Appendix D
Aviation Noise Fundamentals

ESA

AVIATION NOISE FUNDAMENTALS

While a great deal is known about aircraft noise, the methods for calculating noise exposure can be difficult to understand. The following describes what noise is and explains how certain measures of noise relate to one another.

Sound and Noise Definitions

Sound is a complex vibration transmitted through the air, which, upon reaching our ears, may be perceived as being beautiful, desirable or unwanted. Sound moves outward from its point of origin in waves just as ripples move outward from the point at which a pebble enters a pond.

Noise is generally defined as any unwanted sound. For example, sound that is music to one person can be "noise" to another person. In the case of the sound of aircraft arriving and departing an airport, the aircraft sound is almost always unwanted and intrusive enough to be considered noise.

The process of quantifying the effects of sound exposure begins with establishing a unit of measure that accurately compares levels of sound. The physical unit most commonly used to describe sound levels is the decibel (dB). The dB represents a relative measure or ratio to a reference pressure. This reference pressure is a sound that approximates the weakest sound that can be heard by a person with very good hearing in an extremely quiet room. If a scale in dB is established with zero as the threshold of hearing for the weakest sound, then the strongest sound within the range of the human ear would be around 130 dB.

The dB scale is a logarithmic scale increasing by the power of ten which means that 10 dB has ten times greater energy than 1 dB, 20 dB is one hundred times more energy than 1 dB and 30 dB is a thousand times greater. However, for this study, the differences between relative sound energy and perceived loudness are more meaningful than the differences in sound power levels. For example, a single event noise of 70 dB is perceived to be twice as loud as 60 dB and 80 dB is four times louder than 60 dB. Again, using 60 as the reference noise level, 50 dB is perceived by the listener to be half as loud.

Throughout this section, four noise metrics are used in describing noise exposure – dBA, SEL, Lmax, and DNL. Definitions of each of these descriptors are described below.

A-Weighted Sound Level (dBA)- A-weighted sound is a sound pressure level, which has been filtered or weighted to reduce the influence of the low and high extremes. Unweighted sound pressure levels do not correlate well with human assessment and response to noise loudness. As a result, a variety of techniques to filter sound have been developed. A-weighting has been found to correlate well with the human hearing response and with a person’s subjective judgment of the loudness of sounds. A-weighting gives greater emphasis to the sounds in the speech important frequency bands and less emphasis to the lower and higher frequencies. A-weighting is widely used and almost universally accepted in analyzing noise and its affects on people.

Sound Exposure Level (SEL) - SEL is a noise metric derived from the noise energy dose of a single sound event such as a single aircraft overflight or a single vehicle or train compressed to a single second of exposure. As such, the SEL reflects both the maximum sound level and the duration, or length of time, of the sound event.

Lmax - This value represents the maximum sound level detected by an aircraft overflight or over the course of a noise monitoring session.

Equivalent Sound Level (Leq) - Leq, is the energy average noise level over a specified time. This approach is normally employed for durations of 1 hour, 8 hours or a 24 hour period. Equivalent signifies that the total acoustical energy associated with the fluctuating sound (during the specified time period) is equal to the total acoustical energy associated with the steady sound level of Leq for the same specified period of time. The purpose of Leq is to provide a single number measure of noise averaged over a set time period.

Day Night Average Sound Level (DNL) – DNL was developed as a single number measure of community noise exposure. DNL was introduced as a simple method for predicting the effects on a population of the average long-term exposure to noise. DNL is an enhancement of the Equivalent Sound Level (Leq) metric through the addition of a 10 dB penalty for nighttime (10 p.m. to 7 a.m.) noise intrusions. The incorporation of the 10 dB penalty is in recognition of the increased annoyance that is generally associated with noise during the late night and early morning. DNL employs the same energy equivalent concept as Leq and uses a 24 hour time integration period. DNL was developed under Environmental Protection Agency (EPA) auspices, and embodies extensive information regarding the physical description of noise as related to human acceptability in residential areas. The basic elements and concepts of DNL are as follows:

- Frequency Weighting - Use of the standard A-weighting, which most closely reflects the response to the human ear.
- Time-of-Day Weighting - The 10 dB nighttime penalty accounts for greater sensitivity to noise and/or lower background levels at night.
- Energy Averaging - The energy-mean is the best general single-number description of sound level that varies with time, in terms of average community response.

Computation of DNL - In calculating DNL, the Leq level is used as the hourly equivalent sound level. The hourly noise figures are summed for the 15 hours of daylight (7 a.m. to 10 p.m.) and added to the sum of Leq hourly figures for the remaining 9 hours of nighttime with a 10 dB penalty added to the nighttime figures (to reflect added human sensitivity to nighttime noise). The result is the DNL noise level or a 24 hour summary of noise levels for a given location. When aircraft noise contours are calculated, however, the noise levels are solely due to the aircraft and do not include background or ambient noise levels. In 1981, the FAA formally adopted DNL as the single system for determining exposure of individuals to aircraft noise. The use of DNL as the most appropriate measure of noise and its affect on persons was reconfirmed in the early 1990's after careful re-consideration by the Federal Interagency Committee on Urban Noise (FICON). DNL is the most widely accepted descriptor for aviation noise because of the following characteristics:

- DNL is a measurable quantity.
- DNL provides a simple method to compare the effectiveness of alternative airport scenarios.
- DNL can be understood by those who are not familiar with acoustics or acoustical theory.
- DNL is a measure that can describe a community's reactions to environmental noise.

The emergence of DNL as the standard descriptor of aviation noise in land use compatibility planning is due chiefly to the efforts of the EPA. In the spring of 1973, in an effort to comply with the Noise Control Act of 1972, EPA convened a task group with the function to "consider the characterization of the impact of airport community noise and to develop a community noise exposure measure." To accomplish this, the task group had to: determine the merits and shortcomings of methods to characterize the impact of the noise of present or proposed airport operations on the public health and welfare; determine which of such methods is most suitable for adoption by the Federal Government; and determine the implications of issuing Federal regulations establishing a standard method of characterizing the aviation noise, and of specifying maximum permissible levels for public health and welfare.

In 1976, the EPA formally recommended that FAA adopt DNL as the standard aircraft noise descriptor. FAA's decision to adopt DNL was also based on a number of other factors. In 1980, the Federal Interagency Committee on Urban Noise consolidated Federal guidance on the incorporation of noise considerations in local land planning and site review "to encourage noise sensitive development, such as housing, to be located away from major noise sources." The Committee adopted DNL as the best descriptor of noise for land use planning and established related land use compatibility guidelines. In the same year, the Acoustical Society of America developed an American National Standard (ANSI S3.23) which specified DNL as the acoustical measure to be used in assessing compatibility between various land uses and the outdoor noise environment.

Stage Length

An aircraft's "stage length" (or trip length) refers to the distance an aircraft flies to its next destination after departing an airport. The stage length is important in noise modeling, since the longer the distance an aircraft will travel to its next destination the greater its fuel load and overall weight and, as a result, the lower its departure profile will be. Stage lengths used in the INM include the following ranges:

Stage length 1 – 0 to 500 miles
Stage length 2 – 500 to 1000 miles
Stage length 3 – 1000 to 1500 miles
Stage length 4 – 1500 to 2500 miles
Stage length 5 – 2500 to 3500 miles
Stage length 6 – 3500 to 4500 miles

Comparative dBA Sound Level*s*

Table A-1, taken from the Aviation Noise Effects report, provides a general comparison of dBA noise levels experienced in daily life and industry situations. The table indicates ranges of from 20 to over 100 dBA.

TABLE A-1
Typical Decibel (dBA) Values Encountered in Daily Life and Industry

Activity	dBA
Room in a quiet dwelling at midnight	32
Soft whispers at 5 feet	34
Window air conditioner	55
Conversational speech	60
Household department of large store	62
Busy restaurant	65
Vacuum cleaner in private residence (at 10 feet)	69
Ringing alarm clock (at 2 feet)	80
Loudly reproduced orchestral music in large room	82
Printing press plant	86
Heavy city traffic	92
Heavy diesel-propelled vehicle (about 25 feet away)	92
Air grinder	95
Home lawn mower	98
Turbine condenser	98
150 cubic foot air compressor	100
Banging of steel plate	104
Air hammer	107

*When distances are not specified, sound levels are the value at the typical location of the machine operator.
Source: Aviation Noise Effects Report No. FAA-EE-85-2

Variability of Human Responses to Noise

The extent of annoyance caused by a specific noise event may be extreme for one person and non-existent for another person exposed to the exact same event at the same time. Thus, if there is one given about noise analysis, it is that human response to noise is subject to considerable natural variability. Extensive research has been conducted over the past 35 years to try to identify factors that contribute to the variation in human reaction to noise. Knowing what these variables are helps explain why it is not possible to simply state that a given noise level from a given noise source will result in a particular reaction by an individual. What the research has revealed is that an individual's attitude, beliefs, mood and values may greatly influence whether a particular person perceives a particular sound to be annoying or not. The following list provides a number of the emotional variables that have been found to influence a person's reaction to noise.

- <u>Feelings about the Necessity or Preventability of the Noise</u> If people feel that their needs and concerns are being ignored, they are more likely to feel hostile towards the noise source. If people feel that those creating the noise care about their welfare and are doing what they can to mitigate the noise, they are usually more tolerant of the noise and able to accommodate higher noise levels.

- <u>Judgment of the Importance and Value of the Activity Producing the Noise</u> If the noise is produced by an activity which people feel is vital, they are often less bothered by it as they would be if the noise-producing activity is considered superfluous. For example, high noise levels of emergency vehicles is acceptable while high noise from a car stereo boom box is perceived as an annoyance.

- <u>Feeling of Fear Associated with the Noise</u> The extent to which an individual fears physical harm from a source of noise will affect the person's attitude toward the source of noise.

- <u>General Sensitivity to Noise</u> People vary in their ability to hear sound, their physiological predisposition to noise and their emotional experience of annoyance to a given noise.

- <u>Predictability of the Noise</u> Individuals exposed to unpredictable noise have a lower tolerance than those exposed to predictable noise.

- <u>Control Over the Noise Source</u> A person who has no control over the noise source will be more annoyed than one who is able to exercise some control.

All of the items listed need to be kept in mind when considering the response of persons to noise. It needs to be noted that in some cases the actual concern may not even be the noise source, but may be associated with one or more of the emotional variables that influence a person's mood or attitude at the time of a noise event.