:55	532	125	1.2	115	$0.9*V_H$	1.4
121	9:36:47	487	112	1.3	115	$0.9*V_H$	1.4
122	9:39:07	509	119	1.4	115	$0.9*V_H$	1.4
130	9:41:18	511	124	0.0	125	$1.0*V_H$	1.1
132	9:45:04	484	121	0.2	125	$1.0*V_H$	1.1
140	9:47:15	459	109	1.5	101	$0.8*V_H$	2.0
141	9:49:03	496	92	0.6	101	$0.8*V_H$	2.0
142	9:50:27	526	107	1.3	101	$0.8*V_H$	2.0
150	9:52:46	500	86	0.4	88	$0.7*V_H$	2.6
151	9:54:13	528	100	1.0	88	$0.7*V_H$	2.6
152	9:56:16	521	85	0.0	88	$0.7*V_H$	2.6
160	9:57:54	508	94	0.1	76	$0.6*V_H$	3.2
162	10:02:47	497	88	0.1	76	$0.6*V_H$	3.2
163	10:06:01	502	74	-0.3	76	$0.6*V_H$	3.2
180	12:37:35	71	93	0.3	101	$0.8*V_H$	2.0
181	12:39:02	125	108	2.1	101	$0.8*V_H$	2.0
183	12:40:55	107	112	1.0	101	$0.8*V_H$	2.0
210	10:09:38	430	63	4.8	65	$1.0*V_Y$	3.9
211	10:12:38	304	63	11.5	65	$1.0*V_Y$	3.9
214	10:19:15	405	63	12.7	65	$1.0*V_Y$	3.9
215	10:21:07	469	64	14.1	65	$1.0*V_Y$	3.9
216	10:22:36	438	63	14.0	65	$1.0*V_Y$	3.9
217	10:24:15	473	63	11.1	65	$1.0*V_Y$	3.9
311	10:34:43	466	59	-5.0	65	$1.0*V_Y$	3.9
313	10:47:38	506	51	-7.5	65	$1.0*V_Y$	3.9
314	10:52:10	602	57	-12.0	65	$1.0*V_Y$	3.9
320	10:56:31	655	58	-10.2	65	$1.0*V_Y$	3.9
321	11:01:01	435	61	-7.5	65	$1.0*V_Y$	3.9
323	11:09:32	452	61	-9.9	65	$1.0*V_Y$	3.9
330	11:58:14	414	56	-9.9	65	$1.0*V_Y$	3.9
331	12:01:54	379	50	-11.3	65	$1.0*V_Y$	3.9
333	12:09:07	452	52	-13.3	65	$1.0*V_Y$	3.9
341	12:17:07	554	75	-11.1	80	$1.2*V_Y$	3.0
342	12:20:04	368	73	-12.1	80	$1.2*V_Y$	3.0
343	12:22:41	442	83	-8.2	80	$1.2*V_Y$	3.0
344	12:25:35	430	77	-11.5	80	$1.2*V_Y$	3.0
350	12:28:52	475	60	-9.3	60	$0.9*V_Y$	4.3
351	12:32:26	595	51	-10.1	60	$0.9*V_Y$	4.3
352	12:35:07	492	58	-10.6	60	$0.9*V_Y$	4.3

D.7 Robinson R-22

Table D-7. R-22 event TSPI data.

Event #	Overhead Time	Test Altitude (ft)	Test Speed (kts)	Test Descent angle (degrees)	Ref. Speed (kts)	Ref. Speed Adj. Factor, with V_H = 102 kts, V_Y = 53 kts	DUR_{ADJ} (dB)
120	12:07:18	265	85	0.7	90	$0.9*V_H$	2.5
121	12:10:49	302	95	0.0	90	$0.9*V_H$	2.5
122	12:14:24	273	88	0.0	90	$0.9*V_H$	2.5
132	12:24:04	368	79	3.3	81	$0.8*V_H$	3.0
133	12:28:50	498	76	-0.5	81	$0.8*V_H$	3.0
134	12:32:49	353	78	-2.7	81	$0.8*V_H$	3.0
142	12:44:49	353	59	-1.5	72	$0.7*V_H$	3.5
150	12:52:07	368	54	-0.1	63	$0.6*V_H$	4.1
151	12:56:13	554	53	1.2	63	$0.6*V_H$	4.1
154	13:07:13	350	54	1.6	63	$0.6*V_H$	4.1
160	13:10:21	383	49	0.0	54	$0.5*V_H$	4.7
162	13:20:21	271	52	-1.0	54	$0.5*V_H$	4.7
180	13:01:20	84	66	-0.2	72	$0.7*V_H$	3.5
183	13:09:50	89	79	-1.4	72	$0.7*V_H$	3.5
184	13:12:33	82	66	-0.3	72	$0.7*V_H$	3.5
213	13:38:16	287	41	9.6	53	$1.0*V_Y$	4.8
214	13:41:58	373	53	5.7	53	$1.0*V_Y$	4.8
217	13:53:30	418	53	9.2	53	$1.0*V_Y$	4.8
314	14:30:03	512	58	-1.7	53	$1.0*V_Y$	4.8
322	11:49:27	242	36	-7.0	53	$1.0*V_Y$	4.8
323	11:54:30	459	36	-5.7	53	$1.0*V_Y$	4.8
330	12:01:39	534	39	-9.4	53	$1.0*V_Y$	4.8
331	12:07:58	708	37	-10.9	53	$1.0*V_Y$	4.8
332	12:14:58	708	38	-11.1	53	$1.0*V_Y$	4.8
342	12:42:41	286	36	-11.2	53	$1.0*V_Y$	4.8
344	12:54:49	381	45	-7.0	53	$1.0*V_Y$	4.8
350	13:18:50	311	62	-7.1	50	$1.0*V_Y$	4.8
351	13:22:47	126	39	-4.1	50	$1.0*V_Y$	4.8
352	13:27:34	219	38	-9.9	50	$1.0*V_Y$	4.8

APPENDIX E: AIRCRAFT NOISE-POWER-DISTANCE TABLES

Appendix E presents left-side, center, and right-side (relative to the direction of travel) NPDs for all measured aircraft. Hover tabular data are presented for the helicopters. Though the INM 6.0 Series uses a single NPD set (centerline) to model propeller-driven aircraft, the sideline NPDs are presented for completeness and in the event a future release of the INM may utilize sideline NPDs in its calculations. The helicopter noise calculation methodology to be included in the INM 7.0 Series utilizes centerline and sideline NPDs to account for directivity. Tables 13, 14, and 15 in Section 4.0 present the specific flight parameters for each series. Data presented include tabular NPD results generated for four noise metrics: sound exposure level (SEL), denoted by the symbol L_{AE}, maximum, slow, A-weighted sound level (MXSA), denoted by the symbol L_{ASmx}, effective perceived noise level (EPNL), denoted by the symbol L_{EPN}, and tone-adjusted maximum, slow, perceived noise level (MXSPNT), denoted by the symbol L_{PNTSmx}. If the noise from a prescribed study series was not collected or could not be used in the data processing, the missing data are indicated with "ND" (No Data) in the tables. If the noise from a study series was not applicable to a particular aircraft, the missing data is indicated with "NA" (Not Applicable) in the tables. Each aircraft's reference speeds (RS) are also noted in the tables. All speeds are in kts.

E.1 Dynamic Operations Noise-Power-Distance Tables

E.1.1 Maule M-7-235C

As discussed in Section 6.1.3, weather conditions during the Maule study resulted in only two measurement series being completed for this aircraft.

Table E-1. Maule L_{AE} NPDs.

Maule

L_{AE}	300 Series (RS=87)			400 Series (RS=70)			500 Series			600 Series			700 Series		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	87.4	88.0	86.3	80.0	80.7	79.4	ND	ND	ND	ND	ND	ND	ND	ND	ND
400	83.6	83.6	82.3	76.1	77.0	75.6	ND	ND	ND	ND	ND	ND	ND	ND	ND
630	80.9	80.5	79.6	73.5	74.4	73.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
1000	78.0	77.2	76.5	70.6	71.5	70.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
2000	73.1	71.7	71.4	66.0	66.9	65.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
4000	67.6	65.6	65.7	60.5	61.9	59.9	ND	ND	ND	ND	ND	ND	ND	ND	ND
6300	63.6	61.4	61.6	57.0	58.4	56.2	ND	ND	ND	ND	ND	ND	ND	ND	ND
10000	59.1	57.0	57.0	53.0	54.6	52.2	ND	ND	ND	ND	ND	ND	ND	ND	ND
16000	54.0	52.5	52.0	49.2	50.4	48.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
25000	48.5	48.0	47.0	45.9	46.5	44.2	ND	ND	ND	ND	ND	ND	ND	ND	ND

L_{AE}	800 Series			900 Series			1100 Series			1200 Series			2000 Series		
200	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
400	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
630	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
1000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
4000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
6300	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
16000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
25000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table E-2. Maule L_{ASmx} NPDs.

Maule

L_{ASmx}	300 Series (RS=87)			400 Series (RS=70)			500 Series			600 Series			700 Series		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	84.5	83.9	82.2	75.6	76.1	74.7	ND	ND	ND	ND	ND	ND	ND	ND	ND
400	77.9	76.8	75.6	69.0	69.6	68.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
630	73.4	71.9	71.0	64.6	65.1	63.6	ND	ND	ND	ND	ND	ND	ND	ND	ND
1000	68.7	66.8	66.2	60.0	60.4	58.8	ND	ND	ND	ND	ND	ND	ND	ND	ND
2000	61.2	58.7	58.5	52.8	53.0	51.4	ND	ND	ND	ND	ND	ND	ND	ND	ND
4000	53.2	50.2	50.1	45.3	45.2	43.6	ND	ND	ND	ND	ND	ND	ND	ND	ND
6300	47.6	44.5	44.2	40.2	39.9	38.2	ND	ND	ND	ND	ND	ND	ND	ND	ND
10000	41.4	38.4	37.8	34.7	34.4	32.4	ND	ND	ND	ND	ND	ND	ND	ND	ND
16000	34.4	31.8	30.9	28.5	28.6	26.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
25000	27.0	24.9	24.0	22.0	22.8	19.6	ND	ND	ND	ND	ND	ND	ND	ND	ND

L_{ASmx}	300 Series			400 Series			1100 Series			1200 Series			2000 Series		
200	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
400	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
630	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
1000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
4000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
6300	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
16000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
25000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table E-3. Maule L_{EPN} NPDs.

Maule

L_{EPN}	300 Series (RS=87)			400 Series (RS=70)			500 Series			600 Series			700 Series		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	92.4	93.7	91.2	86.2	87.8	85.3	ND	ND	ND	ND	ND	ND	ND	ND	ND
400	88.1	89.0	86.9	82.1	83.8	80.9	ND	ND	ND	ND	ND	ND	ND	ND	ND
630	85.1	85.5	83.7	79.1	80.7	77.9	ND	ND	ND	ND	ND	ND	ND	ND	ND
1000	81.6	81.7	80.1	75.4	77.4	74.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
2000	76.0	75.4	74.1	69.4	71.7	68.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
4000	69.4	68.0	67.2	62.3	64.6	61.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
6300	64.3	62.5	61.8	56.8	59.1	55.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
10000	58.5	55.7	55.1	50.1	52.3	47.6	ND	ND	ND	ND	ND	ND	ND	ND	ND
16000	50.8	46.7	46.6	41.6	43.1	37.9	ND	ND	ND	ND	ND	ND	ND	ND	ND
25000	40.2	35.4	35.1	31.1	32.8	26.7	ND	ND	ND	ND	ND	ND	ND	ND	ND

L_{EPN}	800 Series			900 Series			1100 Series			1200 Series			2000 Series		
200	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
400	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
630	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
1000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
4000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
6300	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
16000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
25000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table E-4. Maule L_{PNTSmx} NPDs.

Maule

L_{PNTSmx}	300 Series (RS=87)			400 Series (RS=70)			500 Series			600 Series			700 Series		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	99.8	100.3	97.5	93.0	94.7	91.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
400	93.0	93.2	90.5	86.3	88.0	84.3	ND	ND	ND	ND	ND	ND	ND	ND	ND
630	88.4	88.2	85.5	81.6	83.1	79.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
1000	83.3	82.7	80.2	76.5	77.9	74.3	ND	ND	ND	ND	ND	ND	ND	ND	ND
2000	75.1	73.7	71.7	68.2	69.4	65.9	ND	ND	ND	ND	ND	ND	ND	ND	ND
4000	65.9	63.8	62.2	58.6	59.6	56.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
6300	59.1	56.6	55.1	51.6	52.7	48.9	ND	ND	ND	ND	ND	ND	ND	ND	ND
10000	51.6	48.6	47.0	43.6	44.4	40.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
16000	42.3	38.4	37.0	33.8	33.8	28.8	ND	ND	ND	ND	ND	ND	ND	ND	ND
25000	30.2	27.2	24.8	21.7	22.3	16.0	ND	ND	ND	ND	ND	ND	ND	ND	ND

L_{PNTSmx}	800 Series			900 Series			1100 Series			1200 Series			2000 Series		
200	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
400	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
630	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
1000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
4000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
6300	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
16000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
25000	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA

E.1.2 Piper Twin Comanche PA-30

Table E-5. PA-30 L_{AE} NPDs.

PA-30

L_{AE}	300 Series (RS=165)			400 Series (RS=135)			500 Series (RS=97)			600 Series (RS=100)			700 Series (RS=96)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	93.2	93.7	89.3	90.6	91.0	86.1	99.1	101.0	98.0	80.6	84.3	83.3	82.5	82.3	82.0
400	88.0	88.8	86.2	85.9	86.6	83.8	95.3	96.6	94.1	77.6	80.4	79.3	78.6	78.4	77.9
630	84.6	85.6	83.2	82.8	83.5	81.0	92.4	93.6	91.1	75.1	77.8	76.7	75.8	75.7	75.1
1000	81.1	82.1	79.5	79.4	80.3	77.6	89.2	90.2	87.8	72.3	74.9	73.9	72.8	72.9	72.2
2000	75.5	76.5	73.3	73.9	75.0	71.9	83.7	84.7	82.3	67.4	70.2	69.3	67.8	68.2	67.4
4000	69.5	70.3	66.4	67.8	69.0	65.4	77.6	78.3	76.0	61.7	64.9	64.1	62.0	62.8	62.1
6300	65.2	65.7	61.3	63.4	64.7	60.5	73.0	73.6	71.3	57.2	60.9	60.1	57.7	58.8	58.3
10000	60.4	60.5	55.4	58.6	59.6	55.2	67.8	68.3	65.9	52.3	56.4	55.6	53.0	54.2	54.0
16000	55.1	54.6	48.9	53.3	53.7	49.7	61.9	62.2	59.7	47.2	51.2	50.5	48.1	49.0	49.3
25000	49.3	48.4	42.7	47.9	47.9	44.5	55.6	55.7	53.2	42.4	46.1	45.6	43.4	44.3	45.1

L_{AE}	800 Series (RS=87)			900 Series (RS=97)			1100 Series			1200 Series			2000 Series		
200	85.6	86.2	84.0	100.0	101.2	100.0	NA	NA	NA	NA	NA	NA	NA	NA	NA
400	81.8	82.4	80.3	95.7	96.8	95.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
630	79.1	79.7	77.7	92.3	93.7	92.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
1000	76.2	76.8	74.7	88.7	90.3	88.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	71.1	71.8	69.9	82.9	84.7	83.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
4000	65.2	65.7	64.1	76.3	78.4	76.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
6300	60.7	61.2	59.8	71.5	73.8	72.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	55.7	56.1	55.1	66.0	68.5	66.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
16000	50.4	50.6	50.0	59.8	62.5	60.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
25000	46.0	45.5	45.7	53.0	56.2	54.5	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table E-6. PA-30 L_{ASmx} NPDs.

PA-30

L_{ASmx}	300 Series (RS=165)			400 Series (RS=135)			500 Series (RS=97)			600 Series (RS=100)			700 Series (RS=96)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	89.0	89.5	94.0	86.0	86.6	88.9	98.0	96.1	95.1	79.7	79.0	77.9	77.4	76.3	75.7
400	81.8	82.6	85.0	78.7	79.8	80.8	90.5	89.0	87.8	72.6	72.6	71.5	70.4	69.8	69.3
630	76.9	77.8	79.0	74.1	75.1	75.3	85.2	84.0	82.8	67.7	68.2	67.2	65.7	65.5	65.0
1000	71.7	72.7	72.6	69.4	70.0	69.5	79.5	78.6	77.4	62.7	63.6	62.7	60.8	60.9	60.4
2000	63.9	64.6	62.5	61.8	62.5	60.4	70.8	70.2	68.9	54.9	56.4	55.7	53.0	53.7	53.3
4000	55.7	56.2	52.2	53.6	54.3	50.7	61.8	61.5	59.8	46.0	48.5	48.0	44.5	45.7	45.6
6300	49.9	50.1	45.0	47.9	48.3	43.9	55.6	55.3	53.5	39.4	43.0	42.6	38.5	40.0	40.2
10000	43.7	43.4	37.1	41.8	41.6	36.4	49.0	48.3	46.5	32.0	36.8	36.5	31.9	33.7	34.2
16000	36.8	35.8	28.2	35.1	34.2	27.8	41.6	40.5	38.7	23.9	30.0	29.8	24.5	26.6	27.4
25000	29.5	28.1	19.5	28.2	26.7	19.3	33.6	32.3	30.8	17.0	22.9	22.7	17.7	19.5	20.4

L_{ASmx}	800 Series (RS=87)			900 Series (RS=97)			1100 Series			1200 Series			2000 Series		
200	80.4	79.8	78.6	99.3	95.9	94.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
400	73.9	73.3	72.1	91.1	88.9	87.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
630	69.5	68.9	67.7	85.2	84.1	82.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
1000	64.8	64.3	63.1	79.2	78.9	77.0	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	57.1	56.8	55.7	70.4	70.6	68.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
4000	48.4	48.3	47.5	61.4	61.7	59.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
6300	42.1	42.1	41.6	55.0	55.5	53.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	35.4	35.3	35.3	48.2	48.7	47.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
16000	28.2	28.0	28.4	40.5	41.1	39.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
25000	21.0	20.6	21.4	32.1	33.1	32.1	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table E-7. PA-30 L_{EPN} NPDs.

PA-30

L_{EPN}	300 Series (RS=165)			400 Series (RS=135)			500 Series (RS=97)			600 Series (RS=100)			700 Series (RS=96)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	98.1	98.0	95.1	95.5	95.4	91.3	103.9	105.0	102.6	84.9	88.0	87.0	87.0	85.7	86.1
400	92.3	92.7	91.3	90.3	90.5	88.5	99.7	100.3	98.1	81.3	83.7	82.5	82.4	81.4	81.4
630	88.6	89.0	87.6	86.7	87.1	85.0	96.3	96.9	94.6	78.2	80.8	79.6	79.1	78.3	78.1
1000	84.5	84.9	82.8	82.4	83.3	80.6	92.5	92.9	90.7	74.8	77.6	76.4	75.4	75.1	74.7
2000	78.1	78.2	75.1	76.1	76.9	73.8	86.3	86.7	84.3	68.7	72.4	70.9	69.3	69.6	68.9
4000	71.1	71.4	66.9	69.0	70.2	65.7	79.3	79.9	77.2	61.0	65.9	64.1	61.5	63.0	61.7
6300	66.0	66.2	60.5	63.6	64.9	59.4	74.1	75.0	71.7	54.3	60.8	58.6	55.0	57.5	55.8
10000	59.8	59.8	52.3	57.4	58.3	51.3	68.2	69.1	65.3	45.5	53.9	51.7	46.9	49.7	48.7
16000	52.3	50.8	39.9	49.8	49.9	39.5	60.8	61.1	57.4	30.8	45.1	43.1	34.7	39.8	39.3
25000	42.1	40.0	19.0	39.5	39.0	20.9	51.1	51.0	47.0	16.8	32.6	30.1	23.0	26.5	24.3

L_{EPN}	800 Series (RS=87)			900 Series (RS=97)			1100 Series			1200 Series			2000 Series		
200	89.0	89.5	87.5	104.9	105.4	104.2	NA	NA	NA	NA	NA	NA	NA	NA	NA
400	84.7	85.3	83.3	100.2	100.5	99.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
630	81.6	82.3	80.3	96.2	97.0	95.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
1000	78.2	79.0	77.1	91.7	93.0	91.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	72.6	73.2	71.4	84.9	86.9	84.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
4000	65.6	66.3	64.5	77.6	80.1	77.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
6300	59.7	60.8	58.7	72.2	75.2	72.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	52.2	53.0	51.2	66.0	69.6	66.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
16000	42.3	42.9	41.5	57.9	61.9	58.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
25000	26.2	29.2	26.2	46.8	52.3	48.9	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table E-8. PA-30 L_{PNTSmx} NPDs.

PA-30

L_{PNTSmx}	300 Series (RS=165)			400 Series (RS=135)			500 Series (RS=97)			600 Series (RS=100)			700 Series (RS=96)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	104.3	104.4	110.9	101.5	101.5	105.5	113.5	111.1	110.6	95.1	93.7	92.4	91.5	90.3	89.5
400	96.9	97.1	101.6	94.0	94.4	96.6	105.8	103.8	102.8	86.7	87.1	85.7	84.0	83.6	82.7
630	91.8	91.9	94.4	89.0	89.2	89.8	100.3	98.5	97.2	81.5	82.5	81.1	78.8	78.9	78.1
1000	86.5	86.1	86.7	84.0	83.4	83.0	94.2	92.5	90.9	75.8	77.6	76.3	73.4	73.9	73.2
2000	78.3	77.2	75.7	75.8	75.3	72.9	85.1	83.3	81.7	66.6	69.6	68.3	64.7	65.9	65.2
4000	69.0	68.0	64.4	66.6	66.3	62.0	75.2	73.6	71.9	55.9	60.6	59.2	54.4	56.7	56.1
6300	62.2	61.3	56.4	59.8	59.5	54.0	68.3	67.1	64.9	47.5	54.1	52.5	46.3	50.1	49.1
10000	54.6	54.2	46.9	52.4	51.9	44.4	60.8	60.0	57.2	36.7	45.9	44.3	36.7	40.6	40.4
16000	46.2	43.9	32.7	43.7	42.3	31.5	52.0	50.0	48.1	21.3	35.8	34.3	24.0	29.8	29.9
25000	35.0	32.3	12.5	32.0	30.4	11.3	41.3	38.6	36.4	2.6	22.4	21.2	7.0	10.5	14.6

L_{PNTSmx}	800 Series (RS=87)			900 Series (RS=97)			1100 Series			1200 Series			2000 Series		
200	93.3	92.9	92.1	114.8	111.3	109.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
400	86.5	86.1	85.2	106.6	104.1	102.2	NA	NA	NA	NA	NA	NA	NA	NA	NA
630	81.7	81.4	80.5	100.3	99.0	96.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
1000	76.7	76.4	75.5	93.3	93.3	90.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	68.5	68.2	67.6	84.2	84.1	81.0	NA	NA	NA	NA	NA	NA	NA	NA	NA
4000	58.7	58.9	58.1	74.1	74.5	71.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
6300	51.3	51.9	51.2	67.1	67.9	64.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	42.6	43.0	42.7	59.4	60.9	57.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
16000	31.8	31.8	31.8	50.1	51.3	48.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
25000	16.1	14.8	16.6	37.8	40.4	38.0	NA	NA	NA	NA	NA	NA	NA	NA	NA

E.1.3 Piper Navajo Chieftain PA-31-350

Table E-9. PA-31 L_{AE} NPDs.

PA-31

L_{AE}	300 Series (RS=156)			400 Series (RS=155)			500 Series (RS=105)			600 Series (RS=160)			700 Series (RS=150)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	89.5	89.6	89.9	86.4	87.9	87.9	94.4	94.9	94.0	85.4	86.8	85.2	84.6	85.5	84.1
400	85.7	85.7	85.4	82.8	84.2	84.2	90.7	91.3	90.5	82.0	83.2	81.7	81.4	81.9	80.6
630	83.1	83.0	82.6	80.3	81.7	81.5	88.3	88.8	88.1	79.7	80.9	79.4	78.9	79.5	78.3
1000	80.4	80.3	79.9	77.8	79.0	78.9	85.8	86.1	85.5	77.3	78.4	77.0	76.5	77.1	75.9
2000	76.0	75.8	75.5	73.5	74.5	74.6	81.6	81.8	81.3	73.4	74.4	73.1	72.5	73.1	71.9
4000	71.2	71.0	70.6	68.8	69.6	69.8	76.9	76.9	76.5	68.9	69.8	68.6	67.9	68.7	67.4
6300	67.6	67.5	67.0	65.1	66.1	66.3	73.3	73.2	72.9	65.4	66.4	65.1	64.4	65.5	63.9
10000	63.5	63.6	62.7	61.2	62.3	62.3	68.9	69.1	68.7	61.3	62.5	61.0	60.3	61.7	59.8
16000	58.6	59.2	57.7	56.4	58.1	57.6	63.6	64.2	63.6	56.1	58.0	56.2	55.3	57.4	54.9
25000	53.2	54.4	52.1	51.1	53.4	52.4	57.2	59.0	58.0	50.1	53.2	50.8	49.6	52.7	49.7

L_{AE}	800 Series (RS=120)			900 Series (RS=105)			1100 Series			1200 Series			2000 Series		
200	88.6	89.0	87.5	96.4	96.0	95.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
400	85.2	85.4	84.0	92.7	92.4	91.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
630	82.4	83.0	81.6	90.2	89.9	89.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
1000	79.7	80.4	79.1	87.5	87.3	86.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	75.5	76.4	75.1	83.1	83.1	82.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
4000	70.7	71.8	70.6	78.0	78.5	77.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
6300	67.2	68.5	67.1	74.2	75.0	74.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	62.9	64.6	63.1	69.6	71.2	69.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
16000	57.8	60.2	58.1	64.1	66.6	65.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
25000	52.0	55.1	52.4	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table E-10. PA-31 L_{ASmx} NPDs.

PA-31

L_{ASmx}	300 Series (RS=156)			400 Series (RS=155)			500 Series (RS=105)			600 Series (RS=160)			700 Series (RS=150)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	88.5	88.2	87.9	85.0	85.9	86.6	92.6	92.1	92.6	86.9	86.9	86.0	85.4	85.1	84.4
400	82.0	81.7	81.4	78.6	79.4	79.9	86.2	85.7	86.2	80.6	80.5	79.7	79.1	78.8	78.1
630	77.7	77.4	77.1	74.3	75.0	75.6	81.9	81.3	81.9	76.5	76.3	75.5	74.9	74.6	73.9
1000	73.1	72.8	72.5	69.8	70.5	71.1	77.5	76.7	77.4	72.1	71.9	71.2	70.6	70.2	69.6
2000	66.0	65.7	65.4	62.8	63.4	64.1	70.5	69.4	70.4	65.4	65.0	64.3	63.8	63.4	62.7
4000	58.5	58.1	57.7	55.3	56.0	56.6	62.9	61.7	62.7	58.0	57.6	56.8	56.4	56.2	55.2
6300	53.1	53.0	52.3	50.1	51.0	51.4	57.4	56.2	57.2	52.7	52.3	51.4	51.0	51.1	49.7
10000	47.2	47.4	46.3	44.3	45.6	45.8	51.1	50.3	51.1	46.6	46.5	45.3	44.9	45.4	43.6
16000	40.6	41.4	39.5	37.8	39.7	39.4	43.8	43.8	44.2	39.4	40.1	38.7	37.9	39.2	36.9
25000	33.6	35.0	32.4	30.6	33.6	32.8	35.8	37.0	36.8	31.5	33.4	31.8	30.2	32.5	29.9

L_{ASmx}	800 Series (RS=120)			900 Series (RS=105)			1100 Series			1200 Series			2000 Series		
200	86.6	86.3	86.0	95.7	94.7	94.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
400	80.2	79.9	79.2	89.2	88.3	88.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
630	76.0	75.7	75.0	84.9	84.0	83.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
1000	71.5	71.2	70.6	80.3	79.5	79.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	64.5	64.2	63.7	73.0	72.5	72.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
4000	56.9	56.8	56.3	65.0	65.1	64.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
6300	51.4	51.6	50.9	59.1	59.8	59.0	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	45.3	45.9	44.9	52.5	54.0	52.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
16000	38.2	39.5	37.9	45.1	47.4	46.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
25000	30.7	32.7	30.3	37.3	40.4	39.6	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table E-11. PA-31 L_{EPN} NPDs.

PA-31

L_{EPN}	300 Series (RS=156)			400 Series (RS=155)			500 Series (RS=105)			600 Series(RS=160)			700 Series(RS=150)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	94.9	95.5	95.2	92.2	94.0	93.7	99.7	101.0	99.5	90.5	92.6	90.2	90.0	91.7	89.4
400	90.8	91.5	90.4	88.1	90.1	89.7	95.8	97.2	95.8	86.8	88.8	86.4	85.9	87.9	85.6
630	88.0	88.8	87.3	85.4	87.3	86.7	93.2	94.6	93.3	84.3	86.2	83.8	83.2	85.4	82.9
1000	85.0	85.7	84.1	82.3	84.4	83.6	90.3	91.7	90.4	81.4	83.5	80.9	80.3	82.5	80.0
2000	79.7	80.6	78.9	77.0	79.2	78.3	85.5	86.7	85.6	76.8	78.6	76.2	75.5	77.6	75.1
4000	73.6	74.7	72.8	70.8	73.4	72.4	79.7	80.7	79.7	71.2	72.9	70.5	69.7	71.9	69.2
6300	69.1	70.4	68.2	66.1	69.0	67.9	75.2	76.3	75.4	66.8	68.7	66.1	65.2	67.6	64.8
10000	63.7	65.4	62.8	60.6	64.1	62.7	69.9	71.1	70.3	61.6	63.6	61.0	59.8	62.5	59.5
16000	57.3	58.7	55.5	53.8	57.3	55.4	63.5	64.8	63.9	55.1	57.6	54.5	52.9	56.3	52.7
25000	49.4	51.2	47.1	45.1	49.8	46.9	55.3	57.4	56.1	45.7	49.5	45.9	43.4	48.0	43.4

L_{EPN}	800 Series (RS=120)			900 Series (RS=105)			1100 Series			1200 Series			2000 Series		
200	93.6	95.1	92.5	101.3	102.0	101.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
400	90.6	91.4	88.8	97.4	98.2	97.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
630	87.4	88.8	86.1	94.8	95.7	95.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
1000	84.2	86.0	83.3	91.8	92.9	92.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	79.3	80.9	78.3	86.8	88.2	87.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
4000	73.4	75.1	72.4	80.7	82.4	81.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
6300	68.7	70.9	68.0	76.1	78.2	77.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	63.2	65.8	62.7	70.7	73.4	72.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
16000	56.4	59.3	56.2	64.4	67.4	66.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
25000	47.3	51.2	47.4	56.6	60.8	59.6	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table E-12. PA-31 L_{PNTSmx} NPDs.

PA-31

L_{PNTSmx}	300 Series (RS=156)			400 Series (RS=155)			500 Series (RS=105)			600 Series(RS=160)			700 Series(RS=150)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	104.4	105.1	103.4	100.7	103.1	102.7	107.8	108.4	108.2	101.9	102.5	101.0	100.8	101.2	99.4
400	97.9	98.6	96.8	94.1	96.6	96.2	101.2	101.8	101.6	95.5	96.1	94.5	93.6	94.8	92.9
630	93.4	94.2	92.3	89.4	92.2	91.9	96.8	97.4	97.2	91.1	91.7	90.1	89.2	90.4	88.5
1000	88.7	89.6	87.5	84.7	87.4	87.2	92.1	92.7	92.5	86.5	87.2	85.4	84.5	85.8	83.9
2000	80.8	81.9	79.5	76.6	79.7	78.8	84.5	85.1	84.9	79.1	79.5	77.7	77.0	78.1	76.2
4000	72.0	73.2	70.7	67.9	71.1	70.1	75.9	76.3	76.2	70.7	71.0	69.1	68.5	69.6	67.5
6300	65.7	67.2	64.5	61.5	65.0	63.9	69.6	70.0	70.1	64.6	64.9	63.0	62.3	63.5	61.4
10000	58.7	60.7	57.6	54.3	58.7	57.3	62.5	63.1	63.3	57.5	58.1	56.2	55.1	56.7	54.5
16000	50.8	52.3	48.9	46.0	50.4	48.5	54.4	55.2	55.2	49.2	50.4	48.5	46.6	48.9	46.5
25000	41.5	43.6	39.3	36.0	41.4	38.9	44.9	46.4	46.2	38.2	40.8	38.7	35.5	39.2	36.0

L_{PNTSmx}	800 Series (RS=120)			900 Series (RS=105)			1100 Series			1200 Series			2000 Series		
200	102.2	102.7	101.4	110.5	110.8	110.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
400	95.4	96.2	94.0	103.9	104.3	104.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
630	91.0	91.8	89.6	99.5	99.9	99.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
1000	86.2	87.2	84.9	94.7	95.2	95.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	78.5	79.3	77.2	86.9	87.8	87.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
4000	69.8	70.7	68.5	78.0	79.3	79.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
6300	63.3	64.4	62.3	71.6	73.1	72.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	55.9	57.6	55.0	64.4	66.5	66.2	NA	NA	NA	NA	NA	NA	NA	NA	NA
16000	47.7	49.1	46.7	56.2	58.9	58.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
25000	37.2	39.0	36.0	46.7	50.6	50.3	NA	NA	NA	NA	NA	NA	NA	NA	NA

E.1.4 Piper Warrior PA-28-161

Table E-13. PA-28 L_{AE} NPDs.

PA-28

L_{AE}	300 Series (RS=105)			400 Series (RS=95)			500 Series (RS=79)			600 Series (RS=100)			700 Series (RS=80)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	85.7	86.5	85.6	81.4	82.7	82.2	89.8	90.9	89.6	75.4	76.1	74.9	73.1	73.5	73.0
400	82.1	82.9	81.9	77.8	79.1	78.5	86.1	87.2	85.9	72.1	72.6	71.6	69.8	70.1	69.5
630	79.5	80.3	79.2	75.2	76.5	75.7	83.4	84.5	83.1	69.6	70.1	69.1	67.4	67.6	67.0
1000	76.6	77.3	76.3	72.3	73.7	72.7	80.3	81.5	80.0	66.9	67.3	66.3	64.4	65.0	64.2
2000	72.0	72.5	71.3	67.4	68.8	67.5	75.3	76.5	74.8	62.2	62.7	61.5	59.6	60.7	59.2
4000	66.8	67.0	65.7	62.0	63.2	61.5	69.8	70.9	69.0	57.0	57.5	56.1	54.7	56.0	54.2
6300	63.0	63.1	61.6	58.1	59.2	57.1	65.9	67.0	64.9	53.1	53.8	52.2	51.2	52.6	50.6
10000	58.7	58.7	57.0	53.9	54.9	52.3	61.6	62.6	60.3	48.9	49.9	48.0	47.5	49.0	47.0
16000	53.6	53.6	51.7	49.2	50.3	47.3	56.6	57.5	55.1	44.8	45.8	44.1	44.4	45.3	43.3
25000	48.2	48.3	46.3	45.1	45.9	42.5	51.3	51.9	49.6	41.0	42.0	40.4	41.5	41.9	39.8

L_{AE}	800 Series (RS=70)			900 Series (RS=87)			1100 Series (RS=105)			1200 Series (RS=105)			2000 Series (RS=105)		
200	72.9	72.6	72.3	91.8	92.0	89.9	82.9	82.4	81.8	84.1	84.6	82.9	85.7	85.1	84.8
400	69.6	69.2	69.1	88.0	88.2	86.1	78.9	77.8	77.8	79.9	80.5	78.8	81.9	81.2	81.0
630	66.9	66.4	66.4	85.3	85.5	83.4	76.0	74.6	74.9	77.0	77.6	75.9	79.2	78.5	78.2
1000	63.6	63.8	63.7	82.3	82.5	80.5	72.8	71.2	71.8	73.8	74.4	72.7	76.2	75.4	75.2
2000	59.0	59.6	59.3	77.3	77.4	75.5	67.8	65.6	66.4	68.6	69.2	67.4	71.4	70.4	70.1
4000	53.6	54.9	54.2	71.7	71.7	69.8	62.5	59.4	60.4	63.0	63.4	61.5	66.4	64.9	64.7
6300	50.1	51.6	50.7	67.5	67.5	65.6	58.9	54.8	56.2	59.1	59.3	57.4	62.8	60.9	60.8
10000	46.6	48.1	47.1	62.9	62.9	60.9	55.1	49.9	51.7	54.8	54.9	52.7	58.9	56.6	56.7
16000	42.9	44.9	43.4	57.6	57.6	55.4	51.0	44.8	47.2	49.8	49.8	47.4	54.3	51.8	52.0
25000	39.4	41.8	39.9	ND	ND	ND	47.0	40.0	43.0	44.8	45.2	42.4	49.3	46.8	47.1

Table E-14. PA-28 L_{ASmx} NPDs.

PA-28

L_{ASmx}	300 Series (RS=105)			400 Series (RS=95)			500 Series (RS=79)			600 Series (RS=100)			700 Series (RS=80)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	83.0	83.5	83.4	78.4	79.8	78.8	86.4	87.3	86.7	71.5	72.1	70.6	69.0	68.1	67.1
400	76.4	76.9	76.7	71.8	73.1	72.1	79.7	80.7	79.9	65.1	65.6	64.1	61.8	61.7	60.7
630	72.0	72.3	72.1	67.3	68.6	67.4	75.1	76.1	75.2	60.7	61.2	59.7	57.0	57.4	56.4
1000	67.2	67.5	67.2	62.5	63.9	62.4	70.3	71.2	70.2	56.1	56.6	55.0	52.0	52.9	51.8
2000	59.7	59.8	59.4	54.9	56.2	54.3	62.7	63.5	62.1	48.6	49.3	47.6	44.3	45.9	44.6
4000	51.8	51.6	51.1	46.7	47.9	45.5	54.6	55.2	53.4	40.5	41.3	39.5	36.1	38.4	36.9
6300	46.2	45.9	45.3	41.0	42.2	39.3	49.1	49.4	47.5	34.8	35.8	33.9	30.5	33.2	31.7
10000	40.0	39.8	39.0	34.9	36.1	32.6	43.0	43.1	41.1	28.7	30.0	28.0	24.3	27.7	26.1
16000	33.0	33.0	31.9	28.2	29.7	25.4	36.3	36.1	34.0	22.2	23.9	21.9	18.0	21.9	20.4
25000	25.7	26.0	24.4	21.4	23.1	18.5	29.0	28.7	26.5	16.3	18.0	16.2	13.4	16.6	15.3

L_{ASmx}	800 Series (RS=70)			900 Series (RS=87)			1100 Series (RS=105)			1200 Series (RS=105)			2000 Series (RS=105)		
200	66.3	66.9	66.3	89.2	88.8	87.2	78.4	74.8	78.0	80.0	80.0	79.3	83.3	81.8	82.5
400	59.7	60.5	59.8	82.6	82.1	80.5	71.7	67.6	71.2	73.3	73.2	72.6	76.6	75.0	75.7
630	55.2	56.2	55.5	78.1	77.5	75.9	67.1	62.7	66.6	68.7	68.5	68.1	72.0	70.4	71.1
1000	50.4	51.7	51.0	73.2	72.6	71.0	62.2	57.4	61.6	63.9	63.5	63.2	67.2	65.5	66.1
2000	43.0	44.7	44.0	65.5	64.7	63.2	54.5	49.1	53.5	56.3	55.4	55.5	59.7	57.7	58.2
4000	35.1	37.2	36.6	57.1	56.2	54.7	46.4	40.3	44.7	48.3	46.9	47.2	51.8	49.4	50.0
6300	29.7	32.1	31.5	51.1	50.2	48.8	40.9	34.0	38.7	42.7	41.0	41.4	46.5	43.7	44.5
10000	24.0	26.7	26.0	44.5	43.8	42.2	35.1	27.0	32.3	36.6	34.7	35.1	40.7	37.6	38.6
16000	18.1	21.1	20.2	37.1	36.7	34.8	29.1	19.4	25.6	29.7	27.7	28.0	34.2	30.9	32.1
25000	13.3	16.0	15.2	29.3	29.3	27.0	23.2	11.9	19.2	22.8	20.7	21.0	27.3	24.0	25.2

Table E-15. PA-28 L_{EPN} NPDs.

PA-28

L_{EPN}	300 Series (RS=105)			400 Series (RS=95)			500 Series (RS=79)			600 Series (RS=100)			700 Series (RS=80)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	90.8	91.5	90.4	86.5	87.5	86.8	95.3	96.2	95.0	79.3	80.6	79.1	77.5	78.3	77.3
400	86.9	87.5	86.4	82.4	83.6	82.6	91.3	92.2	90.9	75.5	76.5	75.2	74.3	74.2	73.1
630	84.0	84.7	83.4	79.3	80.7	79.2	88.4	89.3	87.8	72.5	73.4	72.1	70.3	71.4	69.7
1000	80.8	81.4	79.9	75.8	77.5	75.5	85.0	86.0	84.2	69.3	70.2	68.7	67.0	68.1	66.3
2000	75.4	75.9	74.0	70.1	71.9	69.2	79.2	80.3	78.2	63.7	64.4	62.6	61.1	62.2	60.1
4000	68.8	69.3	66.9	62.9	65.1	61.4	72.7	73.8	71.2	55.8	56.9	54.2	53.1	54.4	51.6
6300	63.6	64.2	61.3	57.2	59.8	55.0	67.6	68.8	65.8	49.3	50.4	47.2	45.8	47.6	44.4
10000	57.3	57.9	54.3	49.9	53.1	46.8	61.6	63.0	59.4	41.2	42.7	38.4	37.6	39.4	35.5
16000	49.3	49.6	46.0	40.7	44.5	35.3	54.3	55.4	51.3	28.8	32.2	25.6	26.8	26.3	23.4
25000	38.5	38.7	34.4	27.4	33.3	22.3	44.7	45.8	40.8	16.9	22.2	13.5	16.5	13.9	12.0

L_{EPN}	800 Series (RS=70)			900 Series (RS=87)			1100 Series (RS=105)			1200 Series (RS=105)			2000 Series (RS=105)		
200	77.2	77.4	76.2	96.7	96.9	94.4	89.2	87.6	87.1	89.3	89.7	87.5	91.5	90.3	90.4
400	73.1	73.0	72.6	92.6	92.8	90.4	84.7	82.5	82.6	84.8	85.3	82.9	87.5	86.2	86.3
630	69.3	70.1	69.0	89.5	89.8	87.4	81.5	78.7	79.1	81.5	82.0	79.6	84.6	83.2	83.1
1000	65.3	67.0	65.4	86.2	86.4	84.0	77.9	74.6	75.3	78.0	78.4	76.0	81.3	79.7	79.6
2000	58.3	61.1	59.1	80.5	80.7	78.1	71.7	67.6	68.6	72.0	72.1	70.0	75.7	73.8	73.8
4000	49.7	53.7	50.6	73.9	74.1	71.3	64.5	58.7	60.5	64.7	64.7	62.6	69.1	66.9	66.9
6300	42.3	47.0	43.9	68.7	69.1	66.0	59.0	51.2	54.1	59.1	58.8	56.7	64.1	61.5	61.6
10000	33.3	38.8	35.3	62.7	63.0	59.8	52.2	41.2	46.2	52.0	51.6	49.3	58.3	55.1	55.2
16000	22.1	27.6	22.3	54.9	55.0	52.0	42.8	29.2	34.8	43.0	41.5	39.3	50.9	46.2	47.0
25000	11.4	17.0	9.9	45.1	44.9	41.5	30.7	17.9	24.2	30.1	28.1	24.1	41.4	35.0	36.2

Table E-16. PA-28 L_{PNTSmx} NPDs.

PA-28

L_{PNTSmx}	300 Series (RS=105)			400 Series (RS=95)			500 Series (RS=79)			600 Series (RS=100)			700 Series (RS=80)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	98.3	98.9	98.7	93.4	95.3	94.1	102.2	102.6	102.4	86.0	87.5	85.6	85.4	82.8	81.9
400	91.5	92.1	91.8	86.4	88.5	87.0	95.3	95.7	95.3	79.1	80.4	78.6	77.5	75.8	75.0
630	86.9	87.3	87.0	81.5	83.7	81.9	90.5	90.8	90.3	74.5	75.5	73.7	72.3	71.0	70.2
1000	81.8	82.1	81.6	76.1	78.7	76.3	85.4	85.7	84.9	69.4	70.4	68.5	66.6	66.0	65.2
2000	73.7	73.9	72.8	67.7	70.5	66.7	77.2	77.5	76.0	61.3	62.1	60.1	57.0	57.7	56.6
4000	64.4	64.7	63.3	58.1	61.0	56.4	68.2	68.4	66.4	51.2	52.2	49.8	45.9	47.5	46.0
6300	57.5	57.8	56.1	50.9	54.1	48.6	61.5	61.6	59.2	43.2	44.0	41.1	36.2	39.1	37.2
10000	49.8	50.1	47.9	42.3	45.9	38.8	54.0	54.1	51.3	33.7	35.0	31.2	24.7	29.5	27.2
16000	40.4	40.4	38.1	31.9	35.8	27.0	45.3	44.9	41.8	20.0	23.3	17.0	9.6	14.5	13.3
25000	28.6	28.1	26.2	16.8	23.2	8.7	34.4	33.9	30.3	5.6	6.5	1.8	2.0	1.7	1.7

L_{PNTSmx}	800 Series (RS=70)			900 Series (RS=87)			1100 Series (RS=105)			1200 Series (RS=105)			2000 Series (RS=105)		
200	81.8	83.0	81.9	103.5	104.1	102.1	95.1	90.4	93.5	95.3	95.3	93.9	99.3	96.8	98.6
400	74.6	76.0	74.9	96.6	97.1	95.1	87.9	82.8	86.3	88.2	88.1	86.8	92.5	89.9	91.5
630	69.6	71.3	70.1	91.9	92.3	90.2	82.8	77.2	81.2	83.2	83.0	81.8	87.9	85.1	86.6
1000	64.2	66.3	65.1	86.8	86.9	84.8	77.3	71.3	75.6	77.9	77.5	76.6	82.8	79.9	81.2
2000	55.0	57.8	56.6	78.6	78.3	76.1	68.6	61.7	66.0	69.5	68.5	68.2	74.5	71.5	72.8
4000	43.5	47.9	46.1	69.3	69.0	66.7	58.7	50.4	55.7	59.8	58.5	58.4	65.3	62.1	63.3
6300	34.2	39.3	37.3	62.4	62.1	59.6	51.7	41.2	48.0	52.6	51.3	51.1	58.5	55.1	56.3
10000	23.5	29.4	28.1	54.5	54.4	51.9	43.7	29.9	38.3	44.4	42.4	42.4	51.1	47.2	48.3
16000	10.0	16.0	13.8	45.5	45.0	42.5	32.5	17.2	26.5	33.9	31.1	31.0	42.5	37.0	38.6
25000	1.7	2.3	1.9	34.5	33.7	30.6	19.0	2.8	10.5	19.4	16.2	14.3	31.6	24.9	27.0

E.1.5 Beech 1900D

Table E-17. 1900D L_{AE} NPDs.

1900D

L_{AE}	300 Series (RS=220)			400 Series			500 Series (RS=160)			600 Series (RS=160)			700 Series (RS=130)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	90.9	91.4	91.2	NA	NA	NA	88.6	89.4	89.2	88.3	90.6	90.1	88.8	ND	93.8
400	87.2	87.6	87.4	NA	NA	NA	84.6	85.7	85.8	84.7	86.4	86.4	85.4	ND	89.0
630	84.5	84.9	84.8	NA	NA	NA	82.0	83.2	83.3	82.1	83.9	83.6	83.0	ND	86.1
1000	81.6	81.9	81.8	NA	NA	NA	79.3	80.5	80.6	79.3	81.0	80.7	80.3	ND	83.1
2000	76.6	77.0	76.8	NA	NA	NA	74.9	76.0	76.0	74.7	76.3	76.0	75.7	ND	78.5
4000	70.9	71.3	70.9	NA	NA	NA	70.0	70.9	70.8	69.2	70.7	70.4	70.3	ND	73.0
6300	66.6	67.1	66.4	NA	NA	NA	66.4	67.2	66.9	65.0	66.2	66.1	66.1	ND	68.8
10000	61.8	62.5	61.3	NA	NA	NA	62.4	63.1	62.5	60.0	60.9	60.9	61.1	ND	63.7
16000	56.2	57.4	55.5	NA	NA	NA	57.8	58.5	57.4	54.0	54.6	54.7	54.9	ND	57.4
25000	50.0	52.2	49.1	NA	NA	NA	52.8	53.7	51.7	47.4	48.2	47.9	48.3	ND	50.2

L_{AE}	800 Series (RS=115)			900 Series (RS=160)			1100 Series			1200 Series			2000 Series		
200	89.1	ND	92.3	87.7	ND	89.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
400	85.5	ND	88.1	84.0	ND	86.0	NA	NA	NA	NA	NA	NA	NA	NA	NA
630	83.1	ND	85.3	81.5	ND	83.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
1000	80.4	ND	82.4	78.7	ND	80.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	76.0	ND	77.8	74.3	ND	76.2	NA	NA	NA	NA	NA	NA	NA	NA	NA
4000	70.8	ND	72.4	69.4	ND	71.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
6300	66.7	ND	68.3	65.8	ND	67.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	61.7	ND	63.2	61.7	ND	63.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
16000	55.7	ND	57.1	57.1	ND	58.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
25000	49.2	ND	50.3	52.2	ND	52.5	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table E-18. 1900D L_{ASmx} NPDs.

1900D

L_{ASmx}	300 Series (RS=220)			400 Series			500 Series (RS=160)			600 Series (RS=160)			700 Series (RS=130)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	90.2	90.2	90.2	NA	NA	NA	87.2	87.9	88.8	85.9	87.8	88.2	85.7	ND	89.8
400	83.7	83.7	83.7	NA	NA	NA	80.8	81.5	82.3	79.4	81.2	81.6	79.3	ND	83.0
630	79.2	79.3	79.2	NA	NA	NA	76.5	77.2	77.9	75.0	76.8	77.1	75.0	ND	78.5
1000	74.5	74.6	74.5	NA	NA	NA	72.1	72.7	73.3	70.3	72.2	72.4	70.4	ND	73.9
2000	66.8	67.0	66.9	NA	NA	NA	65.1	65.7	66.0	63.0	64.9	64.8	63.2	ND	66.6
4000	58.4	58.8	58.4	NA	NA	NA	57.6	58.1	58.2	55.0	56.7	56.5	55.3	ND	58.5
6300	52.4	52.9	52.3	NA	NA	NA	52.4	52.7	52.7	49.2	50.6	50.5	49.5	ND	52.7
10000	45.9	46.7	45.6	NA	NA	NA	46.7	46.9	46.6	42.5	43.5	43.7	42.8	ND	45.9
16000	38.6	39.9	38.0	NA	NA	NA	40.5	40.5	39.7	34.9	35.4	35.8	35.1	ND	37.8
25000	30.9	33.2	30.0	NA	NA	NA	33.9	34.0	32.3	26.9	27.1	27.3	26.7	ND	28.9

L_{ASmx}	800 Series (RS=115)			900 Series (RS=160)			1100 Series			1200 Series			2000 Series		
200	85.7	ND	89.1	86.2	ND	88.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
400	79.2	ND	82.4	79.8	ND	82.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
630	74.9	ND	77.9	75.5	ND	78.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
1000	70.4	ND	73.3	71.1	ND	73.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	63.2	ND	66.1	64.1	ND	66.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
4000	55.4	ND	58.1	56.6	ND	59.0	NA	NA	NA	NA	NA	NA	NA	NA	NA
6300	49.7	ND	52.3	51.4	ND	53.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	43.3	ND	45.7	45.7	ND	47.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
16000	35.8	ND	37.8	39.4	ND	41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA
25000	27.8	ND	29.2	32.9	ND	33.7	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table E-19. 1900D L_{EPN} NPDs.

1900D

L_{EPN}	300 Series (RS=220)			400 Series			500 Series (RS=160)			600 Series (RS=160)			700 Series (RS=130)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	94.4	95.8	94.5	NA	NA	NA	94.9	95.0	93.8	91.4	93.8	93.4	92.1	ND	97.1
400	90.2	91.5	90.2	NA	NA	NA	90.6	91.1	90.2	87.2	89.2	89.5	88.2	ND	92.0
630	87.1	88.6	87.1	NA	NA	NA	87.7	88.3	87.6	84.4	86.3	86.4	85.4	ND	88.6
1000	83.7	85.4	83.5	NA	NA	NA	84.7	85.3	84.6	81.2	83.1	83.2	82.3	ND	85.3
2000	78.2	79.8	77.9	NA	NA	NA	79.7	80.3	79.4	75.8	77.7	77.7	77.0	ND	80.1
4000	71.6	73.3	71.3	NA	NA	NA	73.7	74.2	73.2	69.1	71.1	71.0	70.5	ND	73.7
6300	66.5	68.3	66.1	NA	NA	NA	69.2	69.6	68.4	64.0	66.0	65.8	65.4	ND	68.6
10000	60.7	62.7	59.9	NA	NA	NA	64.0	64.2	62.7	57.7	59.7	59.4	59.2	ND	62.4
16000	53.0	55.8	51.9	NA	NA	NA	57.8	57.8	55.8	49.2	51.2	50.8	50.8	ND	54.3
25000	43.3	47.4	41.8	NA	NA	NA	49.9	50.1	46.7	37.5	39.3	39.0	39.3	ND	42.7

L_{EPN}	800 Series (RS=115)			900 Series (RS=160)			1100 Series			1200 Series			2000 Series		
200	92.4	ND	97.1	93.6	ND	94.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
400	88.5	ND	92.1	89.6	ND	90.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
630	85.7	ND	88.7	86.8	ND	87.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
1000	82.7	ND	85.2	83.8	ND	84.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	77.6	ND	80.0	78.6	ND	79.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
4000	71.0	ND	73.7	72.5	ND	73.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
6300	66.0	ND	68.6	68.0	ND	68.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	59.9	ND	62.2	62.7	ND	63.2	NA	NA	NA	NA	NA	NA	NA	NA	NA
16000	51.8	ND	54.1	56.2	ND	56.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
25000	40.1	ND	42.4	48.0	ND	47.7	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table E-20. 1900D L_{PNTSmx} NPDs.

1900D

L_{PNTSmx}	300 Series (RS=220)			400 Series			500 Series (RS=160)			600 Series (RS=160)			700 Series (RS=130)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	103.9	105.2	103.4	NA	NA	NA	104.5	104.3	104.6	99.1	101.3	101.6	99.4	ND	103.6
400	97.2	98.6	96.6	NA	NA	NA	98.0	97.8	98.0	92.3	94.6	94.9	92.8	ND	96.6
630	92.4	94.1	91.9	NA	NA	NA	93.6	93.4	93.4	87.7	90.0	90.3	88.2	ND	92.0
1000	87.3	89.2	86.9	NA	NA	NA	88.9	88.6	88.5	82.8	85.1	85.3	83.3	ND	87.1
2000	79.2	81.0	78.6	NA	NA	NA	81.4	81.0	80.6	74.7	77.1	77.2	75.4	ND	79.1
4000	70.0	71.8	69.3	NA	NA	NA	72.7	72.2	71.6	65.6	67.9	67.9	66.4	ND	70.1
6300	63.2	65.3	62.5	NA	NA	NA	66.4	65.9	65.2	58.8	61.2	61.0	59.7	ND	63.3
10000	55.6	58.1	54.7	NA	NA	NA	59.5	58.9	57.9	51.1	53.3	53.1	52.1	ND	55.4
16000	46.4	49.7	45.5	NA	NA	NA	51.7	50.9	49.5	41.0	43.4	42.9	42.3	ND	45.9
25000	35.4	40.0	34.2	NA	NA	NA	42.7	41.9	39.0	28.5	30.8	30.3	29.9	ND	33.4

L_{PNTSmx}	800 Series (RS=115)			900 Series (RS=160)			1100 Series			1200 Series			2000 Series		
200	100.0	ND	103.3	103.5	ND	104.2	NA	NA	NA	NA	NA	NA	NA	NA	NA
400	93.3	ND	96.6	97.0	ND	97.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
630	88.8	ND	92.1	92.6	ND	93.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
1000	83.9	ND	87.2	87.8	ND	88.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000	76.1	ND	79.3	80.0	ND	80.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
4000	66.8	ND	70.3	71.1	ND	71.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
6300	60.1	ND	63.5	64.8	ND	65.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
10000	52.6	ND	55.6	57.9	ND	58.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
16000	43.6	ND	46.1	50.0	ND	50.2	NA	NA	NA	NA	NA	NA	NA	NA	NA
25000	31.9	ND	33.8	40.5	ND	40.2	NA	NA	NA	NA	NA	NA	NA	NA	NA

E.1.6 Eurocopter EC-130

Table E-21. EC-130 L_{AE} NPDs.

EC-130

L_{AE}	120 Series (RS=115)			130 Series (RS=125)			140 Series (RS=101)			150 Series (RS=88)			160 Series (RS=76)			180 Series (RS=101)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	89.5	87.2	89.0	91.1	88.3	89.3	88.4	87.2	88.8	89.6	86.4	88.7	88.9	86.6	89.0	90.6	85.3	88.8
400	85.4	83.3	84.5	86.8	84.6	85.4	84.5	83.4	84.9	85.4	82.5	84.7	85.1	82.8	85.0	86.6	81.1	84.8
630	82.5	80.7	81.6	83.7	82.0	82.7	81.7	80.6	82.1	82.5	79.7	81.9	82.3	80.2	82.1	83.7	78.1	82.0
1000	79.4	77.8	78.4	80.3	79.1	79.8	78.6	77.7	78.8	79.2	76.7	78.7	79.2	77.3	78.8	80.5	74.8	78.8
2000	74.0	72.8	72.9	74.3	74.3	74.8	73.2	72.8	73.2	73.4	71.7	73.3	73.8	72.3	73.1	74.9	69.3	73.2
4000	67.5	66.9	66.3	66.9	68.6	69.1	66.7	66.9	66.4	66.3	65.8	66.7	67.3	66.6	66.1	68.1	62.9	66.3
6300	62.5	62.4	61.0	61.1	64.1	64.8	61.6	62.4	61.0	60.9	61.3	61.7	62.3	62.3	60.7	62.8	58.3	61.1
10000	56.7	57.1	54.9	54.2	59.2	59.7	55.8	57.2	54.8	54.5	56.3	55.8	56.5	57.4	54.5	56.8	53.3	55.2
16000	50.5	51.6	48.0	46.9	53.8	54.1	49.4	51.6	48.0	47.5	50.9	49.5	50.3	52.0	47.8	50.3	48.6	48.8
25000	45.0	46.8	41.6	40.1	48.7	49.0	43.8	46.3	41.6	41.2	46.6	44.3	44.8	46.9	41.6	44.7	44.2	43.1

L_{AE}	210 Series (RS=65)			310 Series (RS=65)			320 Series (RS=65)			330 Series (RS=65)			340 Series (RS=80)			350 Series (RS=60)		
200	90.5	87.7	87.8	93.7	93.2	92.5	94.5	93.8	92.2	94.2	94.3	91.1	97.1	92.7	93.7	94.7	93.7	91.3
400	86.2	83.7	83.9	89.9	89.9	89.1	90.7	90.5	88.8	90.5	91.0	87.5	93.2	89.2	90.0	90.8	90.4	87.7
630	83.0	80.8	81.2	87.1	87.6	86.6	87.9	88.1	86.4	87.7	88.6	85.0	90.4	86.8	87.4	88.1	88.1	85.3
1000	79.4	77.8	78.1	83.8	85.0	83.9	84.8	85.6	83.8	84.7	86.1	82.3	87.3	84.2	84.5	85.0	85.6	82.6
2000	73.1	72.6	73.1	78.2	80.8	79.3	79.5	81.4	79.2	79.5	82.0	77.6	81.8	79.7	79.6	79.6	81.6	78.0
4000	65.5	66.6	67.2	71.4	75.8	73.9	73.1	76.4	73.8	73.2	77.2	72.2	75.0	74.6	73.6	73.2	76.7	72.6
6300	59.6	62.0	62.8	66.2	71.8	69.8	68.1	72.6	69.6	68.3	73.5	68.1	69.6	70.6	68.8	68.3	72.9	68.6
10000	52.8	56.8	57.7	60.1	67.3	65.1	62.2	68.1	64.6	62.5	69.1	63.3	63.0	65.9	63.0	62.5	68.3	63.9
16000	45.8	51.5	52.4	53.2	61.9	59.5	55.3	62.8	58.9	55.6	63.8	57.9	55.3	60.2	56.4	55.7	62.8	58.5
25000	39.1	46.4	47.4	46.5	56.1	53.5	48.2	57.0	53.0	48.6	57.9	52.2	47.4	54.1	50.4	48.6	56.5	52.8

Table E-22. EC-130 L_{ASmx} NPDs.

EC-130

L_{ASmx}	120 Series (RS=115)			130 Series (RS=125)			140 Series (RS=101)			150 Series (RS=88)			160 Series (RS=76)			180 Series (RS=101)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	86.5	82.7	85.6	89.0	82.9	86.1	85.6	82.3	84.9	85.4	80.3	84.2	84.3	80.7	84.7	86.5	78.4	85.7
400	79.7	76.0	78.9	82.1	76.2	79.5	78.8	75.8	78.2	78.6	73.6	77.5	77.6	74.1	77.9	79.7	71.4	78.9
630	75.1	71.4	74.2	77.3	71.7	75.0	74.2	71.4	73.5	73.9	69.0	72.8	72.9	69.7	73.2	75.0	66.7	74.2
1000	70.1	66.6	69.1	72.1	66.8	70.1	69.2	66.7	68.5	68.8	64.2	67.9	67.9	64.9	68.1	70.0	61.6	69.1
2000	61.8	58.7	60.9	63.3	59.2	62.4	60.9	59.2	60.2	60.3	56.6	59.7	59.7	57.3	59.5	61.6	53.5	60.7
4000	52.5	50.0	51.5	53.1	50.6	53.7	51.5	50.7	50.7	50.6	48.0	50.6	50.4	48.7	49.7	52.1	44.5	51.1
6300	45.5	43.6	44.4	45.5	44.4	47.2	44.6	44.5	43.6	43.4	41.8	43.8	43.6	42.4	42.5	45.1	38.0	44.0
10000	37.6	36.4	36.4	36.8	37.4	39.8	36.7	37.5	35.8	35.1	35.1	36.1	36.0	35.5	34.5	37.2	30.9	35.9
16000	28.7	28.5	27.1	26.9	29.8	31.6	28.0	29.5	26.8	25.8	27.8	27.3	27.5	27.8	25.5	28.2	23.8	26.9
25000	20.4	21.1	18.3	17.4	22.4	23.9	19.8	21.6	18.4	17.3	20.9	19.2	19.6	20.8	17.5	20.2	17.5	18.8

L_{ASmx}	210 Series (RS=65)			310 Series (RS=65)			320 Series (RS=65)			330 Series (RS=65)			340 Series (RS=80)			350 Series (RS=60)		
200	85.2	81.2	82.2	89.3	89.9	87.7	90.4	88.3	86.6	90.1	89.2	86.8	93.2	88.2	90.0	90.7	89.6	86.0
400	78.2	74.4	75.5	82.4	83.5	81.3	83.6	82.0	80.1	83.4	82.9	80.2	86.5	81.8	83.5	83.9	83.2	79.6
630	73.2	69.8	70.9	77.7	79.2	77.0	79.0	77.8	75.7	78.7	78.7	75.8	81.8	77.6	79.0	79.3	79.0	75.3
1000	67.8	64.8	65.9	72.5	74.6	72.6	74.0	73.4	71.1	73.7	74.3	71.1	76.8	73.1	74.4	74.3	74.5	70.8
2000	58.6	56.9	58.1	63.9	67.4	65.5	65.9	66.6	64.0	65.5	67.3	63.6	68.6	66.1	66.7	66.1	67.5	63.8
4000	48.1	48.0	49.3	54.3	59.4	57.6	56.7	59.1	56.0	56.3	59.8	55.5	59.3	58.3	58.1	56.9	59.7	56.0
6300	40.4	41.5	42.9	47.5	53.4	51.9	50.0	53.7	50.2	49.7	54.4	49.7	52.3	52.7	51.6	50.2	53.9	50.3
10000	31.9	34.2	35.7	39.9	46.8	45.5	42.3	47.6	43.6	42.2	48.3	43.3	44.3	46.3	43.9	42.5	47.3	43.8
16000	22.3	26.2	27.8	31.1	39.7	38.1	33.6	40.6	36.3	33.5	41.3	36.1	35.0	39.0	35.1	33.6	39.9	36.3
25000	14.3	18.9	20.4	22.4	32.4	30.1	24.6	33.2	28.7	24.6	33.8	28.7	25.2	31.2	26.4	24.5	32.1	28.8

Table E-23. EC-130 L_{EPN} NPDs.

EC-130

L_{EPN}	120 Series (RS=115)			130 Series (RS=125)			140 Series (RS=101)			150 Series (RS=88)			160 Series (RS=76)			180 Series (RS=101)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	92.9	90.5	92.1	94.0	91.7	92.9	91.6	89.9	91.8	92.7	89.3	91.9	92.4	89.6	92.1	94.4	88.5	92.6
400	88.4	85.9	87.3	89.5	87.7	88.8	87.4	85.6	87.6	88.2	84.8	87.5	88.0	85.4	87.7	90.1	83.7	88.3
630	85.1	82.8	84.0	86.2	84.6	85.7	84.2	82.5	84.4	84.9	81.7	84.2	84.9	82.3	84.5	87.0	80.2	85.1
1000	81.4	79.3	80.4	82.3	81.2	82.1	80.5	79.3	80.7	81.2	78.3	80.5	81.3	79.1	80.6	83.2	76.5	81.3
2000	74.8	73.4	73.7	75.0	75.3	76.3	74.0	73.4	74.0	74.3	72.3	74.1	74.9	73.3	73.7	76.6	70.0	74.8
4000	66.6	66.0	65.5	65.4	67.9	69.1	65.9	66.1	65.3	65.3	64.9	66.1	66.7	66.0	64.9	68.5	61.7	66.6
6300	60.1	59.8	59.1	58.2	62.3	63.4	59.5	60.4	58.6	58.5	58.9	59.5	60.0	60.0	57.9	62.0	54.5	60.0
10000	51.9	51.9	50.5	49.2	54.6	55.9	51.4	52.9	50.0	49.5	51.2	50.9	51.5	52.5	48.7	53.1	45.3	51.0
16000	39.4	40.5	37.6	34.8	43.7	45.1	39.3	41.8	36.3	35.2	40.0	38.4	38.7	41.7	33.9	39.4	31.8	37.1
25000	22.4	27.0	22.5	21.1	25.8	27.9	22.3	29.5	21.3	18.1	26.8	20.7	21.1	26.2	17.3	20.8	19.1	24.0

L_{EPN}	210 Series (RS=65)			310 Series (RS=65)			320 Series (RS=65)			330 Series (RS=65)			340 Series (RS=80)			350 Series (RS=60)		
200	93.5	90.9	91.5	96.6	96.3	95.2	97.4	96.7	95.1	97.0	97.3	94.1	99.4	95.1	96.3	97.7	96.5	94.2
400	89.0	86.3	87.1	92.3	92.7	91.4	93.3	93.1	91.4	92.9	93.6	90.0	95.2	91.3	92.3	93.5	93.0	90.4
630	85.6	83.1	83.9	89.1	90.1	88.7	90.3	90.5	88.7	89.9	91.1	87.3	92.1	88.6	89.5	90.5	90.4	87.6
1000	81.6	79.4	80.3	85.5	87.2	85.6	86.7	87.6	85.7	86.5	88.3	84.2	88.4	85.7	86.4	86.9	87.6	84.6
2000	73.8	73.1	74.3	78.8	82.2	80.3	80.2	82.7	80.4	80.3	83.5	79.0	81.8	80.7	80.9	80.6	82.7	79.2
4000	63.7	65.2	66.6	70.7	76.1	73.9	72.8	76.7	74.0	72.9	77.7	72.5	73.9	74.6	73.9	73.1	76.8	72.7
6300	55.9	58.9	60.2	64.6	71.5	69.1	66.9	72.3	68.8	67.2	73.3	67.5	67.9	70.0	68.0	67.4	72.4	67.8
10000	45.7	51.1	52.2	57.1	66.2	63.3	59.8	67.0	62.8	60.2	68.2	61.6	60.4	64.5	60.6	60.5	67.1	62.1
16000	27.1	39.0	41.4	47.0	59.0	55.5	50.0	60.0	54.6	50.7	61.5	53.6	50.6	56.8	51.1	51.0	59.9	54.1
25000	9.4	27.4	24.9	33.9	49.6	45.6	35.1	50.8	43.9	36.2	52.7	43.0	36.0	46.9	38.4	36.8	50.1	43.7

Table E-24. EC-130 L_{PNTSmx} NPDs.

EC-130

L_{PNTSmx}	120 Series (RS=115)			130 Series (RS=125)			140 Series(RS=101)			150 Series (RS=88)			160 Series (RS=76)			180 Series (RS=101)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	99.6	95.1	99.2	102.6	95.7	99.1	99.1	94.8	98.4	99.1	93.2	97.8	98.0	93.7	98.1	100.4	91.6	99.5
400	92.6	88.0	92.0	95.6	88.7	92.1	92.1	87.9	91.4	92.1	86.1	90.8	91.0	86.8	91.0	93.4	84.2	92.5
630	87.7	82.9	87.1	90.6	83.7	87.4	87.1	83.2	86.4	87.1	81.2	85.9	86.1	82.1	86.1	88.4	78.9	87.5
1000	82.2	77.7	81.7	85.0	78.4	82.2	81.6	78.1	81.0	81.7	76.0	80.5	80.6	76.9	80.6	82.9	73.4	81.9
2000	73.0	69.1	72.5	75.2	69.9	74.0	72.3	69.8	71.8	72.3	67.7	71.6	71.6	68.4	71.1	73.5	64.5	72.5
4000	62.2	59.1	61.9	62.8	60.3	64.4	61.4	60.0	60.6	60.7	57.8	61.1	60.9	58.4	59.6	62.8	54.1	61.7
6300	54.1	51.9	53.8	54.5	52.9	56.9	53.2	53.0	52.6	52.4	50.0	53.1	52.7	51.0	51.2	54.8	45.6	53.6
10000	44.4	43.1	43.7	44.1	44.1	47.7	43.4	44.3	42.5	42.0	41.3	42.9	42.5	42.0	40.4	44.8	35.2	43.3
16000	31.2	30.6	30.1	30.2	32.2	35.8	30.1	32.1	28.3	27.4	29.4	29.6	29.4	29.5	24.9	30.1	15.2	28.3
25000	10.8	7.5	6.4	2.0	14.1	18.3	9.2	9.9	8.8	5.3	5.8	9.5	10.0	10.6	7.4	8.4	1.1	4.1

L_{PNTSmx}	210 Series (RS=65)			310 Series (RS=65)			320 Series (RS=65)			330 Series (RS=65)			340 Series (RS=80)			350 Series (RS=60)		
200	98.3	94.4	95.7	102.6	103.1	100.5	103.7	101.6	99.8	103.3	102.4	99.9	105.7	100.9	102.9	103.6	102.1	98.6
400	91.1	87.1	88.6	95.6	96.4	93.9	96.7	95.1	93.1	96.3	95.8	93.1	98.8	94.3	96.1	96.7	95.5	91.9
630	86.0	82.0	83.6	90.6	91.9	89.4	91.8	90.7	88.5	91.4	91.4	88.4	93.9	89.9	91.6	91.8	91.0	87.5
1000	80.2	76.7	78.1	85.0	87.0	84.8	86.3	86.0	83.7	86.1	86.8	83.4	88.5	85.1	86.7	86.4	86.3	82.8
2000	69.8	67.7	69.2	75.2	79.0	76.9	77.0	78.4	75.8	76.9	79.2	75.4	79.1	77.4	78.6	77.2	78.5	75.0
4000	56.9	57.1	59.1	64.4	70.0	68.1	66.8	70.0	66.9	66.7	70.7	66.4	68.6	68.8	69.1	67.1	69.8	66.1
6300	47.6	49.3	51.3	56.8	63.6	61.7	59.4	63.8	60.3	59.4	64.6	59.8	61.2	62.5	61.8	59.6	63.5	59.6
10000	36.0	40.0	41.9	47.8	56.8	54.4	50.6	57.0	52.6	50.7	57.9	52.4	52.6	55.5	52.9	51.0	56.3	52.3
16000	17.6	26.5	30.5	36.2	48.3	45.1	39.4	48.7	43.2	39.6	49.9	43.2	41.7	46.3	41.6	39.7	47.6	42.9
25000	1.8	6.0	12.7	19.0	37.7	33.7	24.3	38.3	31.7	24.4	40.0	31.6	26.7	35.1	28.3	25.0	36.6	31.9

E.1.7 Robinson R-22

Table E-25. R-22 L_{AE} NPDs.

R-22

L_{AE}	120 Series (RS=90)			130 Series (RS=81)			140 Series (RS=72)			150 Series (RS=63)			160 Series (RS=54)			180 Series (RS=72)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	85.5	86.5	86.0	85.8	84.9	85.6	84.7	86.5	86.2	85.2	85.6	85.4	85.7	87.4	85.4	85.3	83.3	85.5
400	81.7	82.9	82.4	82.3	81.2	82.1	81.1	83.1	82.8	81.6	82.1	81.7	82.2	83.8	81.9	81.5	79.3	81.6
630	79.2	80.4	79.8	79.7	78.6	79.5	78.4	80.6	80.4	79.0	79.6	79.2	79.6	81.2	79.4	78.8	76.4	78.7
1000	76.3	77.6	76.9	76.8	75.7	76.6	75.6	78.0	77.1	76.0	76.8	76.3	76.7	78.4	76.6	75.8	73.2	75.7
2000	71.4	72.8	72.1	71.7	70.8	71.6	70.7	73.4	72.8	71.1	72.0	71.5	71.7	73.6	71.7	70.5	68.0	70.5
4000	65.6	66.9	66.4	65.6	65.1	65.7	64.7	67.8	67.4	65.2	66.2	65.8	66.0	67.9	66.2	64.4	62.0	64.5
6300	61.1	62.4	62.0	60.9	60.8	61.3	60.4	63.5	63.3	60.7	61.9	61.5	61.6	63.6	62.1	60.0	57.6	60.3
10000	56.1	57.1	57.1	55.7	55.9	56.6	55.4	58.5	58.4	55.8	57.1	56.7	56.8	58.6	57.3	55.5	52.9	56.0
16000	50.7	51.3	51.7	50.3	50.6	51.3	50.2	52.6	52.7	50.8	51.8	51.4	51.9	53.0	52.1	51.1	48.3	51.7
25000	45.5	46.7	47.1	45.1	46.0	46.5	46.1	47.0	47.0	46.4	46.8	47.0	47.2	47.7	47.8	47.3	43.9	47.7

L_{AE}	210 Series (RS=53)			310 Series (RS=53)			320 Series (RS=53)			330 Series (RS=53)			340 Series (RS=53)			350 Series (RS=50)		
200	86.5	84.9	86.0	86.8	89.3	89.8	87.0	91.2	90.0	88.7	89.1	90.4	86.9	89.2	89.0	84.7	89.0	87.9
400	82.7	81.0	82.2	83.4	86.0	86.6	83.8	87.9	86.7	85.5	85.9	87.1	83.4	85.6	85.5	81.0	85.6	84.4
630	80.0	78.4	79.6	81.0	83.6	84.2	81.1	85.5	84.4	83.2	83.5	84.8	80.8	83.1	83.0	78.5	83.1	82.0
1000	77.1	75.4	76.6	78.4	81.1	81.3	78.3	82.9	81.8	80.6	80.9	82.3	78.0	80.1	80.2	75.6	80.5	79.3
2000	72.0	70.4	71.6	73.9	76.6	76.8	73.7	78.6	77.4	76.2	76.4	77.7	73.1	75.7	75.4	70.7	75.9	74.6
4000	66.2	64.7	65.5	68.3	71.3	71.1	68.3	73.2	72.0	70.7	70.9	72.2	67.3	70.4	69.4	65.0	70.4	68.9
6300	62.0	60.5	60.9	64.3	67.2	66.7	64.1	69.2	67.7	66.6	66.6	67.8	63.0	66.2	64.9	60.8	66.0	64.5
10000	57.4	55.9	56.0	59.6	62.3	61.4	59.3	64.4	62.6	61.7	61.5	62.6	58.0	61.1	59.5	56.1	60.8	59.4
16000	52.5	51.2	51.0	54.1	56.7	55.2	53.8	58.6	56.5	56.0	55.5	56.5	52.6	55.3	53.8	51.5	54.8	53.7
25000	47.9	46.6	46.2	48.7	50.8	49.1	48.8	52.4	50.3	50.2	49.1	50.1	47.6	49.7	48.0	47.0	49.3	48.6

Table E-26. R-22 L_{ASmx} NPDs.

R-22

L_{ASmx}	120 Series (RS=90)			130 Series (RS=81)			140 Series (RS=72)			150 Series (RS=63)			160 Series (RS=54)			180 Series (RS=72)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	80.7	82.1	81.4	82.6	79.1	81.3	79.3	81.6	83.5	79.3	80.1	80.0	79.1	80.4	80.6	79.7	75.1	80.1
400	74.2	75.6	74.9	75.9	72.5	74.8	72.8	75.1	77.0	72.8	73.4	73.4	72.3	74.0	74.0	73.1	68.3	73.4
630	69.8	71.2	70.5	71.4	68.1	70.4	68.4	70.7	72.5	68.4	69.0	68.9	67.8	69.6	69.6	68.6	63.6	68.9
1000	65.1	66.4	65.8	66.4	63.3	65.7	63.7	66.1	67.7	63.8	64.4	64.1	63.1	65.1	64.9	63.8	58.7	64.0
2000	57.5	58.8	58.3	58.1	55.6	58.1	56.2	58.6	59.7	56.3	57.0	56.4	55.5	57.8	57.2	56.0	50.7	56.0
4000	49.0	50.0	49.7	48.9	47.3	49.5	47.9	50.2	50.8	47.9	48.8	47.9	47.0	49.6	49.1	47.1	42.1	47.0
6300	42.8	43.6	43.6	42.4	41.3	43.3	41.9	44.0	44.7	41.8	42.7	41.8	40.9	43.5	43.1	40.8	36.1	40.6
10000	36.0	36.4	36.7	35.1	34.7	36.3	35.2	37.0	37.8	35.0	36.1	35.2	34.3	36.6	36.3	34.0	29.6	34.0
16000	28.5	28.5	29.1	27.1	27.6	28.7	27.8	29.4	30.0	27.5	28.7	28.0	27.0	28.7	28.8	27.1	22.7	27.5
25000	21.0	20.8	21.7	19.5	20.7	21.2	20.5	22.0	22.2	20.1	21.4	20.9	19.9	21.3	21.2	21.2	16.3	21.7

L_{ASmx}	210 Series (RS=53)			310 Series (RS=53)			320 Series (RS=53)			330 Series (RS=53)			340 Series (RS=53)			350 Series (RS=50)		
200	79.4	77.5	79.7	81.8	84.1	84.7	81.8	85.8	85.6	86.5	87.5	87.2	82.4	84.5	83.8	77.8	81.6	82.7
400	72.9	70.9	73.1	75.4	77.7	78.4	75.3	79.4	79.2	80.1	81.0	80.8	75.8	78.1	77.2	71.3	75.2	76.2
630	68.4	66.3	68.6	71.0	73.5	74.1	70.9	75.1	74.9	75.8	76.7	76.4	71.4	73.8	72.8	66.9	70.8	71.9
1000	63.6	61.6	63.8	66.4	68.9	69.6	66.3	70.7	70.3	71.2	72.1	71.8	66.7	69.4	68.1	62.2	66.3	67.3
2000	55.8	53.9	56.0	58.9	61.7	62.4	58.8	63.6	63.1	63.8	64.8	64.5	59.0	62.2	60.2	54.6	58.9	59.8
4000	47.0	45.4	47.1	50.4	53.5	54.3	50.7	55.7	54.8	55.4	56.6	56.4	50.9	54.2	51.3	46.4	50.6	51.3
6300	40.8	39.3	40.6	44.3	47.8	48.2	44.9	50.0	48.8	49.4	50.6	50.5	45.1	48.3	45.2	40.5	44.5	44.8
10000	34.1	32.8	33.5	38.1	41.5	41.4	38.5	43.5	42.0	42.8	43.8	43.7	38.7	41.5	38.3	33.9	37.7	37.5
16000	26.9	25.9	25.9	31.0	34.4	33.5	31.2	36.0	34.1	35.2	35.8	35.8	31.4	33.5	30.6	26.7	29.9	29.4
25000	19.9	19.4	18.7	23.6	26.7	25.0	23.6	28.1	25.9	27.2	27.2	27.3	23.7	25.0	23.0	19.7	22.1	21.7

Table E-27. R-22 L_{EPN} NPDs.

R-22

L_{EPN}	120 Series (RS=90)			130 Series (RS=81)			140 Series (RS=72)			150 Series (RS=63)			160 Series (RS=54)			180 Series (RS=72)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	89.1	89.2	89.2	88.9	88.3	88.6	88.0	89.1	89.3	88.6	88.5	88.3	89.2	89.9	88.8	89.1	87.0	89.7
400	84.6	85.0	85.0	85.1	83.9	84.6	83.8	85.3	85.1	84.4	84.5	84.3	85.2	85.9	84.7	84.8	82.4	85.3
630	81.6	82.2	82.1	81.8	81.0	81.7	80.7	82.5	81.9	81.3	81.6	81.3	82.0	83.1	81.6	81.7	79.1	82.2
1000	78.3	78.9	78.8	78.4	77.7	78.4	77.3	79.4	78.9	77.8	78.4	78.0	78.7	79.8	78.4	78.3	75.5	78.8
2000	72.6	73.4	73.4	72.4	72.1	72.8	71.5	74.3	73.8	72.1	72.9	72.4	73.0	74.5	73.0	72.4	69.4	72.8
4000	65.4	66.7	66.5	65.1	65.3	65.7	64.3	67.9	67.6	64.7	66.1	65.3	65.7	67.7	66.3	64.9	61.6	65.6
6300	59.4	61.1	60.7	58.8	59.5	59.9	58.0	62.8	62.2	58.5	60.5	59.4	59.8	62.1	60.6	58.8	54.8	59.6
10000	51.8	53.4	53.1	50.9	51.6	52.5	50.5	55.9	56.0	50.8	52.8	51.6	52.4	54.9	53.3	50.2	45.2	51.2
16000	41.5	42.1	42.9	39.7	40.1	42.1	40.2	46.0	45.7	39.8	41.9	40.7	89.2	89.9	88.8	89.1	87.0	89.7
25000	27.2	28.6	25.2	26.3	29.2	25.2	23.8	31.7	32.2	27.2	26.2	24.9	85.2	85.9	84.7	84.8	82.4	85.3

L_{EPN}	210 Series (RS=53)			310 Series (RS=53)			320 Series (RS=53)			330 Series (RS=53)			340 Series (RS=53)			350 Series (RS=50)		
200	90.0	88.6	89.3	89.7	91.5	91.5	90.1	93.5	92.8	90.9	91.1	92.3	89.7	91.0	90.7	88.0	91.0	90.2
400	85.7	84.3	85.0	85.7	87.7	87.9	86.3	89.8	88.8	87.2	87.4	88.6	85.6	87.3	87.0	83.8	87.2	86.4
630	82.6	81.2	81.8	82.9	85.0	85.2	83.6	87.2	86.2	84.6	84.8	86.0	82.7	84.5	84.1	80.8	84.6	83.5
1000	79.1	77.8	78.4	79.8	82.1	82.1	80.2	84.4	83.2	81.6	81.9	83.1	79.4	81.4	81.0	77.6	81.6	80.5
2000	73.3	72.0	72.4	74.2	77.1	76.8	74.9	79.5	78.2	76.6	76.7	77.9	73.9	76.5	75.4	71.9	76.6	75.2
4000	66.0	65.0	64.9	67.7	70.9	70.2	68.2	73.6	71.9	70.3	70.5	71.4	66.9	70.4	68.6	64.7	70.4	68.6
6300	59.8	59.1	58.5	62.4	65.9	64.9	62.8	69.2	66.9	65.2	65.5	66.3	61.4	65.4	62.9	58.6	65.2	63.1
10000	52.1	51.1	50.3	55.5	59.7	57.9	56.0	63.2	60.3	58.8	59.2	59.8	54.5	58.6	55.7	50.8	57.5	55.7
16000	41.3	38.7	37.9	46.5	51.5	49.4	46.7	54.2	51.5	50.5	50.0	51.2	44.7	49.2	45.3	39.8	47.3	45.7
25000	26.9	27.0	26.0	31.6	39.4	36.1	32.2	42.8	38.9	38.2	37.2	39.4	32.2	34.6	33.5	27.4	33.6	28.6

Table E-28. R-22 L_{PNTSmx} NPDs.

R-22

L_{PNTSmx}	120 Series (RS=90)			130 Series (RS=81)			140 Series (RS=72)			150 Series (RS=63)			160 Series (RS=54)			180 Series (RS=72)		
Dist. (ft)	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right	Left	Center	Right
200	93.7	93.7	93.7	95.5	92.0	93.9	92.5	93.8	95.0	92.4	93.8	93.0	91.9	92.6	92.6	93.1	89.0	93.8
400	86.9	86.9	87.0	88.1	85.2	87.2	85.0	87.1	88.2	85.1	86.2	86.1	84.7	85.9	85.7	86.1	81.7	86.9
630	82.3	82.2	82.3	83.2	80.5	82.5	80.3	82.5	83.4	80.3	81.6	81.3	80.0	81.3	81.1	81.3	76.6	82.0
1000	77.3	77.2	77.3	77.8	75.5	77.5	75.3	77.6	78.4	75.2	76.7	76.1	75.0	76.5	76.2	76.1	71.2	76.8
2000	69.0	69.0	69.2	68.8	67.3	69.3	67.3	69.6	70.0	67.1	68.7	67.6	66.7	68.7	68.4	67.5	62.8	68.2
4000	59.4	59.7	59.9	58.5	58.1	59.9	57.8	60.3	60.8	57.6	59.4	58.1	57.1	59.6	59.3	57.8	52.8	58.5
6300	52.0	52.8	52.7	50.8	51.1	52.6	50.5	53.0	53.7	50.4	52.4	50.9	49.7	52.8	52.2	50.2	44.5	51.1
10000	43.0	44.2	43.4	41.4	42.0	43.8	41.5	44.6	44.8	41.2	43.1	41.8	40.7	43.9	43.5	40.7	34.2	41.7
16000	32.1	31.4	32.3	29.0	29.4	32.2	30.3	31.9	31.7	30.1	31.7	29.4	28.9	31.8	32.0	27.8	17.9	28.7
25000	14.3	10.9	14.1	10.5	9.5	15.1	12.3	12.9	14.2	11.8	12.4	12.9	10.9	13.3	15.1	13.9	2.7	15.4

L_{PNTSmx}	210 Series (RS=53)			310 Series (RS=53)			320 Series (RS=53)			330 Series (RS=53)			340 Series (RS=53)			350 Series (RS=50)		
200	92.3	91.4	92.1	94.0	95.8	96.0	94.9	97.9	97.6	97.9	99.3	98.7	94.2	96.4	94.8	90.5	93.6	93.9
400	85.3	84.4	85.2	87.2	89.2	89.4	87.5	91.3	90.9	91.3	92.6	92.1	87.6	89.8	88.0	83.7	86.9	87.3
630	80.5	79.5	80.4	82.6	84.6	84.8	82.9	86.9	86.4	86.7	88.0	87.6	83.1	85.3	83.3	79.0	82.4	82.7
1000	75.3	74.3	75.2	77.6	79.8	80.0	78.0	82.2	81.6	81.8	83.1	82.7	78.2	80.6	78.2	74.1	77.6	77.9
2000	66.8	66.2	66.6	69.5	72.1	72.4	70.2	74.7	73.8	73.9	75.2	75.0	70.5	73.0	70.3	66.2	69.8	70.0
4000	57.0	56.7	56.6	59.9	63.5	63.7	61.2	66.4	65.0	65.2	66.3	66.0	61.6	64.4	61.2	56.8	61.0	60.8
6300	49.5	49.5	48.8	52.7	57.1	57.2	54.4	60.3	58.4	58.6	59.9	59.4	54.8	58.2	54.2	49.6	54.3	53.8
10000	40.1	40.3	39.1	44.4	49.4	49.6	46.2	53.2	51.0	51.1	52.3	52.0	46.9	50.2	45.6	40.5	45.4	44.6
16000	28.2	27.1	26.5	34.2	40.0	39.8	35.9	42.4	40.5	41.4	42.0	42.4	36.9	39.4	34.6	28.3	33.7	33.4
25000	12.0	8.2	7.0	20.1	27.5	27.3	22.1	30.5	28.2	29.0	28.9	30.5	23.6	24.0	17.9	11.1	15.6	15.9

E.2 L_{AE} NPD Plots

Presented below are graphical plots of the final integrated procedure L_{AE} NPDs for each Dynamic Operations measurement series run for each aircraft measured in the Fitchburg study. Refer to Tables 13 and 14 in Sections 4.1 and 4.2, respectively, for specifics on the operational characteristics associated with each measurement series. Sound levels from the centerline and sideline microphones are presented here as aircraft left, center, and right data.

E.2.1 Maule M-7-235C

Weather conditions during the Maule study resulted in only two measurement series being completed for this aircraft. Accordingly, data are only presented for the Maule 300 and 400 Series.

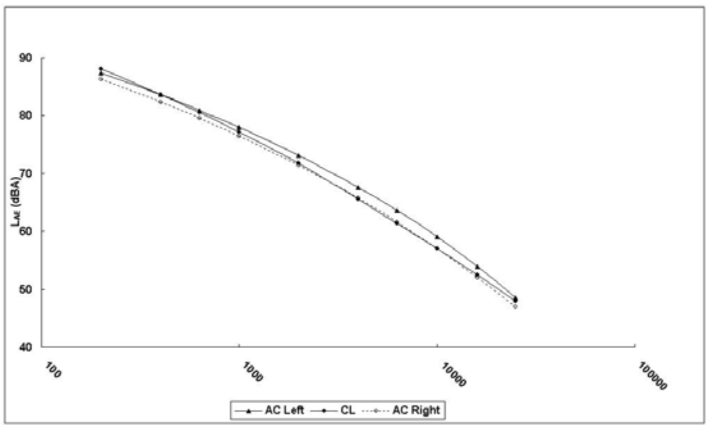

Figure E-1. Maule 300 Series L_{AE} Data (Ref. Spd. = 87 kts.)

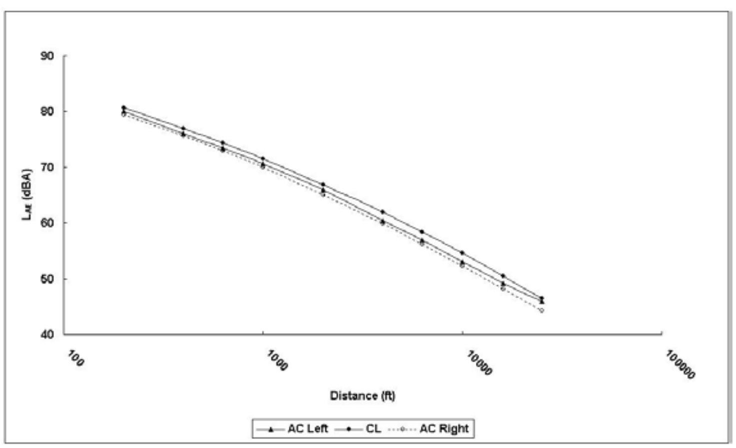

Figure E-2. Maule 400 Series L_{AE} Data (Ref. Spd. = 70 kts.)

E.2.2 Beech 1900D

During processing, the centerline microphone noise data for the 700, 800, and 900 measurement series were found to be contaminated by a poor signal-to-noise ratio. Therefore, only left-side and right-side NPDs are presented for the 700, 800, and 900 Series.

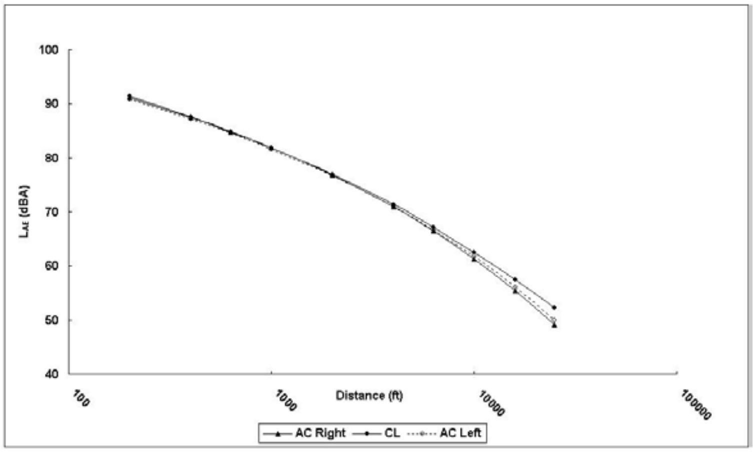

Figure E-3. 1900D 300 Series L_{AE} Data (Ref. Spd. = 220 kts.)

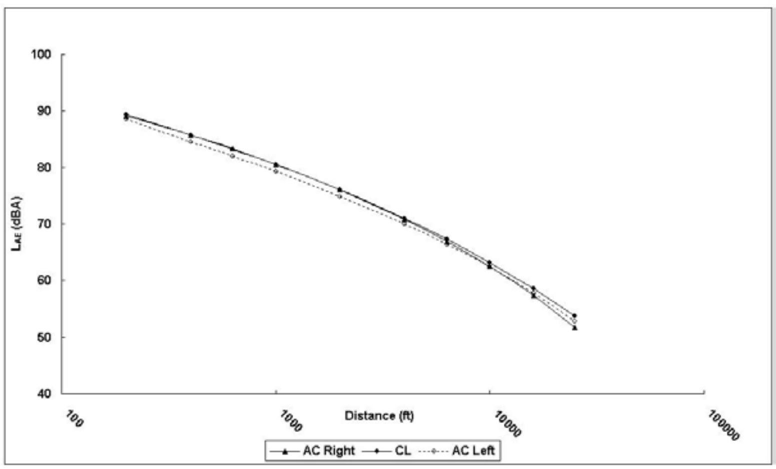

Figure E-4. 1900D 500 Series L_{AE} Data (Ref. Spd. = 160 kts.)

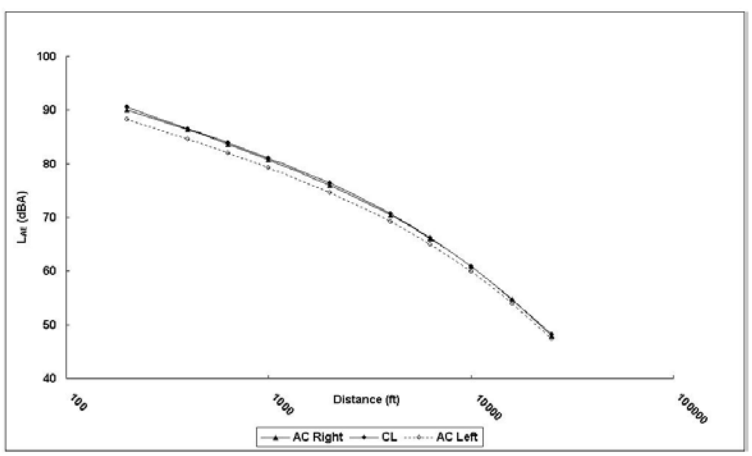

Figure E-5. 1900D 600 Series L_{AE} Data (Ref. Spd. = 160 kts.)

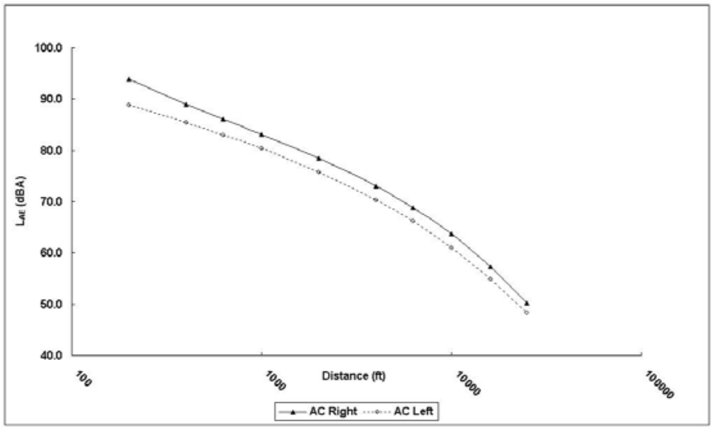

Figure E-6. 1900D 700 Series L_{AE} Data (Ref. Spd. = 130 kts.)

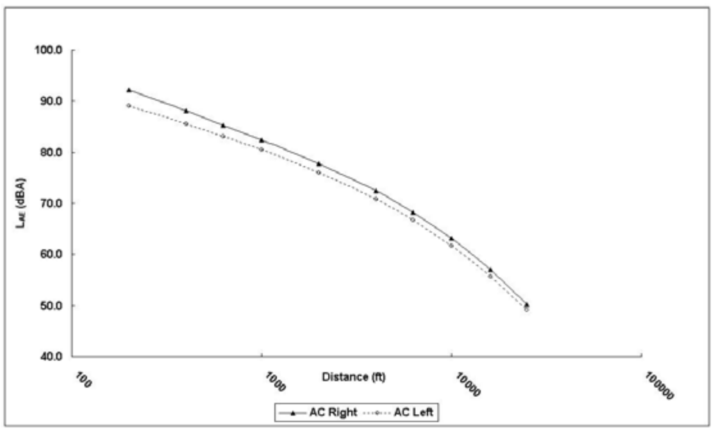

Figure E-7. 1900D 800 Series L_{AE} Data (Ref. Spd. = 115 kts.)

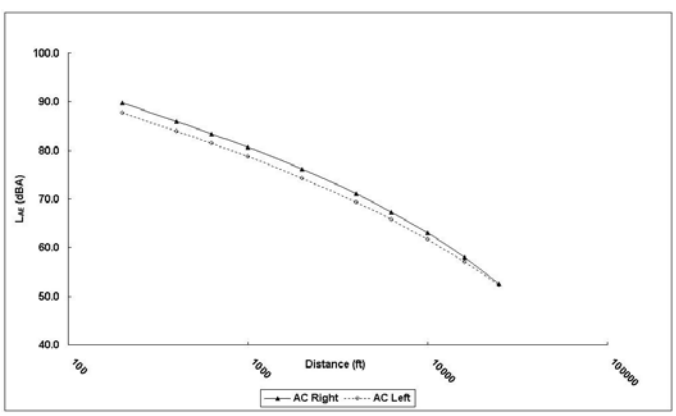

Figure E-8. 1900D 900 Series L_{AE} Data (Ref. Spd. = 160 kts.)

E.2.3 Piper Twin Comanche PA-30

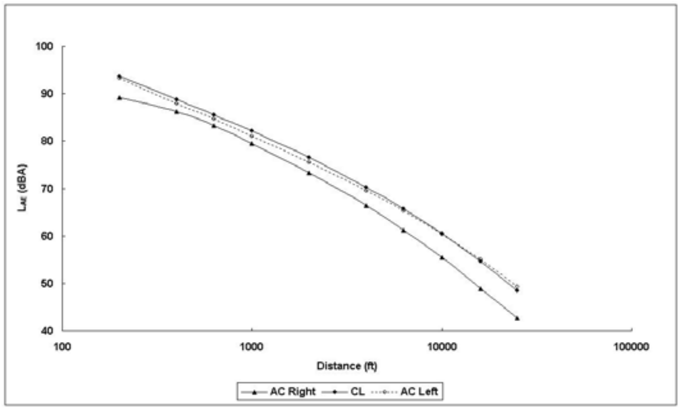

Figure E-9. PA-30 300 Series L_{AE} Data (Ref. Spd. = 165 kts.)

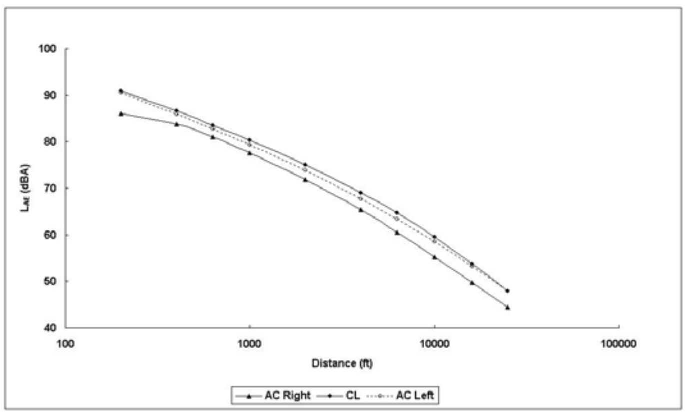

Figure E-10. PA-30 400 Series L_{AE} Data (Ref. Spd. = 135 kts.)

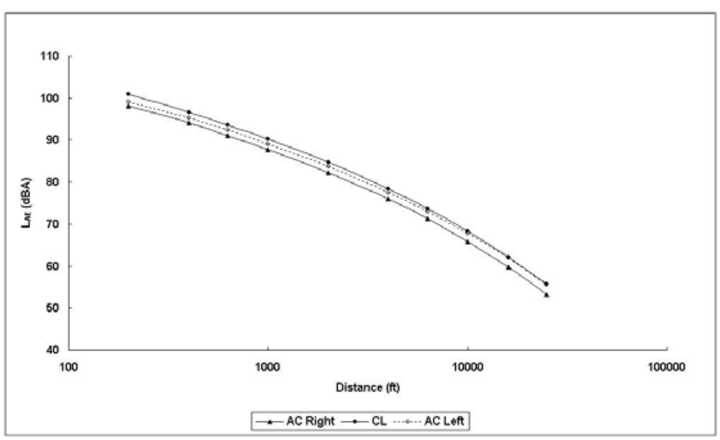

Figure E-11. PA-30 500 Series L_{AE} Data (Ref. Spd. = 97 kts.)

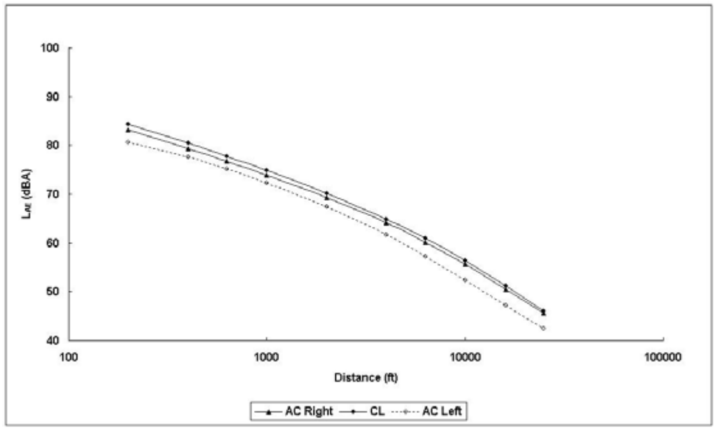

Figure E-12. PA-30 600 Series L_{AE} Data (Ref. Spd. = 100 kts.)

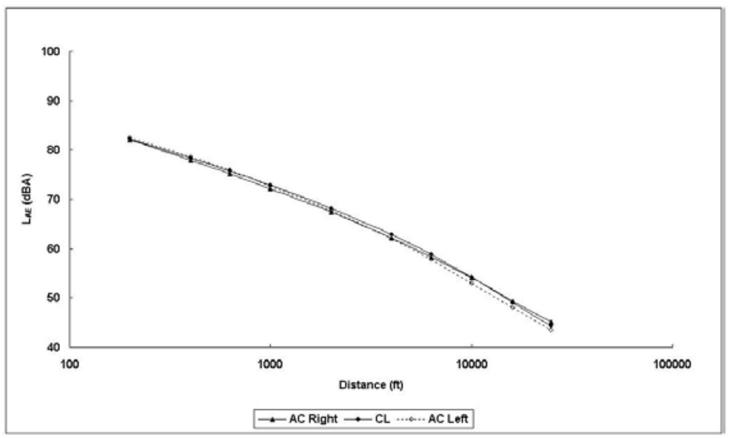

Figure E-13. PA-30 700 Series L_{AE} Data (Ref. Spd. = 96 kts.)

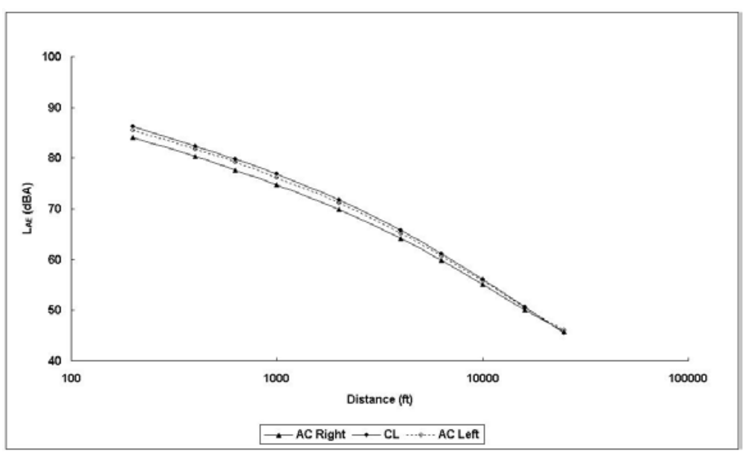

Figure E-14. PA-30 800 Series L_{AE} Data (Ref. Spd. = 87 kts.)

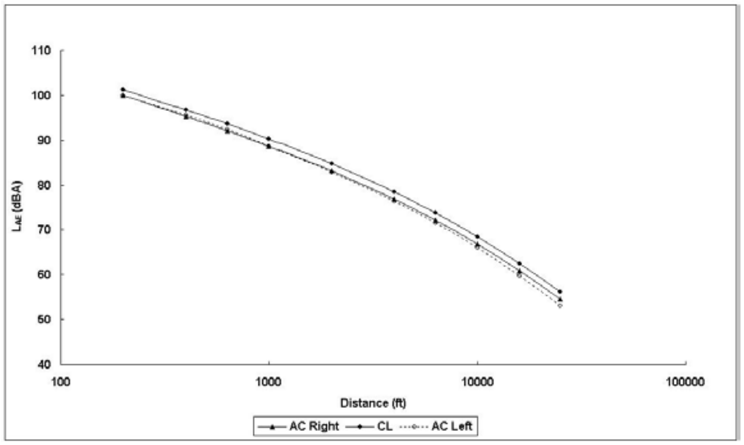

Figure E-15. PA-30 900 Series L_{AE} Data (Ref. Spd. = 97 kts.)

E.2.4 Piper Navajo Chieftain PA-31-350

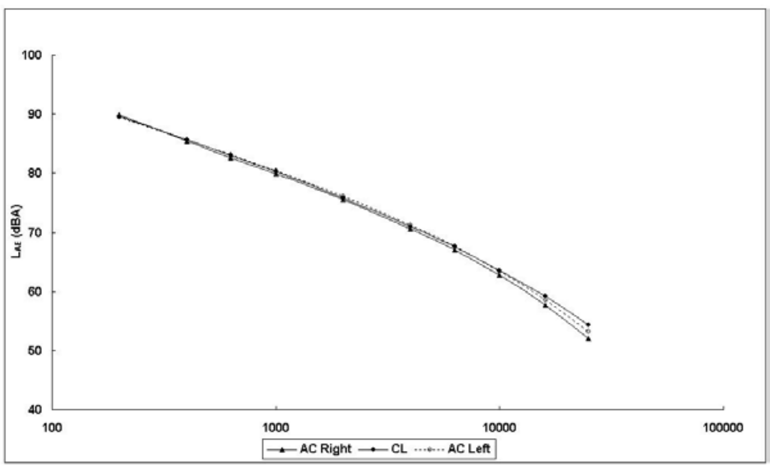

Figure E-16. PA-31 300 Series L_{AE} Data (Ref. Spd. = 156 kts.)

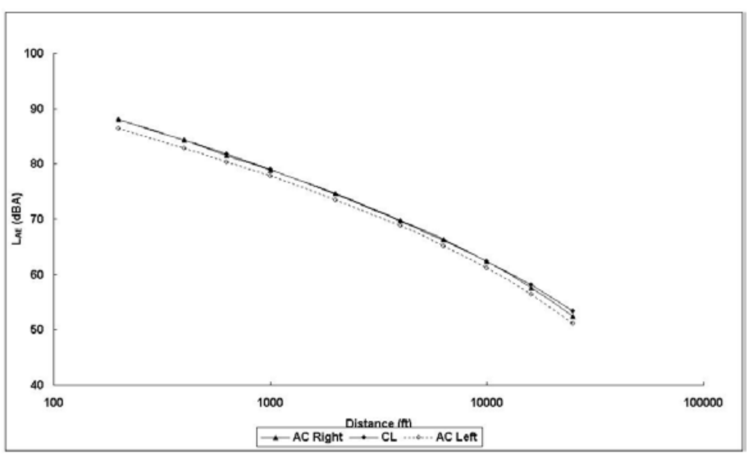

Figure E-17. PA-31 400 Series L_{AE} Data (Ref. Spd. = 155 kts.)

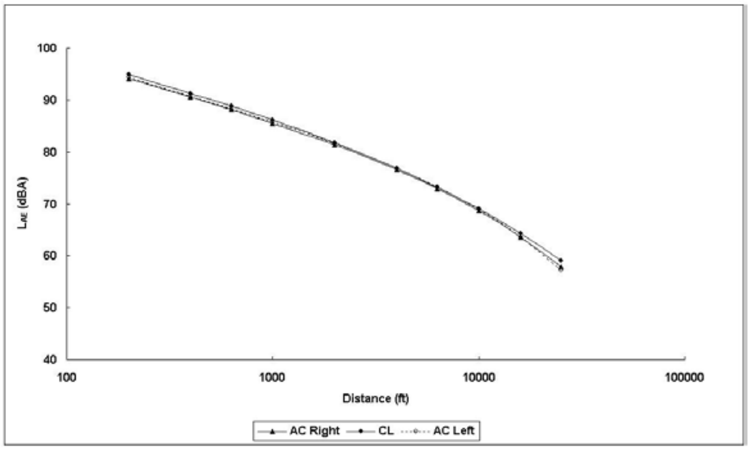

Figure E-18. PA-31 500 Series L_{AE} Data (Ref. Spd. = 105 kts.)

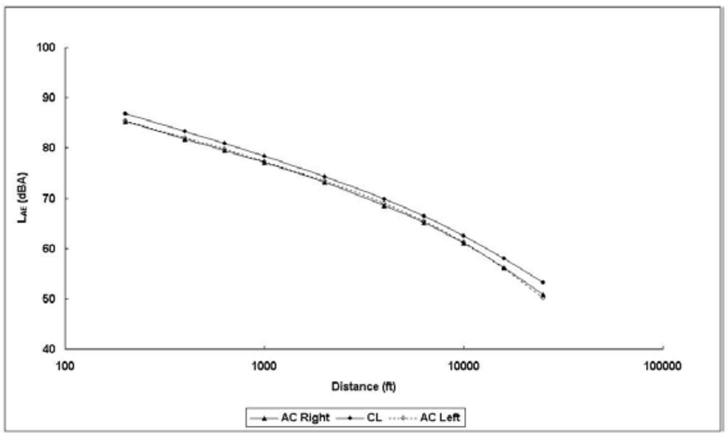

Figure E-19. PA-31 600 Series L_{AE} Data (Ref. Spd. = 160 kts.)

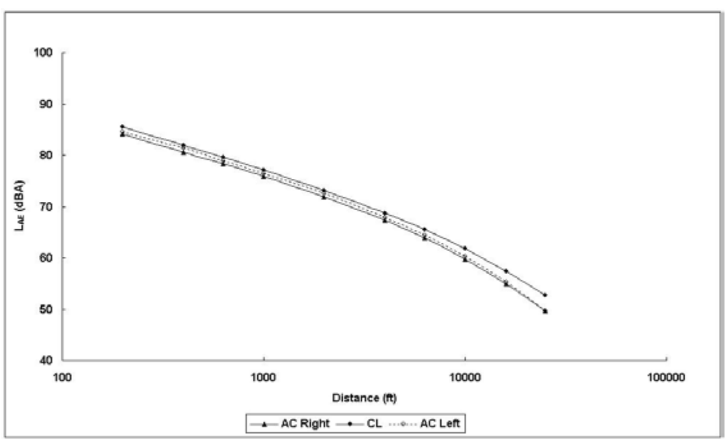

Figure E-20. PA-31 700 Series L_{AE} Data (Ref. Spd. = 150 kts.)

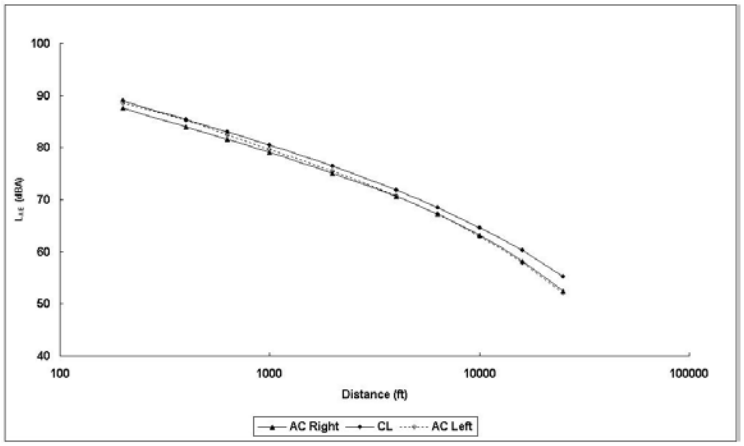

Figure E-21. PA-31 800 Series L_{AE} Data (Ref. Spd. = 120 kts.)

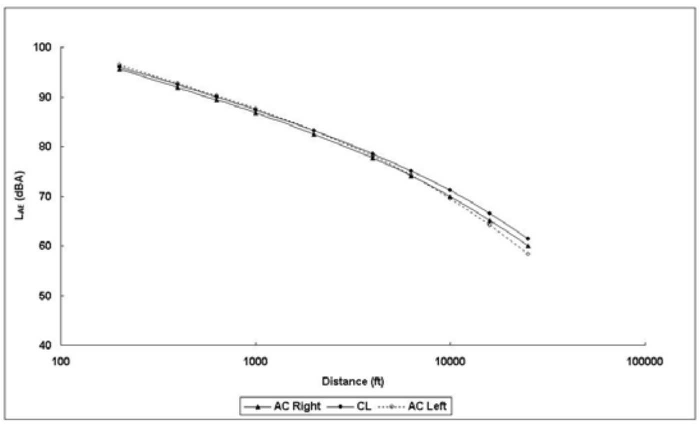

Figure E-22. PA-31 900 Series L_{AE} Data (Ref. Spd. = 105 kts.)

E.2.5 Piper Warrior PA-28-161

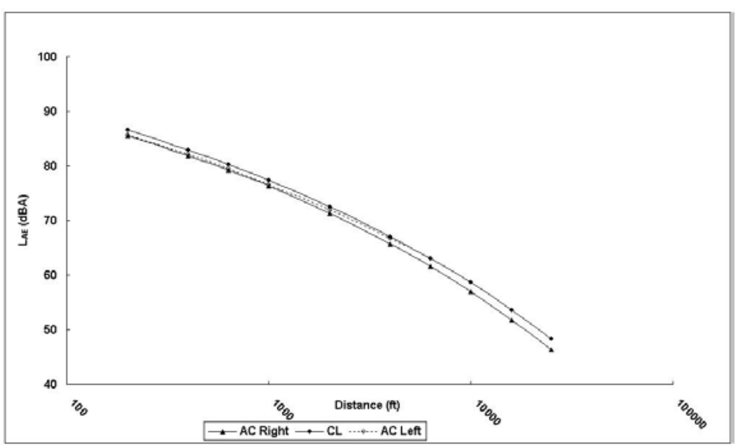

Figure E-23. PA-28 300 Series L_{AE} Data (Ref. Spd. = 105 kts.)

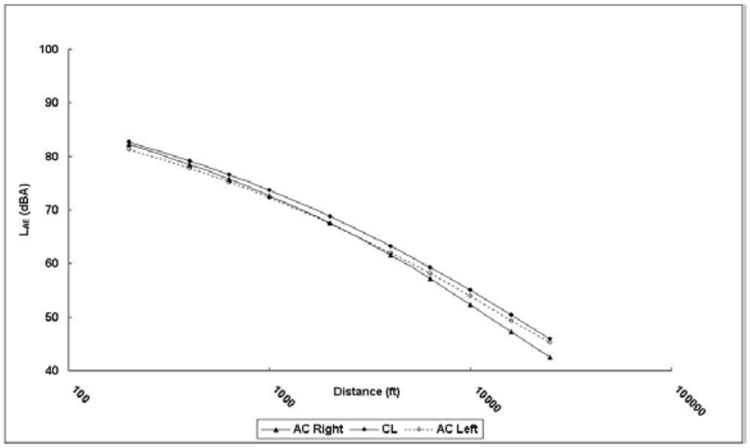

Figure E-24. PA-28 400 Series L_{AE} Data (Ref. Spd. = 95 kts.)

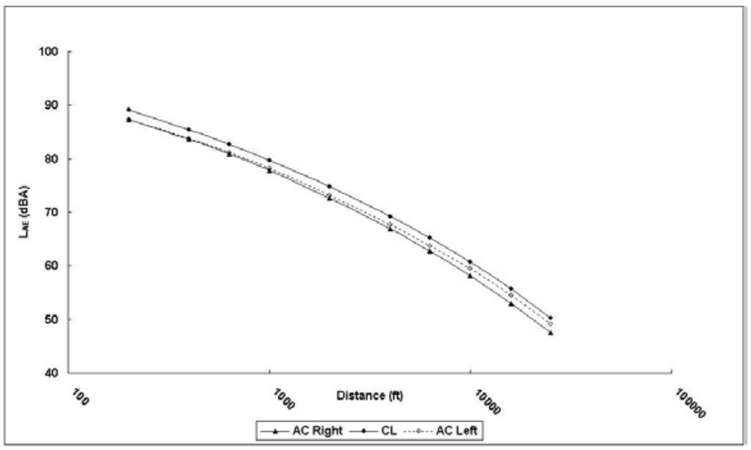

Figure E-25. PA-28 500 Series L_{AE} Data (Ref. Spd. = 79 kts.)

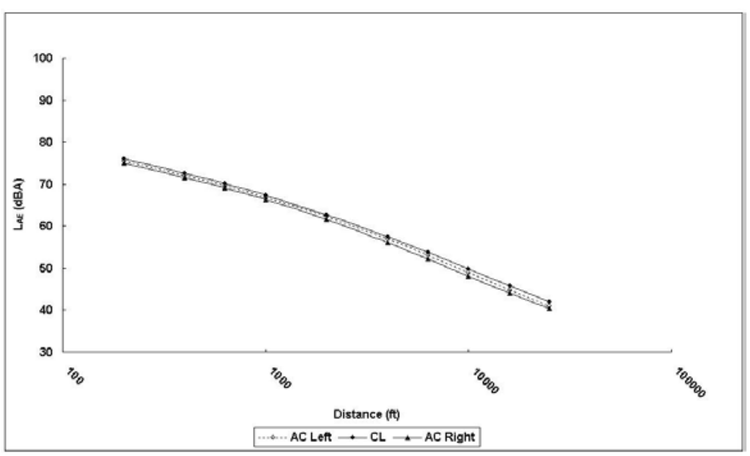

Figure E-26. PA-28 600 Series L_{AE} Data (Ref. Spd. = 100 kts.)

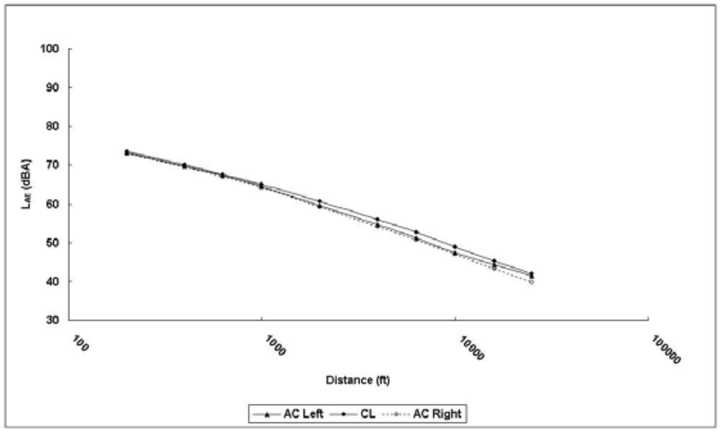

Figure E-27. PA-28 700 Series L_{AE} Data (Ref. Spd. = 80 kts.)

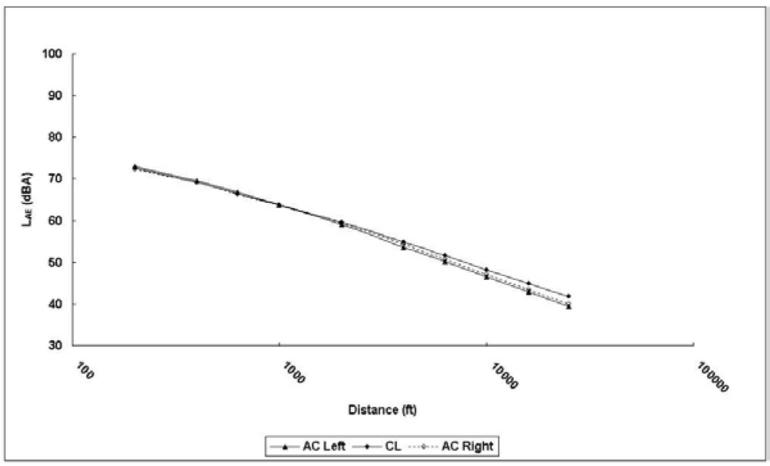

Figure E-28. PA-28 800 Series L_{AE} Data (Ref. Spd. = 70 kts.)

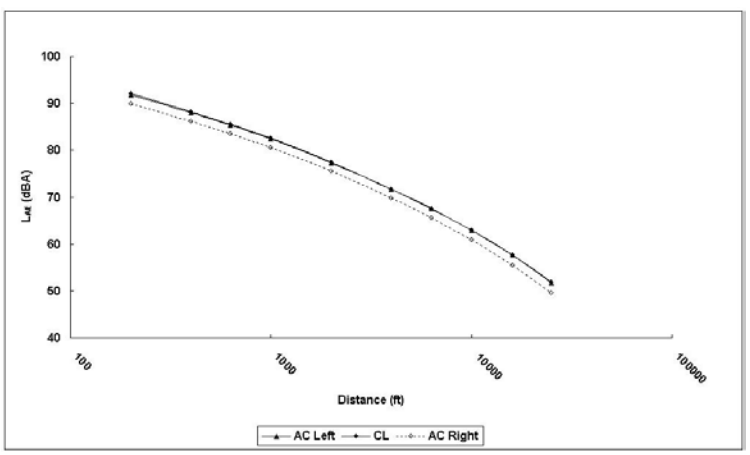

Figure E-29. PA-28 900 Series L_{AE} Data (Ref. Spd. = 87 kts.)

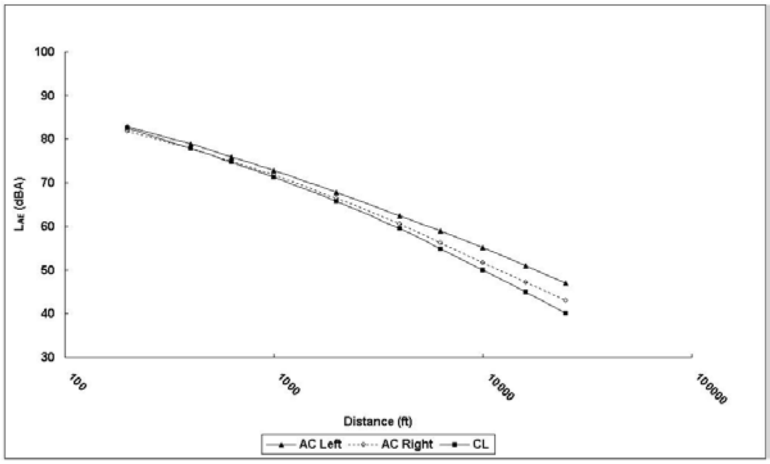

Figure E-30. PA-28 1100 Series L_{AE} Data (Ref. Spd. = 105 kts.)

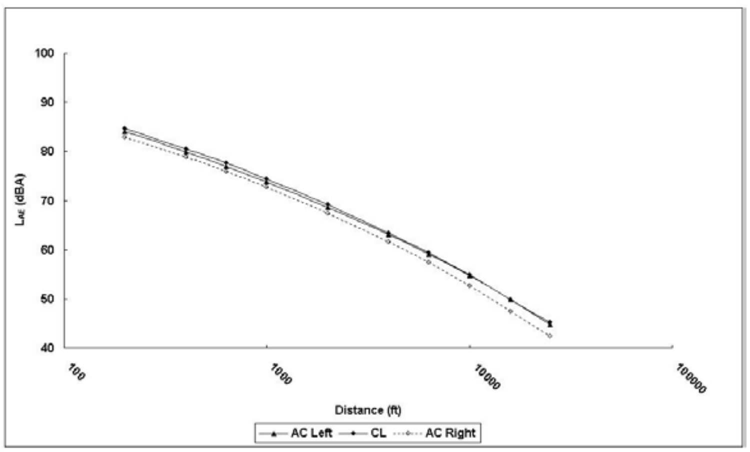

Figure E-31. PA-28 1200 Series L_{AE} Data (Ref. Spd. = 105 kts.)

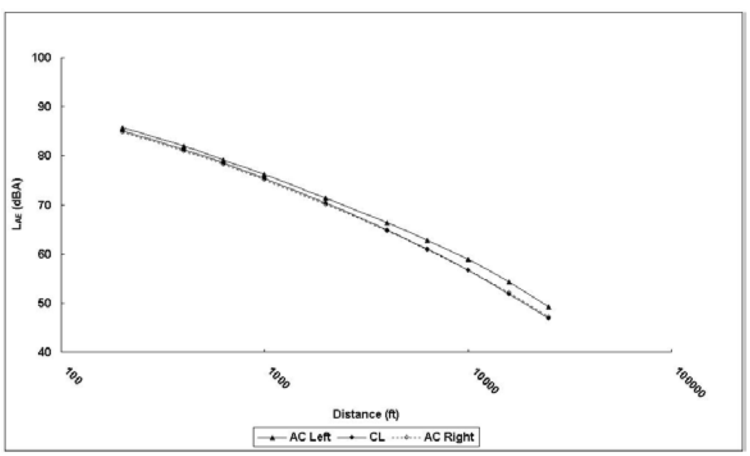

Figure E-32. PA-28 2000 Series L_{AE} Data (Ref. Spd. = 105 kts.)

E.2.6 Eurocopter EC-130

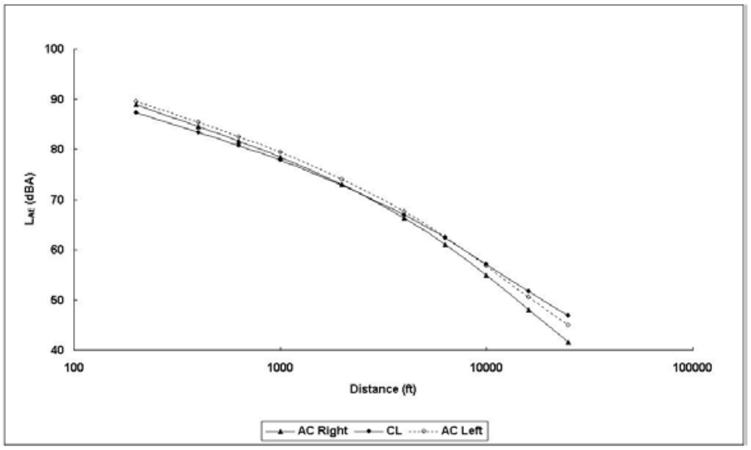

Figure E-33. EC-130 120 Series L_{AE} Data (Ref. Spd. = 115 kts.)

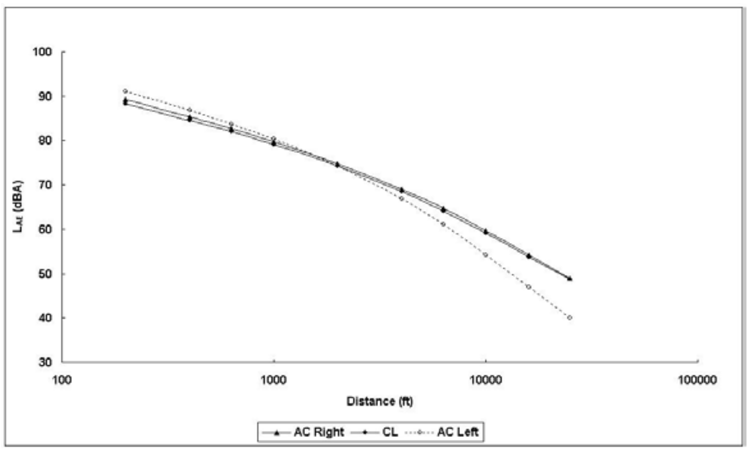

Figure E-34. EC-130 130 Series L_{AE} Data (Ref. Spd. = 125 kts.)

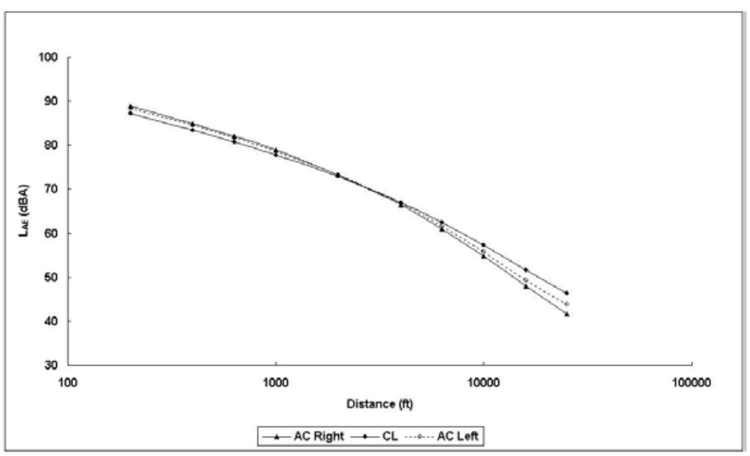

Figure E-35. EC-130 140 Series L_{AE} Data (Ref. Spd. = 101 kts.)

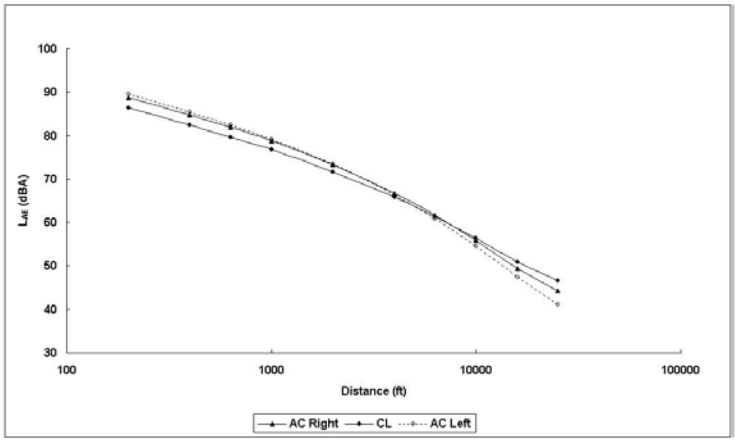

Figure E-36. EC-130 150 Series L_{AE} Data (Ref. Spd. = 88 kts.)

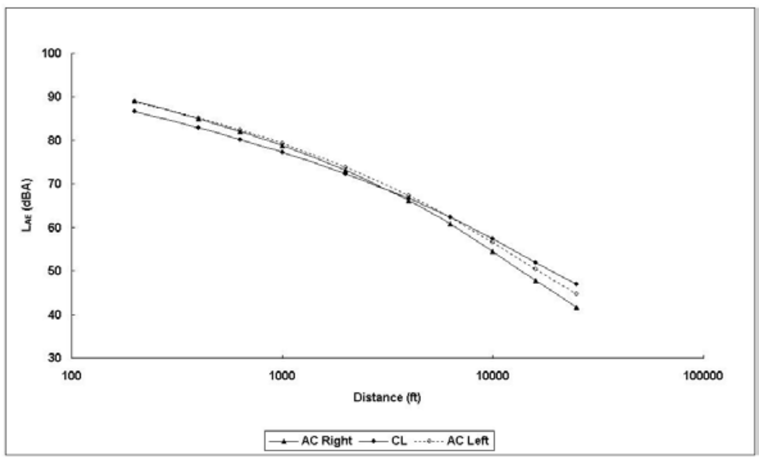

Figure E-37. EC-130 160 Series L_{AE} Data (Ref. Spd. = 76 kts.)

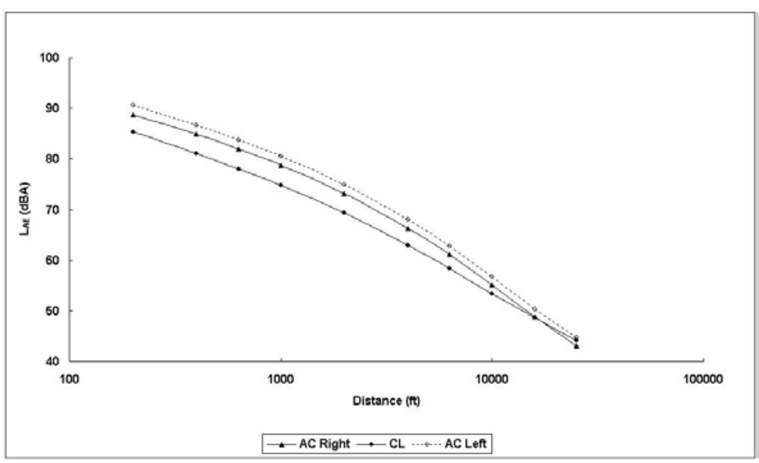

Figure E-38. EC-130 180 Series L_{AE} Data (Ref. Spd. = 101 kts.)

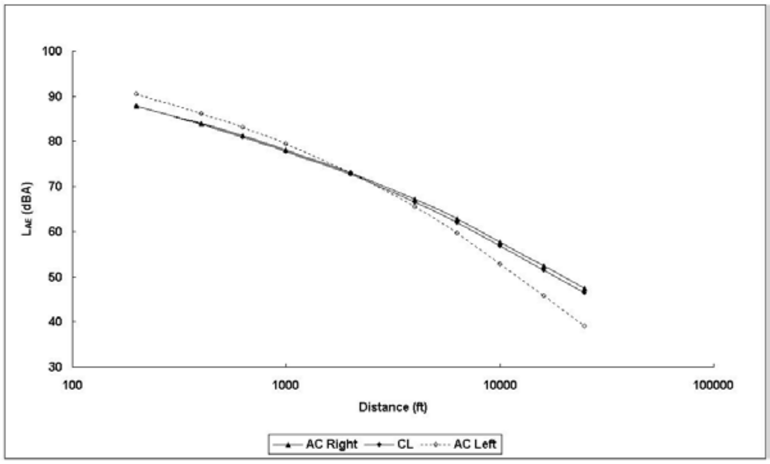

Figure E-39. EC-130 210 Series L_{AE} Data (Ref. Spd. = 65 kts.)

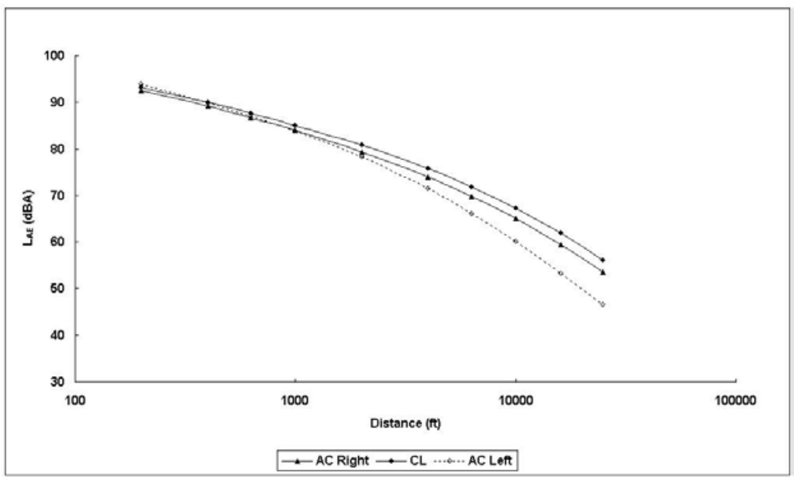

Figure E-40. EC-130 310 Series L_{AE} Data (Ref. Spd. = 65 kts.)

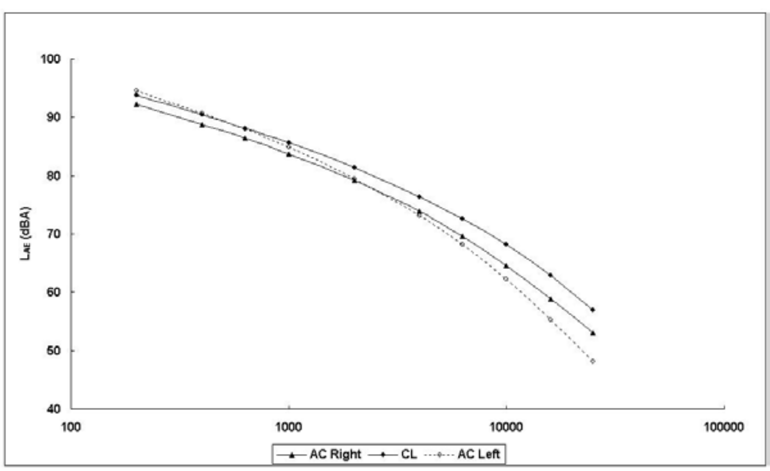

Figure E-41. EC-130 320 Series L_{AE} Data (Ref. Spd. = 65 kts.)

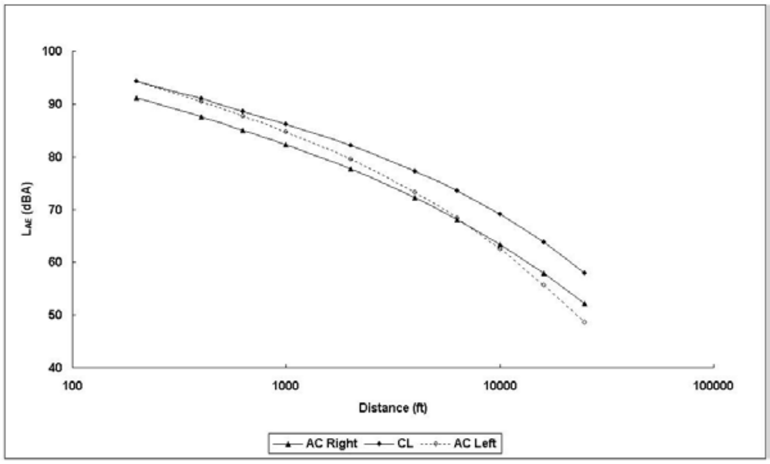

Figure E-42. EC-130 330 Series L_{AE} Data (Ref. Spd. = 65 kts.)

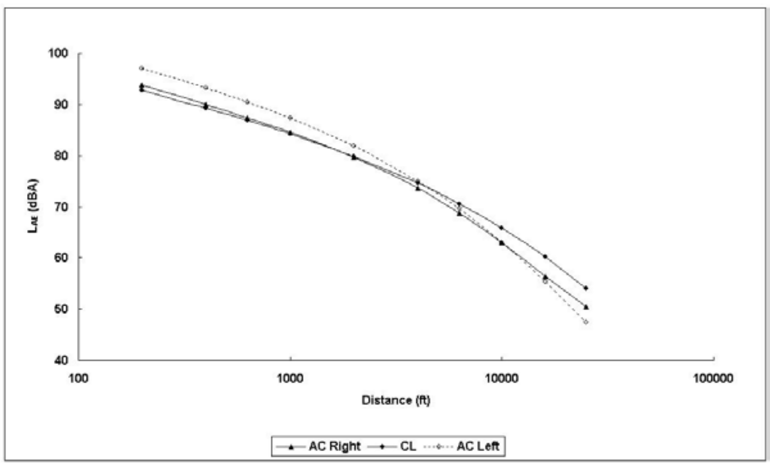

Figure E-43. EC-130 340 Series L_{AE} Data (Ref. Spd. = 80 kts.)

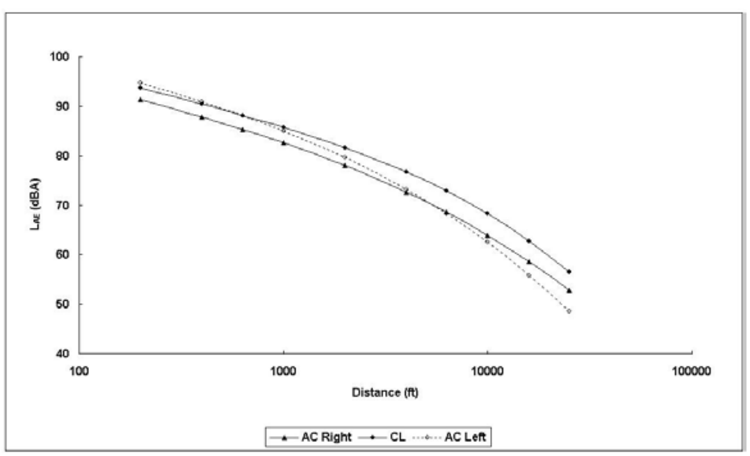

Figure E-44. EC-130 350 Series L_{AE} Data (Ref. Spd. = 60 kts.)

E.2.7 Robinson R-22

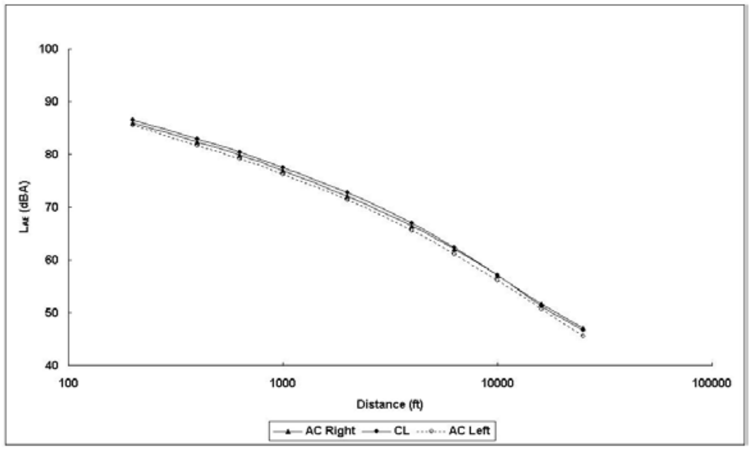

Figure E-45. R-22 120 Series L_{AE} Data (Ref. Spd. = 90 kts.)

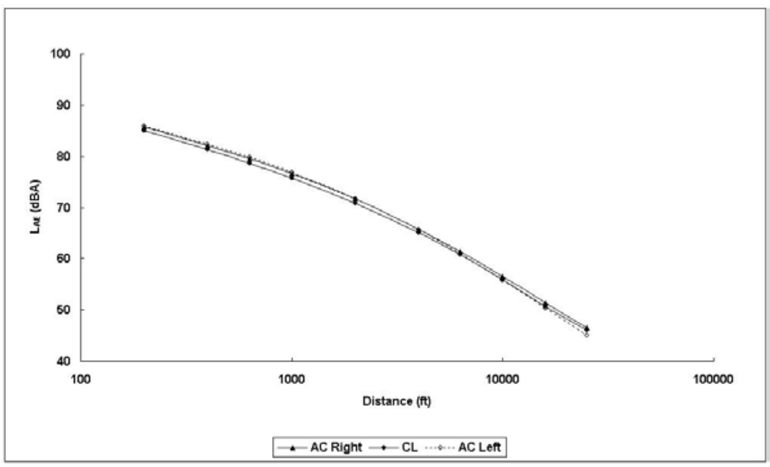

Figure E-46. R-22 130 Series L_{AE} Data (Ref. Spd. = 81 kts.)

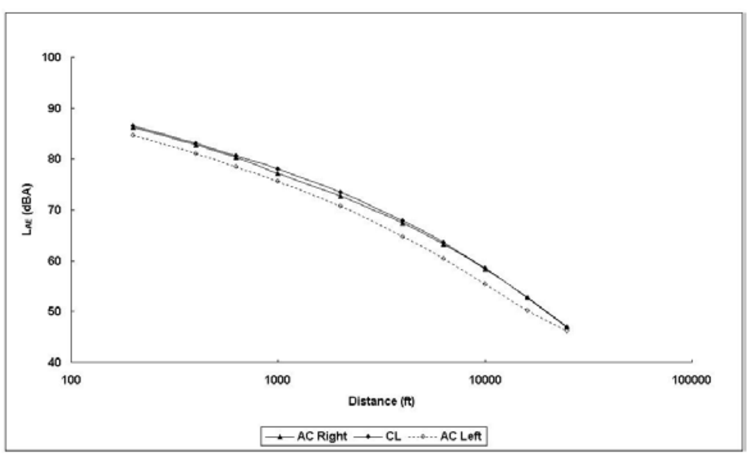

Figure E-47. R-22 140 Series L_{AE} Data (Ref. Spd. = 72 kts.)

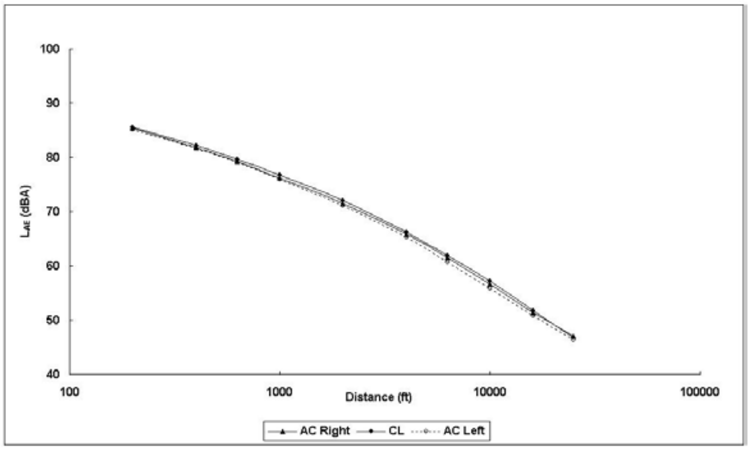

Figure E-48. R-22 150 Series L_{AE} Data (Ref. Spd. = 63 kts.)

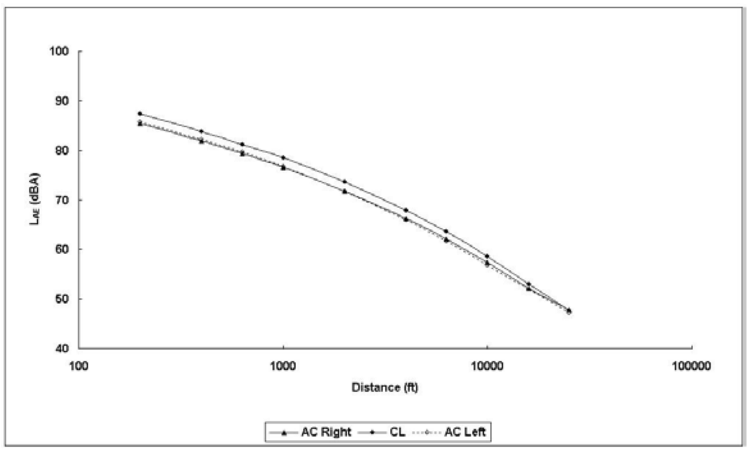

Figure E-49. R-22 160 Series L_{AE} Data (Ref. Spd. = 54 kts.)

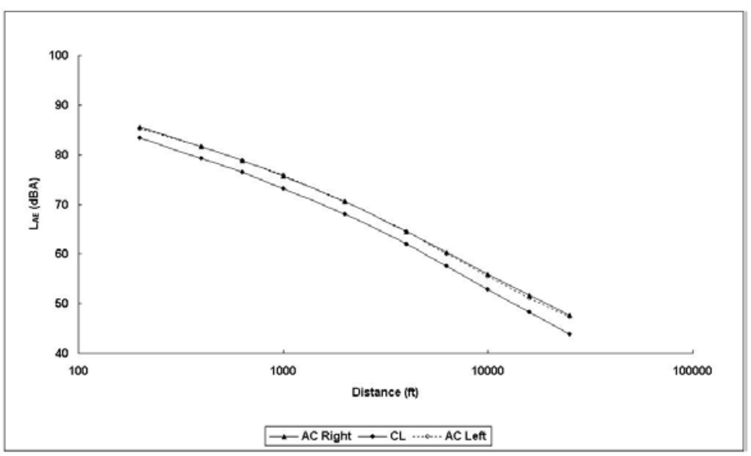

Figure E-50. R-22 180 Series L_{AE} Data (Ref. Spd. = 72 kts.)

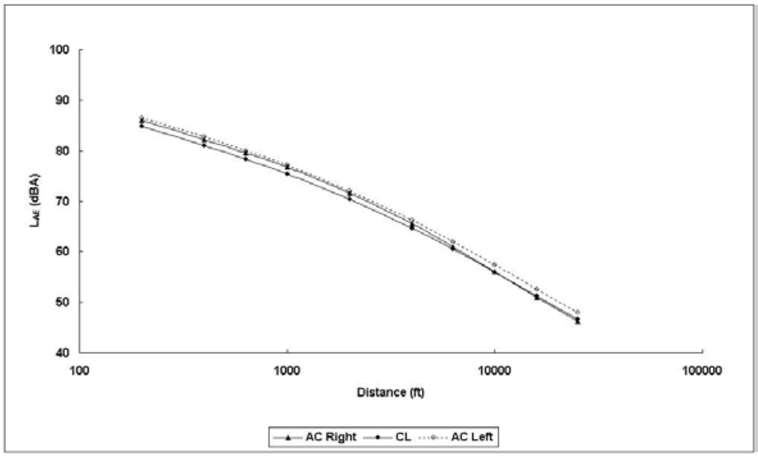

Figure E-51. R-22 210 Series L_{AE} Data (Ref. Spd. = 53 kts.)

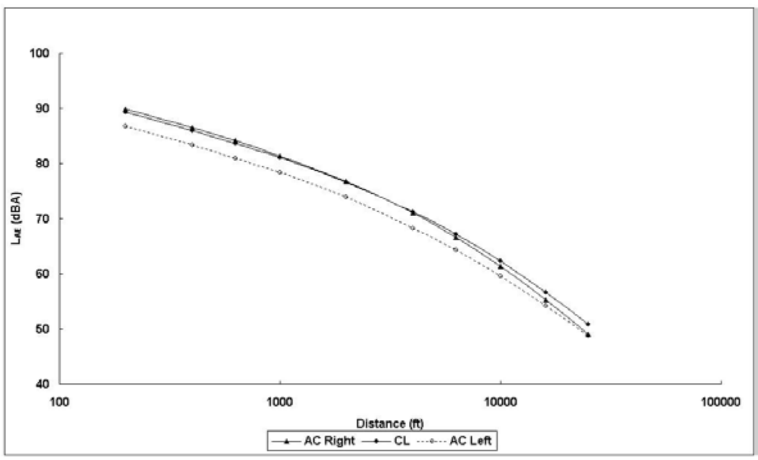

Figure E-52. R-22 310 Series L_{AE} Data (Ref. Spd. = 53 kts.)

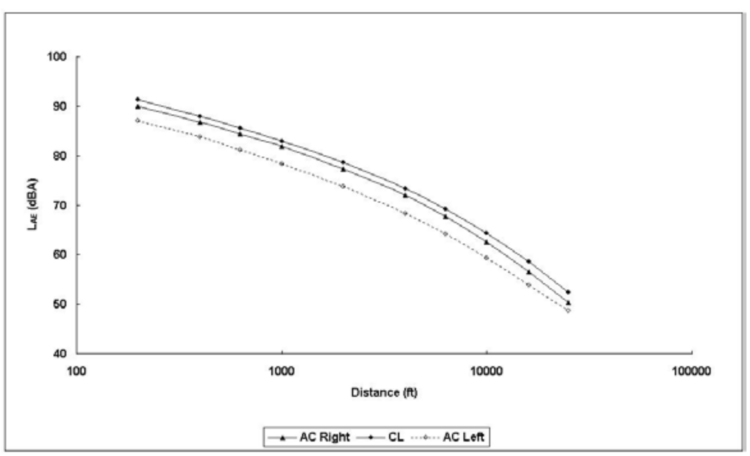

Figure E-53. R-22 320 Series L_{AE} Data (Ref. Spd. = 53 kts.)

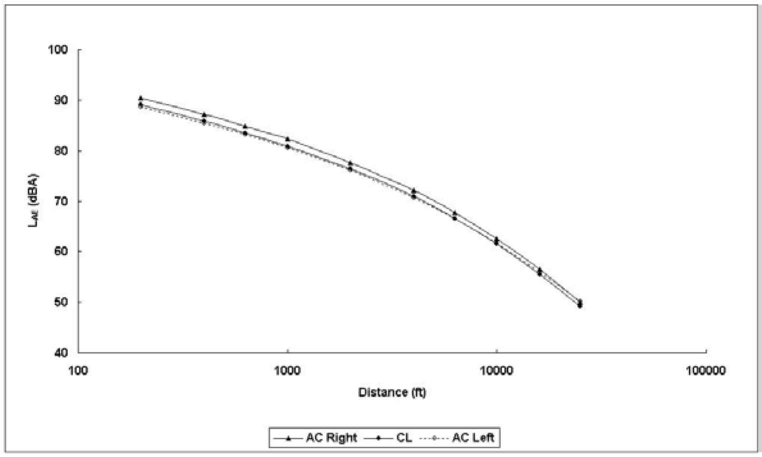

Figure E-54. R-22 330 Series L_{AE} Data (Ref. Spd. = 53 kts.)

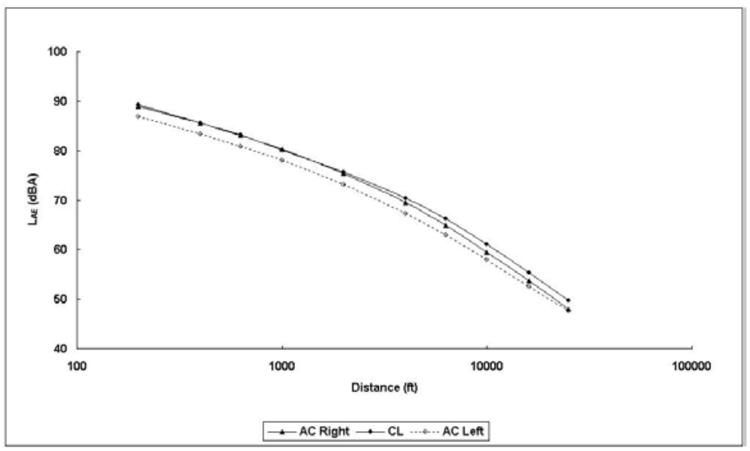

Figure E-55. R-22 340 Series L_{AE} Data (Ref. Spd. = 53 kts.)

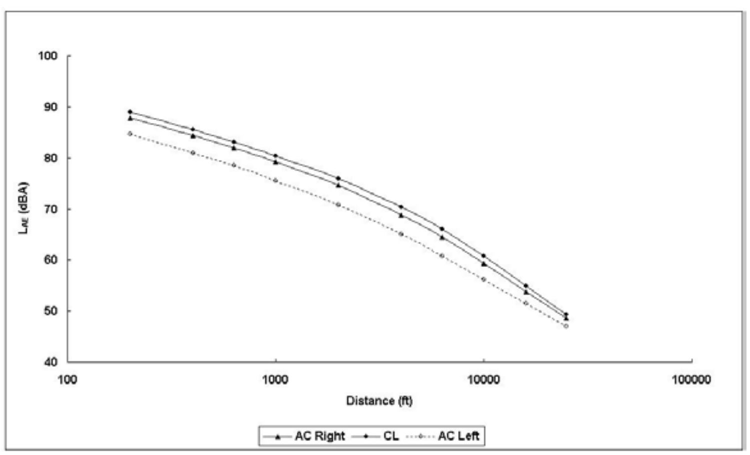

Figure E-56. R-22 350 Series L_{AE} Data (Ref. Spd. = 53 kts.)

E.3 Helicopter Hover Sound Level Data Tables

Helicopter Static Operations test events included Event 410, designed to measure HIGE, and Event 420, designed to measure HOGE. L_{Aeqt} and L_{PNTt} NPD data are presented for the helicopter hover noise at the initial L_0 position (see Figure 15 in Section 6.2 for a diagram of the helicopter sweep positions), as well as L_{Aeqt} and L_{PNTt} directivity data for off-reference orientations. For the EC-130 HIGE and HOGE events and the R-22 HIGE event, the time-period (t) is ten seconds; for the R-22 HOGE event, the time-period is six seconds.

E.3.1 Hover In-Ground Effect Data

In Tables E-29 and E-30, L_{Aeqt} and L_{PNTt} NPD data are presented for the EC-130 and R-22 HIGE helicopter noise at the initial L_0 position (see Figure 15 above for a diagram of the helicopter sweep positions).

E.3.1.1 Hover Noise-Power-Distance Curves

The HIGE reference altitude for both helicopters was five feet, measured from the bottom of the helicopter skids.

Table E-29. EC-130 HIGE longitudinal axis NPDs.

Reference orientation L_0 (see Figure 15)		
Dist. (ft)	**L_{Aeq10s}**	**L_{PNT10s}**
200	79.0	92.4
400	72.5	85.4
630	68.1	80.5
1000	63.4	75.2
2000	55.9	67.1
4000	47.6	58.2
6300	41.6	51.8
10000	35.2	44.3
16000	28.1	35.4
25000	20.6	16.2

Table E-30. R-22 HIGE longitudinal axis NPDs.

Reference orientation L_0 (see Figure 15)		
Dist. (ft)	**L_{Aeq10s}**	**L_{PNT10s}**
200	75.1	90.0
400	68.5	82.9
630	64.0	77.8
1000	59.1	72.2
2000	51.3	63.2
4000	42.9	53.9
6300	37.3	46.9
10000	31.4	38.7
16000	25.2	28.7
25000	18.7	6.7

E.3.1.2 Directivity Data

The A-weighted directivity adjustments to be applied to the above EC-130 and R-22 HIGE data for off-reference orientations are presented in Table E-31, along with the perceived level directivity adjustments, denoted by the symbols ΔL_{Aeqt} and ΔL_{PNTt}, respectively. These directivity adjustments may be added to the L_{Aeqt} and L_{PNTt} NPDs in Tables E-29 and E-30 to develop directivity adjusted NPDs for HIGE.

Table E-31. HIGE 360-degree directivity NPD adjustments.

180 R	165 L	150 L	135 L	120 L	105 L	90 L	75 L	60 L	45 L	30 L	15 L	L 0	15 R	30 R	45 R	60 R	75 R	90 R	105 R	120 R	135 R	150 R	165 R	180 R
EC-130 ΔL_{Aeq10s} (dB(A))																								
9.1	6.8	4.4	2.1	2.1	2.0	2.0	0.8	-0.3	-1.5	-1.0	-0.5	0.0	1.7	3.5	5.2	5.1	5.0	4.9	4.8	4.8	4.7	6.2	7.6	9.1
R-22 ΔL_{Aeq10s} (dB(A))																								
0.1	1.2	2.4	3.5	2.8	2.1	1.4	1.6	1.7	1.9	1.3	0.6	0.0	0.8	1.7	2.5	2.5	2.6	2.6	2.7	2.8	2.9	2.0	1.0	0.1
EC-130 ΔL_{PNT10s} (dB)																								
8.9	7.1	5.2	3.4	3.4	3.4	3.4	2.0	0.6	-0.8	-0.5	-0.3	0.0	1.8	3.6	5.4	5.5	5.7	5.8	5.7	5.6	5.5	6.6	7.8	8.9
R-22 ΔL_{PNT10s} (dB)																								
1.5	2.2	2.8	3.5	2.7	1.8	1.0	0.9	0.8	0.7	0.5	0.2	0.0	0.9	1.7	2.6	3.0	3.4	3.8	3.9	4.1	4.2	3.3	2.4	1.5

E.3.2 Hover Out-of-Ground Effect Data

In Tables E-32 and E-33, L_{Aeqt} and L_{PNTt} NPD data are presented for the EC-130 and R-22 HOGE helicopter noise at the initial L_0 position (see Figure 15 in Section 6.2 for a diagram of the helicopter sweep positions).

E.3.2.1 Hover Noise-Power-Distance Curves

The HOGE reference altitude for both helicopters was the main rotor diameter multiplied by 2.5. This resulted in reference altitudes of 88 ft for the EC-130 and 63 ft for the R-22, measured from the bottom of the helicopter skids.

Table E-32. EC-130 HOGE longitudinal axis NPDs (Ref. Alt. = 88 ft).

Reference orientation L_0 (see Figure 15)		
Dist. (ft)	**L_{Aeq10s}**	**L_{PNT10s}**
200	83.6	95.4
400	77.2	88.6
630	72.8	83.8
1000	68.1	78.6
2000	60.4	70.2
4000	51.4	61.1
6300	44.8	54.9
10000	37.5	47.6
16000	29.9	38.1
25000	22.5	23.1

Table E-33. R-22 HOGE longitudinal axis NPDs (Ref. Alt. = 63 ft).

Reference orientation L_0 (see Figure 15)		
Dist. (ft)	**L_{Aeq6s}**	**L_{Peq6s}**
200	80.3	94.3
400	73.7	87.2
630	69.0	82.3
1000	64.1	76.8
2000	55.8	67.3
4000	46.4	56.2
6300	39.7	48.6
10000	32.4	39.5
16000	25.1	25.4
25000	18.5	6.7

E.3.2.2 Directivity Data

The A-weighted directivity adjustments to be applied to the above EC-130 and R-22 HOGE data for off-reference orientations are presented in Table E-34 along with the perceived level directivity adjustments, denoted by the symbols ΔL_{Aeqt} and ΔL_{PNTt}, respectively. These directivity adjustments may be added to the L_{Aeqt} and L_{PNTt} NPDs in Tables E-32 and E-33 to develop directivity adjusted NPDs for HIGE.

Table E-34. HOGE 360-degree directivity NPD adjustments.

180 R	165 L	150 L	135 L	120 L	105 L	90 L	75 L	60 L	45 L	30 L	15 L	L 0	15 R	30 R	45 R	60 R	75 R	90 R	105 R	120 R	135 R	150 R	165 R	180 R
EC-130 ΔL_{Aeq10s} (dB(A))																								
6.4	5.6	4.8	4.0	4.5	5.0	5.5	5.2	4.9	4.6	3.1	1.5	0.0	0.3	0.7	1.0	0.6	0.3	-0.1	0.9	2.0	3.0	4.1	5.3	6.4
R-22 ΔL_{Aeq6s} (dB(A))																								
1.0	0.7	0.3	0.0	-0.1	-0.1	-0.2	-0.6	-1.1	-1.5	-1.0	-0.5	0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	0.3	0.8	1.4	1.3	1.1	1.0
EC-130 ΔL_{PNT10s} (dB)																								
6.4	6.1	5.9	5.6	5.9	6.2	6.5	6.1	5.7	5.3	3.5	1.8	0.0	0.8	1.7	2.5	2.2	2.0	1.7	2.9	4.2	5.4	5.7	6.1	6.4
R-22 ΔL_{PNT6s} (dB)																								
1.9	1.3	0.7	0.1	0.0	0.0	-0.1	-0.8	-1.5	-2.2	-1.5	-0.7	0.0	0.2	0.3	0.5	0.4	0.2	0.1	0.7	1.2	1.8	1.8	1.9	1.9

E.4 Helicopter Idle Data

The parameters for the helicopter Flight Idle and Ground Idle events are described in Table 15 in Section 4.3. The NPDs presented in Table E-35 were constructed using 10-second equivalent continuous A-weighted and perceived sound pressure levels, L_{Aeq10s} and L_{PNT10s}.

Table E-35. Helicopter idle NPD curves.

L_{Aeq10s}

	EC-130 Ground	EC-130 Flight	R-22 Ground	R-22 Flight
Dist. (ft)	**dB(A)**	**dB(A)**	**dB(A)**	**dB(A)**
200	64.7	74.5	59.2	69.4
400	58.1	68.0	52.9	63.1
630	53.7	63.5	48.6	58.9
1000	49.1	58.6	44.2	54.5
2000	41.9	50.8	37.5	47.7
4000	34.4	42.3	30.5	40.6
6300	29.2	36.5	25.6	35.7
10000	23.5	30.4	20.5	30.2
16000	17.0	23.7	15.0	24.1
25000	9.8	16.6	9.4	17.6

L_{PNT10s}

Dist. (ft)	dB	dB	dB	dB
200	79.9	88.7	76.7	85.0
400	72.8	81.6	69.1	78.1
630	67.4	76.7	63.7	73.3
1000	62.0	71.3	57.8	68.2
2000	53.0	62.3	47.1	59.8
4000	41.6	52.9	34.2	50.7
6300	33.6	45.7	23.9	43.9
10000	24.9	36.4	10.6	37.6
16000	6.0	26.8	6.1	28.0
25000	6.7	6.7	6.7	6.7

The L_{Aeq10s} and L_{PNT10s} HIGE directivity adjustments in Table E-31 may be applied to the EC-130 and R-22 Flight Idle and Ground Idle data for off-reference orientations. These directivity adjustments may be added to the NPDs in Table E-35 to develop directivity-adjusted NPDs for Flight Idle and Ground Idle.

APPENDIX F: SPECTRAL CLASS PROCESSING INFORMATION

The INM utilizes spectral data for some of its calculations, e.g., atmospheric absorption. Accordingly, representative spectral data are presented for each Dynamic Operations measurement series for which data were collected. Provided below is the 1,000-ft LFO, APP, and DEP adjusted spectral information used to determine each aircraft's LFO, APP, and DEP spectral classes. Each spectrum was generated from Dynamic Operations noise data collected during LFO, APP, and DEP events. These data were adjusted to 1,000 ft in VCAF's FAR 36 processing software, grouped by configuration and power settings, and arithmetically averaged together. Each spectrum has been normalized to 70.0 dB at 1,000 Hz per the methodology employed in Reference 7. The INM spectral class assignments determined for these aircraft are listed in Table F-1.

Table F-1. INM spectral class assignments.

Aircraft	Operation	Spectral Class Assignment
PA-30	DEP	113
	APP	213
	LFO	213
PA-31	DEP	109
	APP	213
	LFO	112
PA-28	DEP	113
	APP	213
	LFO	213
1900D	DEP	109
	APP	213
	LFO	NA
Maule	DEP	ND
	APP	ND
	LFO	112
EC-130	DEP	116
	APP	217
	LFO	303
R-22	DEP	115
	APP	217
	LFO	303

F.1 Piper Twin Comanche PA-30

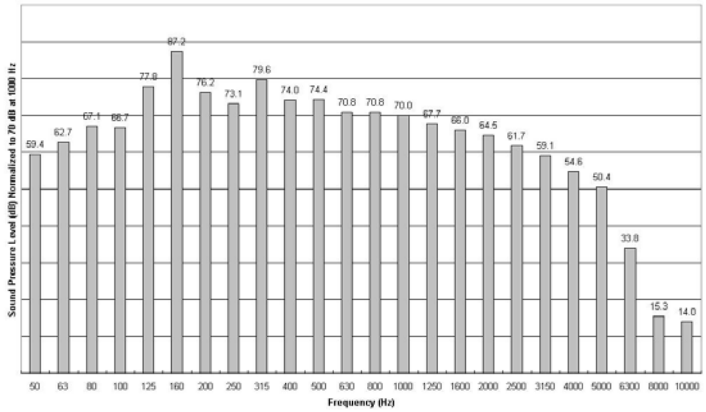

Figure F-1. PA-30 average 1000-ft 600 Series APP spectrum (normalized)

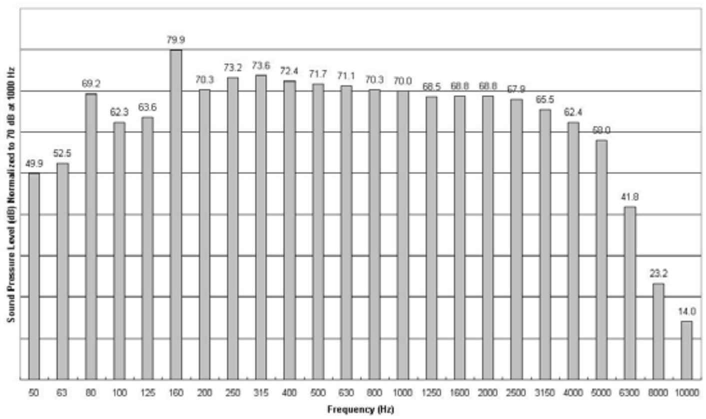

Figure F-2. PA-30 average 1000-ft 500 Series DEP spectrum (normalized)

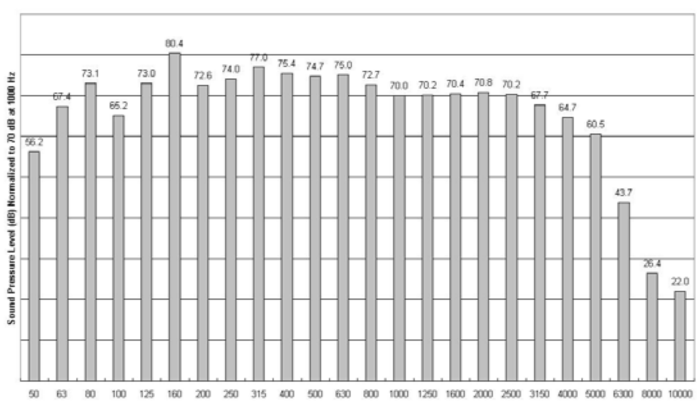

Figure F-3. PA-30 average 1000-ft 300 Series LFO spectrum (normalized)

F.2 Piper Navajo Chieftain PA-31-350

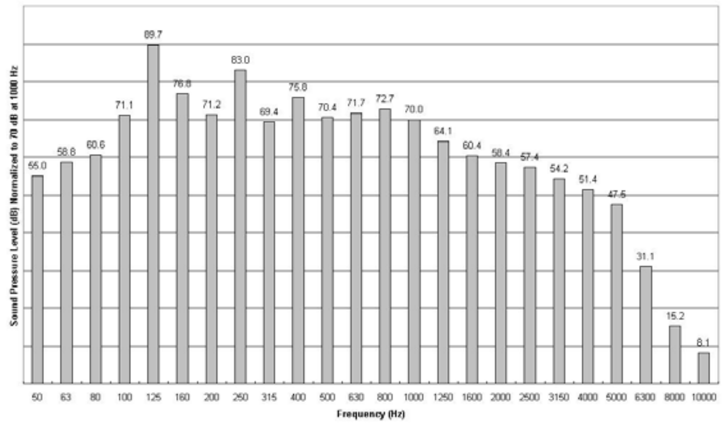

Figure F-4. PA-31 average 1000-ft 600 Series APP spectrum (normalized)

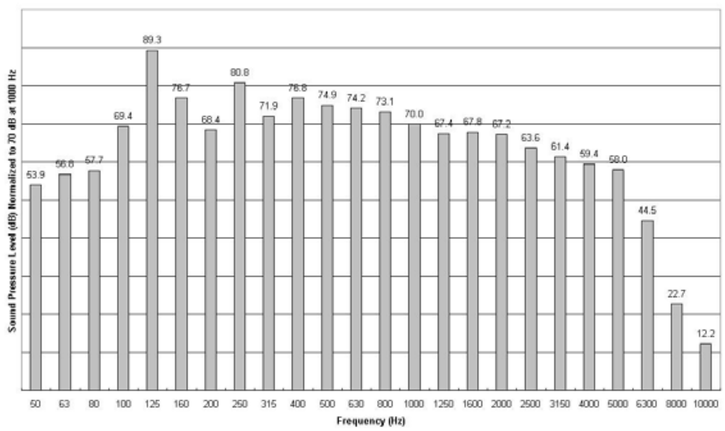

Figure F-5. PA-31 average 1000-ft 500 Series DEP spectrum (normalized)

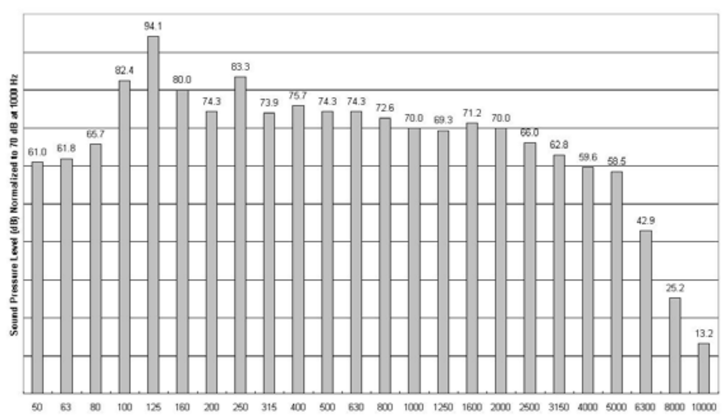

Figure F-6. PA-31 average 1000-ft 300 Series LFO spectrum (normalized)

F.3 Piper Warrior PA-28-161

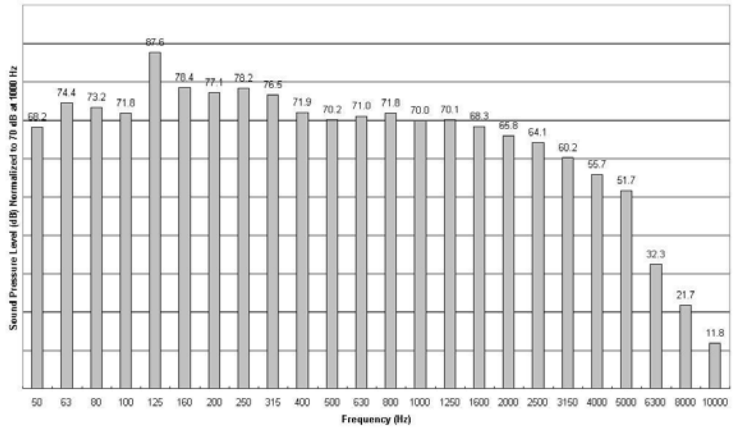

Figure F-7. PA-28 average 1000-ft 600 Series APP spectrum (normalized)

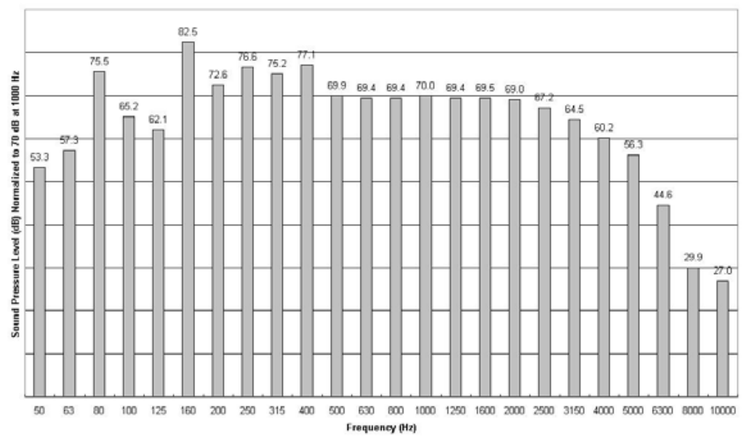

Figure F-8. PA-28 average 1000-ft 500 Series DEP spectrum (normalized)

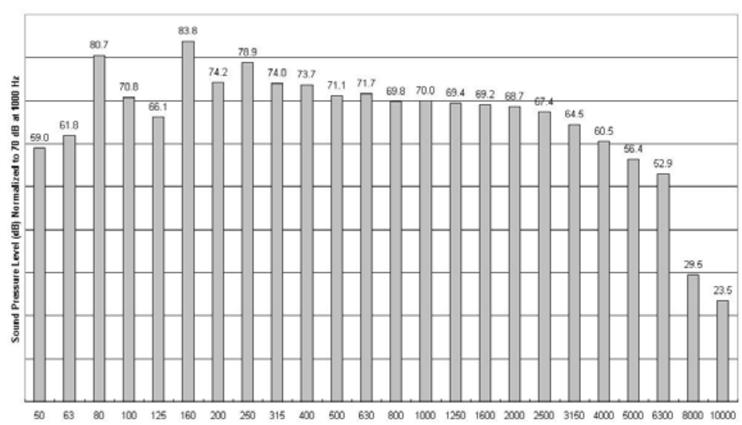

Figure F-9. PA-28 average 1000-ft 300 Series LFO spectrum (normalized)

F.4 Beech 1900D

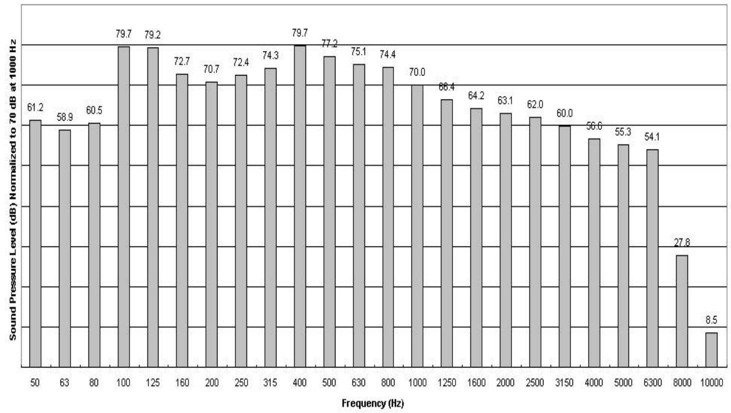

Figure F-10. 1900D average 1000-ft 600 Series APP spectrum (normalized)

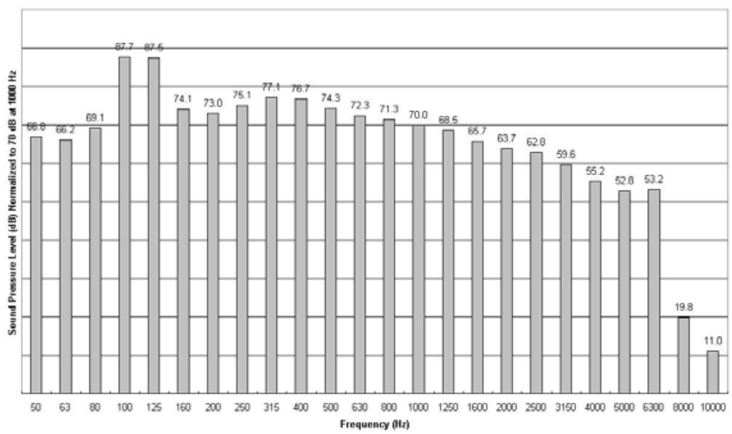

Figure F-11. 1900D average 1000-ft 500 Series DEP spectrum (normalized)

F.5 Maule M-7-235C

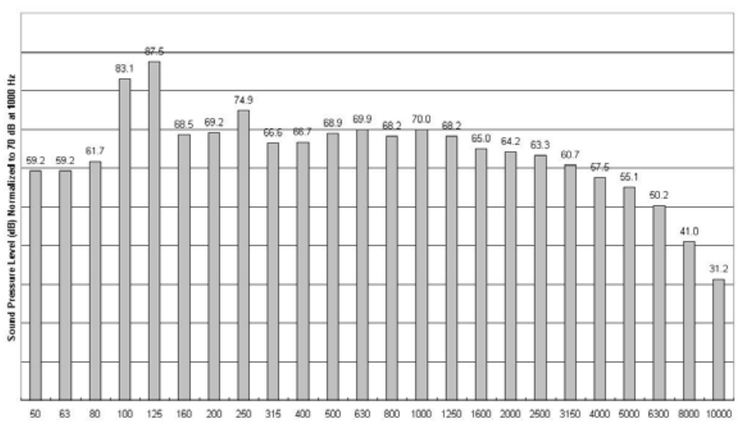

Figure F-12. Maule average 1000-ft 300 Series LFO spectrum (normalized)

F.6 Eurocopter EC-130

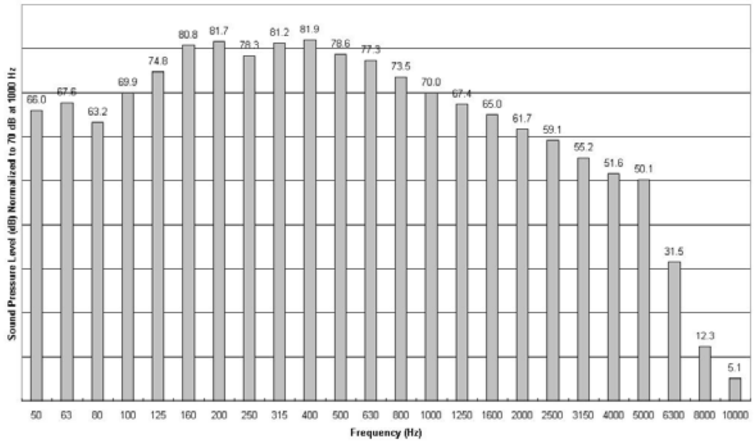

Figure F-13. EC-130 average 1000-ft 310 Series APP spectrum (normalized)

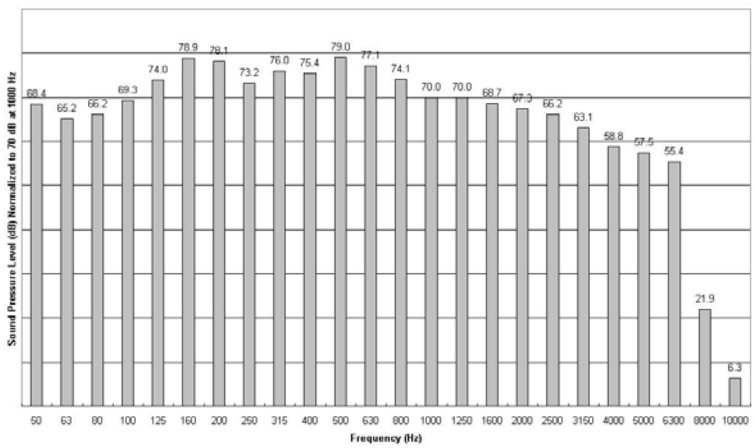

Figure F-14. EC-130 average 1000-ft 210 Series DEP spectrum (normalized)

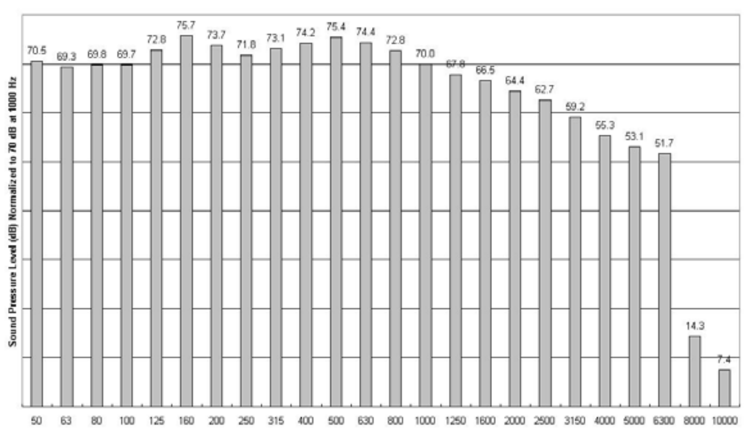

Figure F-15. EC-130 average 1000-ft 120 Series LFO spectrum (normalized)

F.7 Robinson R-22

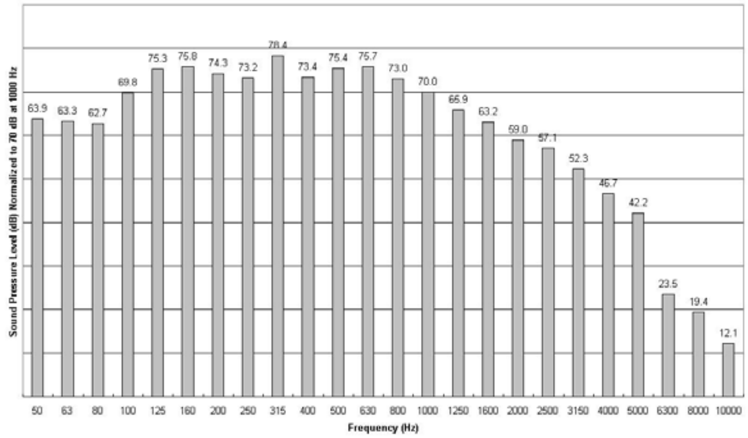

Figure F-16. R-22 average 1000-ft 310 Series APP spectrum (normalized)

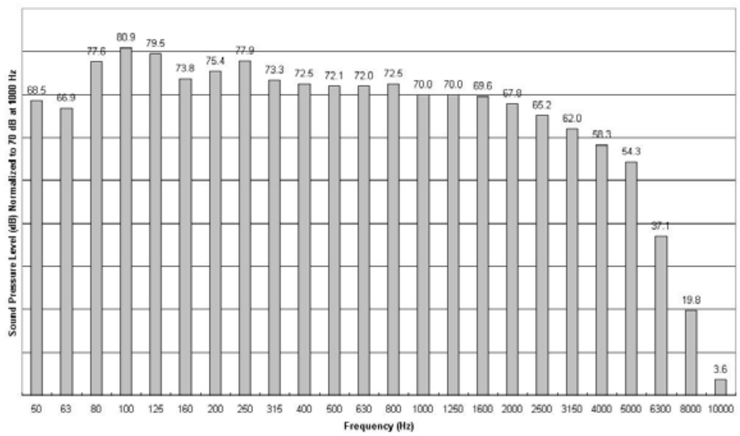

Figure F-17. R-22 average 1000-ft 210 Series DEP spectrum (normalized)

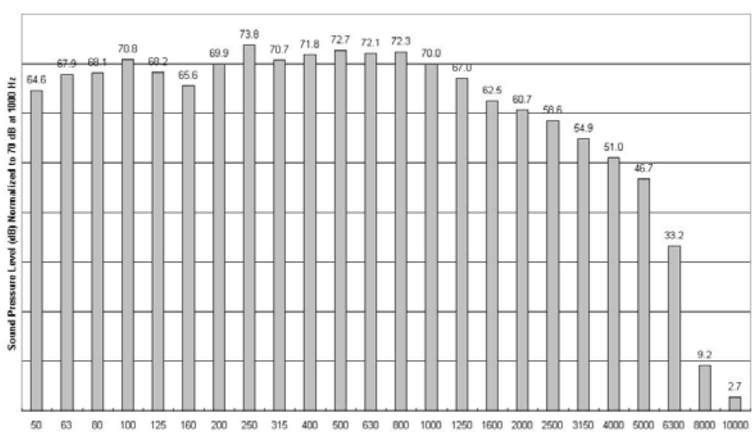

Figure F-18. R-22 average 1000-ft 120 Series LFO spectrum (normalized)

APPENDIX G: INM DATABASE TABLES

G.1 Propeller-Driven Aircraft Database File Formats

Instructions on how to build the necessary INM database tables, including AIRCRAFT.DBF, NOIS_GRP.DBF, NPD_CURV.DBF, PROFILE.DBF, PROF_PTS.DBF, PROCEDUR.DBF, FLAPS.DBF, and THR_PROP.DBF, can be found in Appendices E and F of the INM User's Guide (Reference 5). Included in the attached CD-ROM are completed versions of these files constructed using Fitchburg NPD data from Appendix E and the aircraft performance data presented for the Maule M-7-235C, Twin Comanche PA-30, Navajo Chieftain PA-31-350, Warrior PA-28-161, and Beech 1900D in Appendix A. As discussed in Section 6.0, each measurement series NPD was generated from Dynamic Operations noise data collected during one to six DEP, APP, or LFO events. These data were adjusted in VCAF's FAR 36 processing software, grouped by configuration and power settings, and arithmetically averaged together.

The INM 6.0 series (consist with SAE-AIR-1845) uses a single NPD set that varies only with power state. For this reason, the centerline NPD curve is selected as the representative NPD to calculate propeller-driven aircraft noise.

G.1.1 Database Table Notes

G.1.1.1 NPD_CURV.DBF Reference Speed Duration Adjustment

As discussed in Section 6.0, INM NPDs for exposure-based noise metrics are derived for a reference speed of 160 kts. The propeller-driven aircraft and helicopter NPD noise metric information contained in the NPD_CURV.DBF files described in this appendix and found on the included CD-ROM are the only data in this report which have been adjusted to a reference speed of 160 kts.

G.1.1.2 PROFILE.DBF Spectral Class Information

The spectral class information included in the PROFILE.DBF file is based on an analysis of adjusted 1,000-ft. spectra. These spectra, presented in Appendix F, consist of actual Fitchburg data, and, as discussed in Appendix F and Reference 7, are used by the INM to perform calculations which require spectral data, e.g., atmospheric absorption.

G.1.2 INM vs. As-Measured L_{AE} Data

As a check of reasonableness, centerline microphone field measurement data collected for the propeller-driven aircraft were compared with INM, Version 6.1 predictions for single event DEPs, LFOs, and APPs. The L_{AE} results from these sensitivity tests are presented in Figures G-1 through G-5. In general, there was very good agreement between the INM predictions and the as-measured data. The INM generally produced sound levels within about 2.0 dB(A) of the as-measured data.

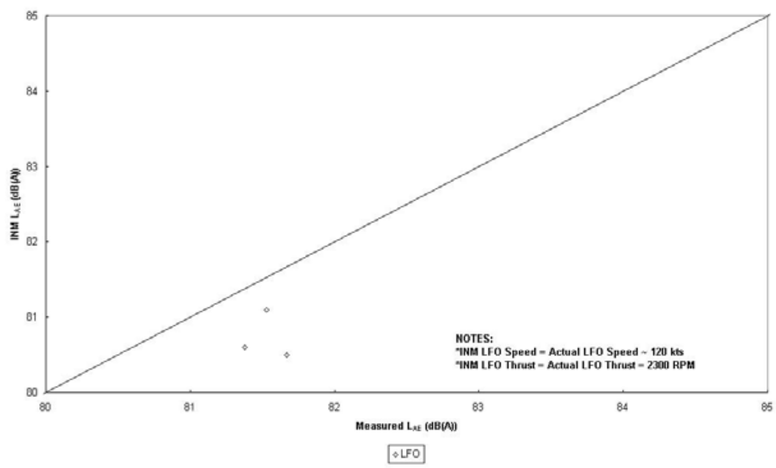

Figure G-1. Maule INM vs. Measured centerline L_{AE} comparison

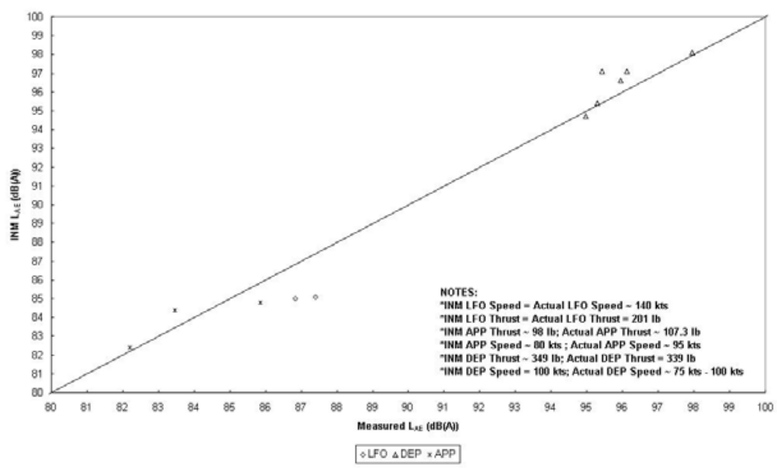

Figure G-2. PA-30 INM vs. Measured centerline L_{AE} comparison

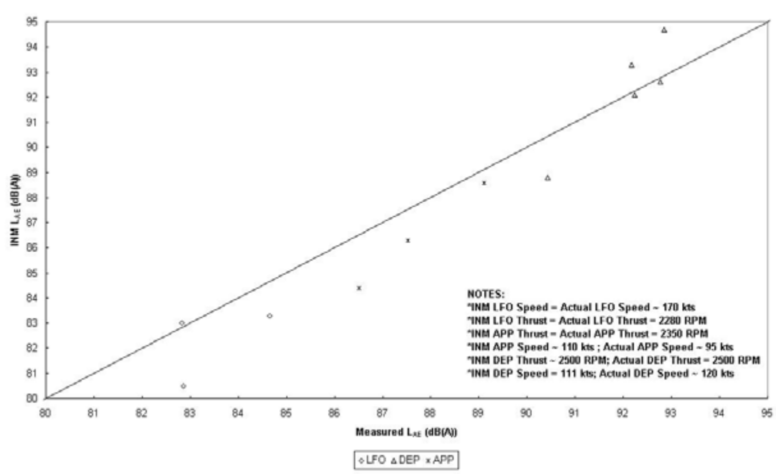

Figure G-3. PA-31 INM vs. Measured centerline L_{AE} comparison

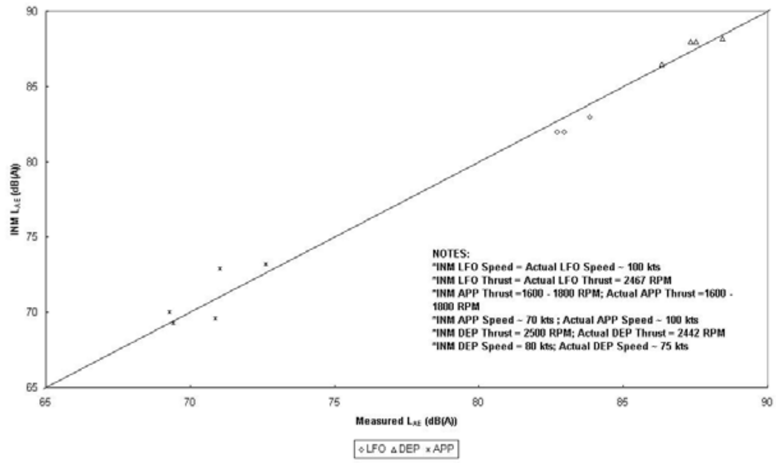

Figure G-4. PA-28 INM vs. Measured centerline L_{AE} comparison

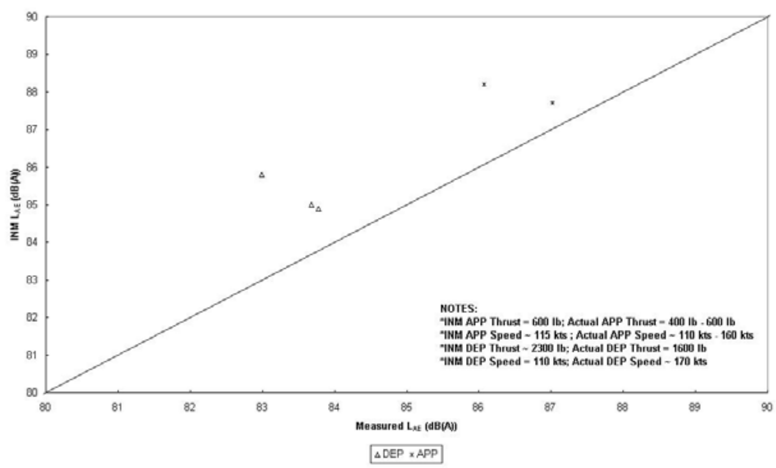

Figure G-5. 1900D INM vs. Measured centerline L_{AE} comparison

G.2 Helicopter Database File Formats

G.2.1 INM Version 6.1 vs. As-Measured L_{AE} Data

Database files containing helicopter NPD and performance characteristics data were distributed with INM Version 6.0c to facilitate simplified, uniform modeling of helicopter operations in INM. In keeping with the modeling technique used in the database file containing helicopter NPD data, nominal thrust settings (THR_SET) of 1, 2, and 3 were assigned to the three R-22 and EC-130 DEP, APP, and LFO NPDs contained in the Fitchburg NPD_CURV.DBF file. The characteristics of these NPDs are described in Table G-1.

Table G-1. Thrust setting identifiers in INM Fitchburg helicopter modeling.

	EC-130			R-22		
Operation Mode	**Thrust Setting**	**Ref. Speed (kts)**	**Ref. Descent Angle (degrees)**	**Thrust Setting**	**Ref. Speed (kts)**	**Ref. Descent Angle (degrees)**
APP	1	65 (V_Y[8])	-3	1	53 (V_Y)	-3
APP	2	65 (V_Y)	-6	2	53 (V_Y)	-6
APP	3	65 (V_Y)	-9	3	53 (V_Y)	-9
DEP[9]	1	65 (V_Y)	NA	1	53 (V_Y)	NA
DEP	2	65 (V_Y)	NA	2	53 (V_Y)	NA
LFO	1	113.4 (0.9*V_H[10])	NA	1	91.8 (0.9*V_H)	NA
LFO	2	113.4 (0.9*V_H)	NA	2	91.8 (0.9*V_H)	NA
LFO	3	113.4 (0.9*V_H)	NA	3	91.8 (0.9*V_H)	NA

Centerline microphone field measurement data collected for the Eurocopter EC-130 and Robinson R-22 helicopters were compared with INM, Version 6.1, predictions for single event DEPs, LFOs, and APPs. The L_{AE} results from these sensitivity tests are presented in Figures G-6 and G-7. Excellent agreement is illustrated between the INM predictions and the as-measured data. The INM generally produced sound levels within about 2.0 dB(A) of the as-measured data.

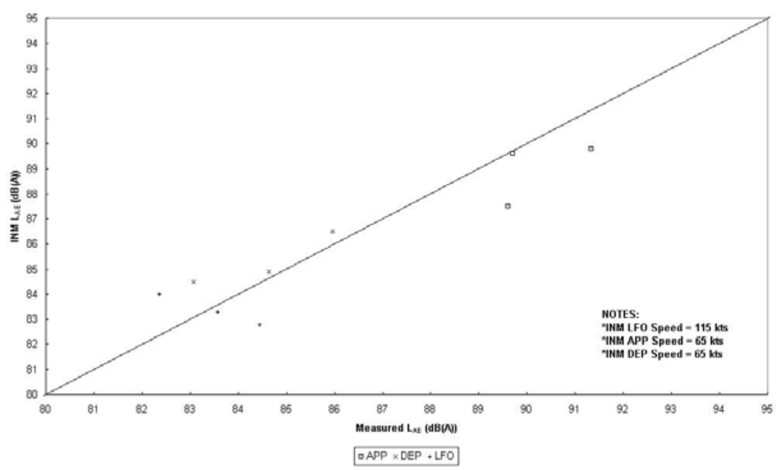

Figure G-6. EC-130 INM vs. Measured centerline L_{AE} comparison

8 V_Y = speed for best rate of climb, 65 kts for the EC-130 and 53 kts for the R-22

9 Though the INM requires at least two departure NPD curves, only one departure NPD curve was measured. Therefore, the departure NPD curve was duplicated in the INM.

10 V_H = maximum speed in level flight with maximum continuous power, 126 kts for the EC-130 and 102 kts for the R-22

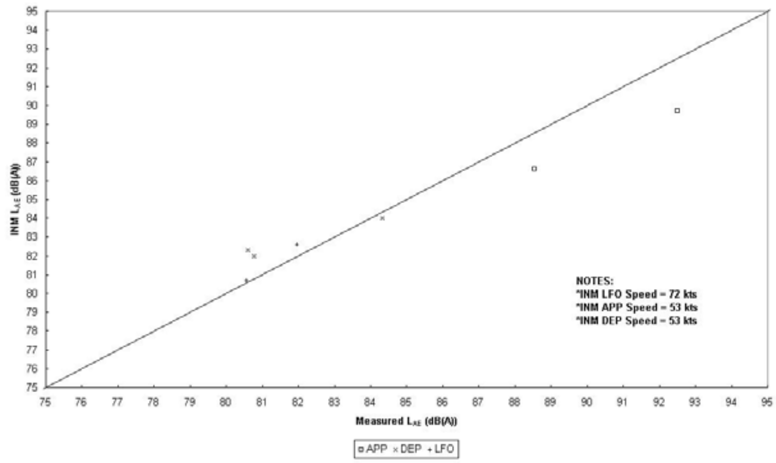

Figure G-7. R-22 INM vs. Measured centerline L_{AE} comparison

G.2.2 Helicopter Data for INM 7.0

Consistent with the data collected in the Rainbow reports (Reference 9), INM 7.0 will include data identified in Section 4.0 of this report. This includes additional NPDs to account for directivity, 360-degree directivity patterns for static operations, and a blade tip mach number correction to account for source noise effects directly related to speed. DIRECTIVITY.DBF, HELICOPTER.DBF, and NPD_HELO.DBF are database files containing helicopter-specific noise and operational data. These database files were developed using EC-130 and R-22 noise NPDs and hover noise and performance data, and have been included in Appendix G for completeness. As with the propeller-driven aircraft NPDs, each helicopter measurement series NPD was generated from Dynamic Operations noise data collected during one to six DEP, APP, or LFO events. These data were adjusted in VCAF's FAR 36 processing software, grouped by configuration and power settings, and arithmetically averaged together according to the procedures given in Section 5.0. NPD_HELO.DBF includes left-side, center, and right-side NPDs, which will be fully utilized in INM 7.0.

APPENDIX H: ACRONYMS AND ABBREVIATIONS

AFE	Airport Field Elevation
AGL	Above Ground Level
APP	Approach
ASCII	American Standard Code for Information Interchange
DAT	Digital Audio Tape
dB	Decibel, a unit of noise level or noise exposure level
dB(A)	Decibel with A-weighting applied
DBF	dBase IV database file format
DEP	Departure
EPR	Engine Pressure Ratio
FAA	Federal Aviation Administration
FIT	Fitchburg Municipal Airport
FPM	Feet Per Minute
ft	Feet
GLB	GLB Electronics, Inc. (Buffalo, New York)
HNM	Heliport Noise Model
hp	Horsepower
hr	Hour
IAS	Indicated Airspeed
IFR	Instrument Flight Rules
in-Hg	Inches of Mercury
INM	Integrated Noise Model
ISA	International Standard Atmosphere
KCAS	Knots Calibrated Airspeed
KIAS	Knots Indicated Airspeed
KTAS	Knots True Airspeed
kts	Knot(s)
$\mathbf{L_{AE}}$	Sound exposure level
$\mathbf{L_{Aeqt}}$	Time-period, equivalent, continuous, A-weighted sound pressure level
$\mathbf{L_{ASmx}}$	Maximum, slow-scale, A-weighted sound level
lb	Pound(s) force or weight
$\mathbf{L_{EPN}}$	Effective perceived noise level
LFO	Level Flight
$\mathbf{L_{PNTSmx}}$	Tone-adjusted, maximum, slow-scale, perceived noise level
$\mathbf{L_{PNTt}}$	Time-period, equivalent, continuous, perceived noise level
MAP	Manifold Pressure
MGTW	Maximum Gross Takeoff Weight
mm	Millimeter
MSL	Mean Sea Level
N1	Low pressure rotor speed as a percentage of a reference speed
nmi	Nautical Miles
NPD	Noise-Power-Distance
NPS	National Park Service
ROC	Rate of Climb

RPM	Revolutions Per Minute
RWY	Runway
s	Second
TAMS	Transportable Automated Meteorological Station
TSPI	Time-Space-Position Information
VCAF	Volpe Center Acoustics Facility
VFR	Visual Flight Rules
$\mathbf{V_H}$	Maximum speed in level flight with maximum continuous power (kts)
Volpe	John A. Volpe National Transportation Systems Center
$\mathbf{V_Y}$	Speed for best rate of climb (kts)