2.0 AIRCRAFT NOISE LEVELS

The FAR Part 150 process requires a thorough examination of the airport noise environment and depiction of aircraft noise levels on a map that represents the airport area's exposure to noise. This chapter describes the standardized units for noise measurement, computer modeling of aircraft-generated noise levels, and community response to noise.

2.1 MEASUREMENT OF SOUND

Simply defined, sound is sensation perceived by the sense of hearing. Sound may be considered beautiful, desirable, or unwanted, depending on the listener's point of view. A number of variables are used to describe sound, these include amplitude (loudness), frequency (pitch), and duration.

2.1.1 Amplitude

Amplitude, measured in decibels (dB), is commonly referred to as loudness. Decibels are logarithmic units.[1] Thus, a 10-dB increase in a sound seems twice as loud to the listener, while a 10-dB decrease seems only half as loud. Amplitude can easily be measured with the aid of a sound level meter that corresponds to the decibel scale.

2.1.2 Frequency

Frequency is measured in cycles per second or Hertz (Hz), and is defined as the number of sound waves per second of an alternating current. The greater number of Hz, the higher the frequency is. Sounds with energy concentration between 2,000 Hz and 8,000 Hz are perceived to be louder than sounds of equal sound pressure level at lower frequencies.[2] Therefore, scientists have developed an A-weighted scale that reduces the relative weighting of lower frequency sounds in the overall weighted measure. This measurement of sound, referred to as dBA, is the standard established by the FAA for FAR Part 150 Noise Studies. This refined measurement of sound, more closely measures people's perception of sound levels.[3] A listing of common sounds and their respective dBA levels is provided in **Exhibit 2.1-1.**[4]

2.1.3 Duration

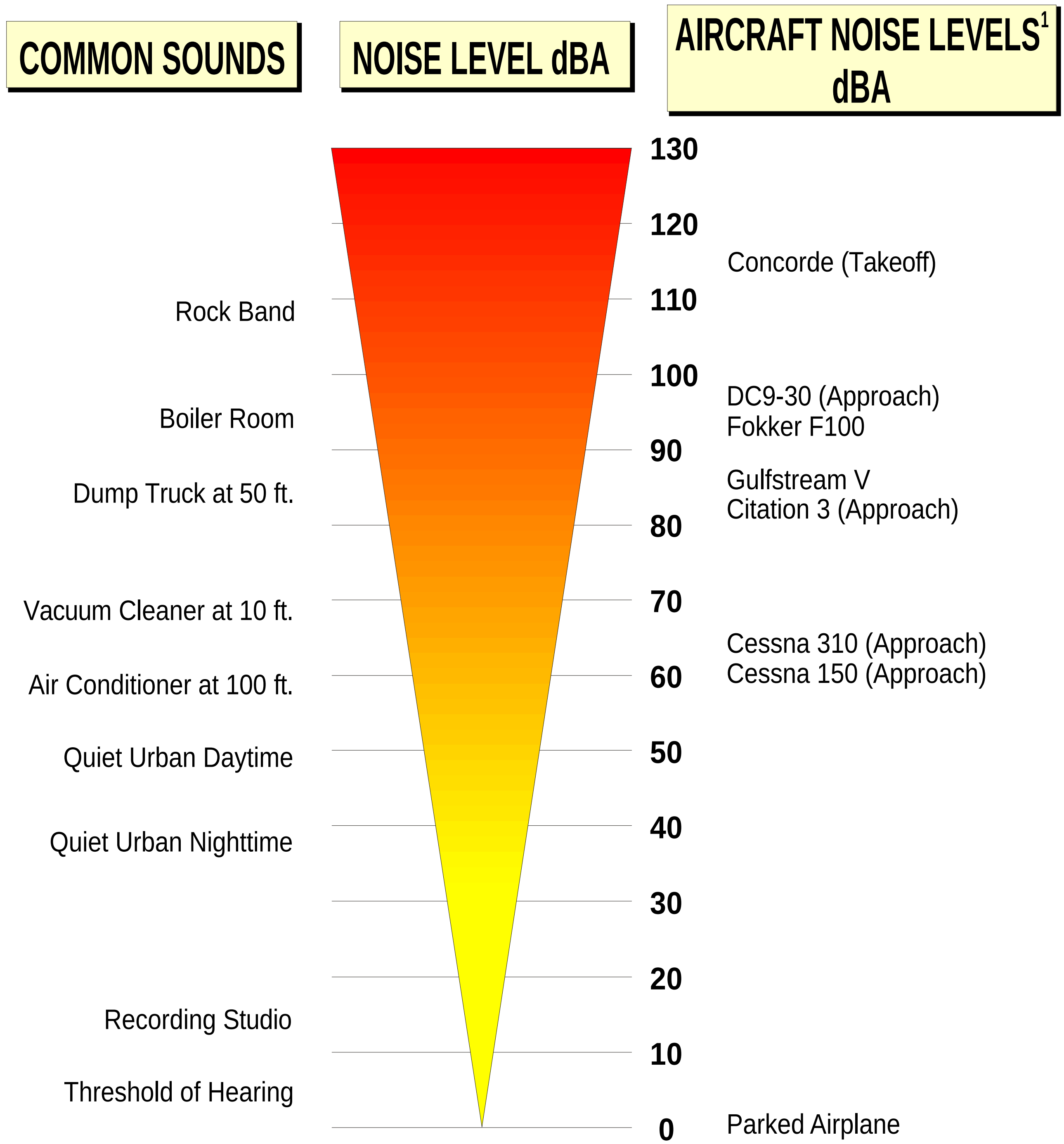
A final characteristic of sound is its duration, or how long it lasts. As an airplane is approaching the observer, its sound reaches a maximum level as it flies directly overhead and then diminishes as the plane moves away. This change in sound pressure level can be illustrated as a bell-shaped curve.

2.2 MEASUREMENT OF NOISE

Noise is defined as unwanted sound; an undesirable by-product of society's normal day-to-day activities. How loud a sound is, what frequency the sound is, and how long a sound lasts is what causes a sound to be perceived as noise. Noise is emitted from many sources, including factories, railroads, power generation plants, highway vehicles, and aircraft. Aircraft noise is a composite of noises that an aircraft makes, including the roar of jet exhaust and fan noise produced by rotating blades inside jet engines and propeller pitch power settings associated with propeller driven aircraft.

The airport noise environment is comprised of a series of individual aircraft operations, including arrivals, departures, taxiing, overflights, and engine run-ups. These operations may occur frequently or sporadically. The airport noise environment, including aircraft operations and ambient noise, is best described using three noise metrics. These metrics are particularly important in understanding the aircraft noise analysis for the Airport:

- Sound Exposure Level
- Equivalent Sound Level
- Day-Night Average Sound Level



[1]Noise Levels Measured for Flyovers at 500 Feet Altitude
Adapted from information contained in the
Federal Interagency Committee on Noise (FICON)
Technical Report, August 1992.

CINCINNATI MUNICIPAL-LUNKEN AIRPORT PART 150 STUDY	COMMON SOUNDS AND THEIR dBA	EXHIBIT 2.1-1

2.2.1 Sound Exposure Level (SEL)

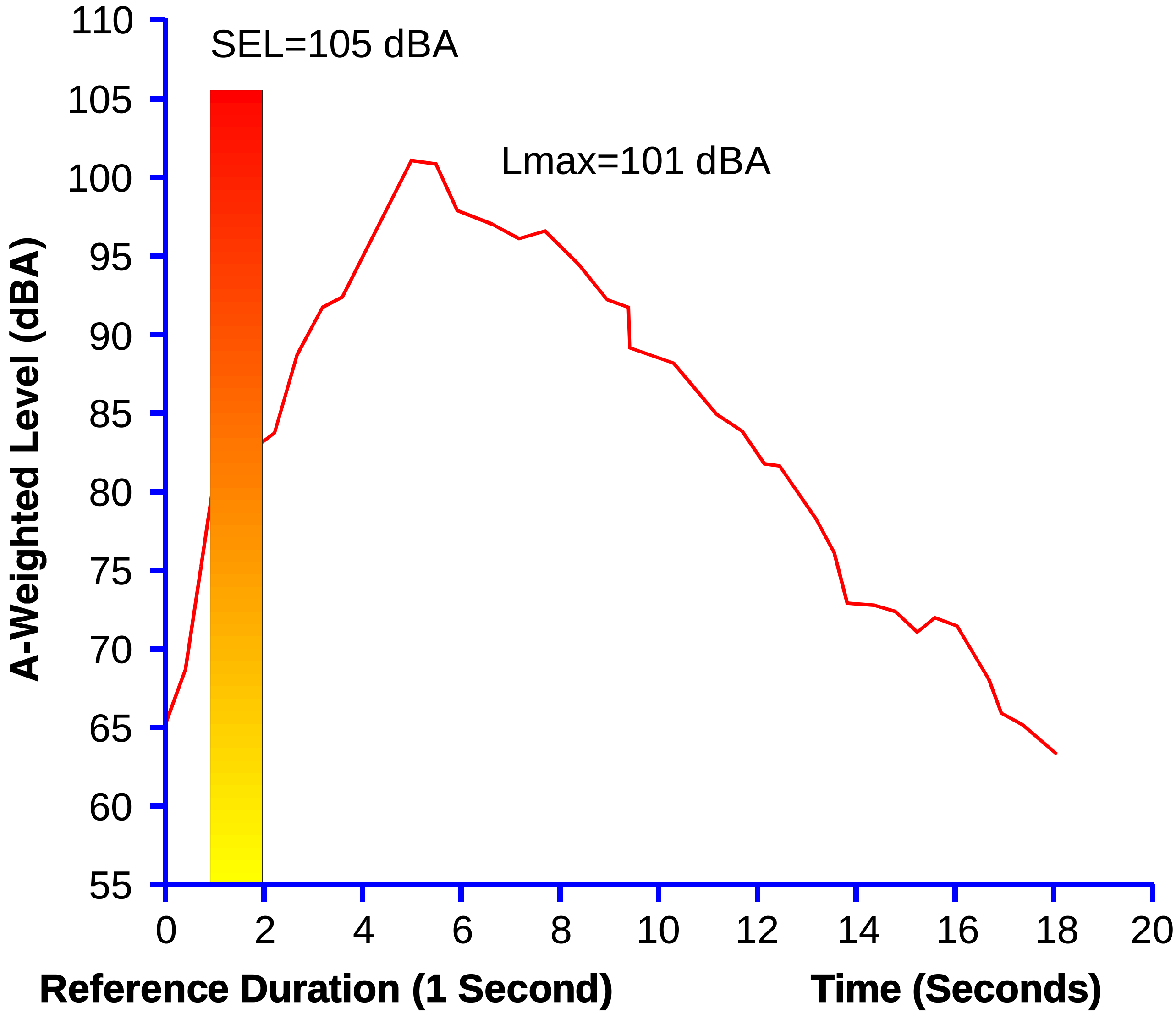
Sound Exposure Level is a measure of the A-weighted total sound energy of a single noise event, such as an aircraft flyover, represented as the A-weighted decibel level of that event including its intensity, frequency, and duration. This measure is normalized to reference duration of one second so that noise events of different duration's can be compared.

The SEL concept is illustrated in **Exhibit 2.2-1**.[5] As shown, the noise level rises to a peak and then subsides to the ambient or background noise level. The energy under the curve and the energy in the SEL have the same total weighted sound energy when integrated over time. This measure is very helpful in computing equivalent sound level and day-night sound level, which are typically used in aircraft noise model calculations.

2.2.2 Equivalent Sound Level (Leq)

The single value of sound level calculated for a given period of time is the Leq. This metric is A-weighted and accounts for all of the sound energy occurring during a particular period of time (i.e., one minute, one hour, one day, etc.). Leq includes "peak" sounds as well as "valleys" within a particular time frame. The purpose of Leq is to identify the average noise level over a period of time. Leq is easily measured with sound equipment.

Typical sounds one might hear in a quiet residential neighborhood are illustrated in **Exhibit 2.2-2**.[6] As shown, these sounds would produce a sound level of approximately 58 Leq.



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SOUND EXPOSURE LEVEL CONCEPT

EXHIBIT 2.2-1

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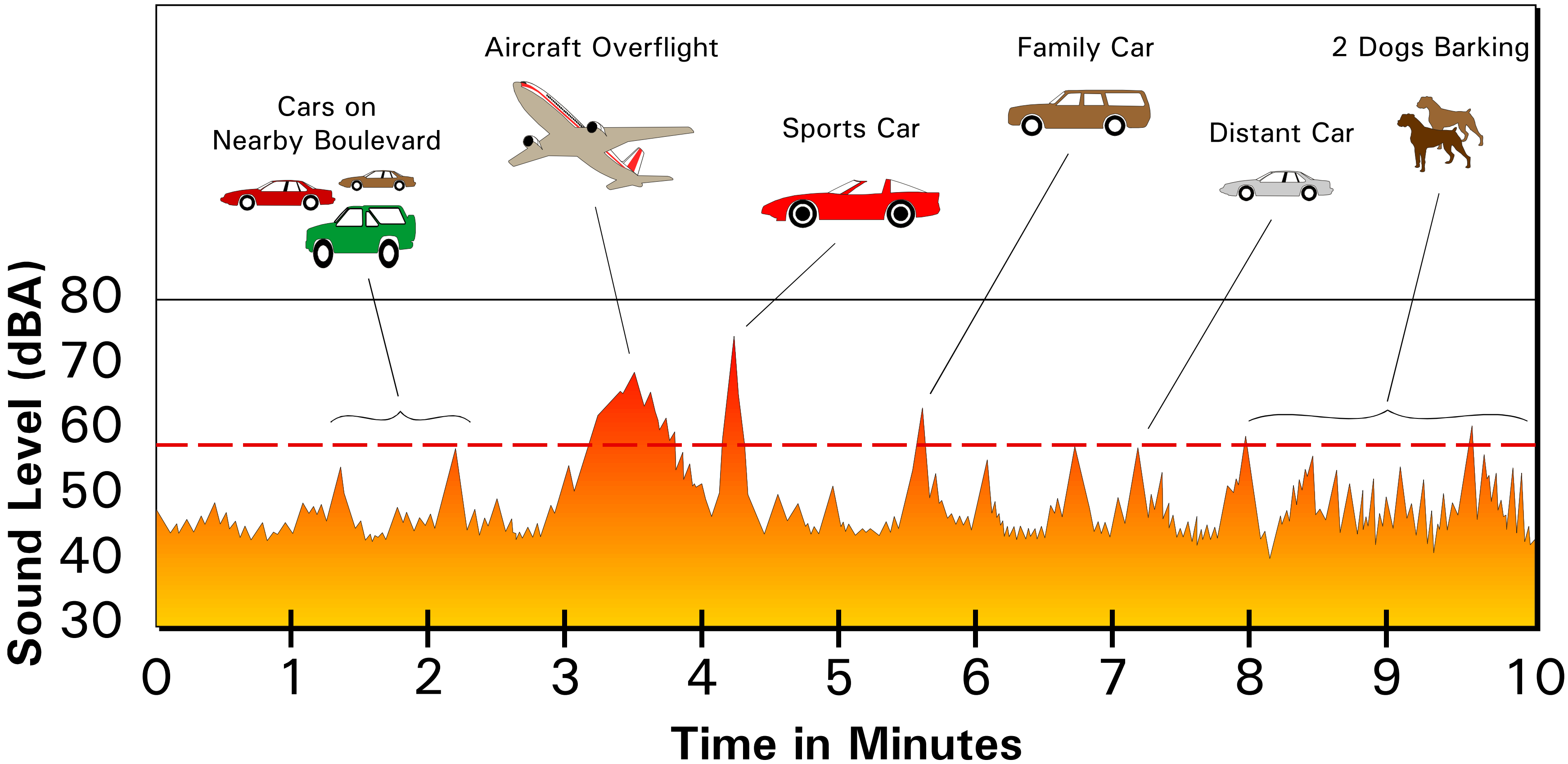

Source: Condensed from information contained in the Federal Interagency Committee on Noise (FICON) Technical Report, August 1992.

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LUNKEN AIRPORT
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NEIGHBORHOOD SOUND LEVELS

EXHIBIT
2.2-2

2.2.3 Day-Night Average Sound Levels (DNL)

DNL, formerly referred to as Ldn, was developed as a single measurement of community noise exposure. The Environmental Protection Agency (EPA) introduced DNL as a simple method for predicting the effects of the average long-term exposure to environmental noise on a population. In the FAR Part 150 process, it is the primary system for measuring noise impacts. Federal Department of Housing and Urban Development (HUD) regulations also include DNL as the standard for measuring outdoor noise environments.

The SELs from aircraft events are averaged over a 24-hour period to determine the DNL. In aircraft noise measurement, DNL represents all of the sound pressure present in a 24-hour period. As part of the calculation of DNL, a 10-dB penalty is applied to each aircraft event that occurs between 10:00 p.m. and 7:00 a.m. Noise occurring at night is generally more annoying to people than the same noise occurring during the day because people's sensitivity to noise increases during sleeping hours and nighttime ambient noise levels are typically lower than daytime levels. DNL differs from SEL in that it focuses on a number of events rather than a single event; however the Integrated Noise Model (INM) utilizes SEL for each aircraft event to determine the contribution to the DNL.

2.3 NOISE MODELING

In 1978, the FAA released the first version of a computer simulation model designed to assess aircraft noise impacts, and continually refines this model to keep pace with changes in aircraft noise technology. Today, the FAA-approved INM is the standard aircraft modeling program used for civilian airports.[7] Since its introduction, five additional versions of the INM have been released, and its aircraft database has been updated numerous times to reflect changes in the existing and projected aircraft fleet mix.

The most recent version, INM 6.1, was utilized for this FAR Part 150 Study. This version includes a database on aircraft noise and performance characteristics representative of individual air carrier, air taxi/commuter, general aviation, air cargo, and military aircraft types powered by turbojet, turbofan, and propeller-driven engines. The INM incorporates detailed information about each aircraft, including departure profiles for applicable trip lengths, approach profiles, and SEL versus distance curves at various thrust settings. Surrounding terrain data was also included in this modeling effort.

INM has the capability to deal with engine run-up operation noise on the run-up pad or maintenance area. The inputs for run-up operation noise include aircraft type, location of run-up pad or maintenance area, the heading of the airplane, the average duration of the run-up event, and the number of times the run-up event occurs during the day and night time period.

INM uses a single directivity pattern to calculate noise around an airplane on a run-up pad or maintenance area. The INM aircraft profile and noise calculation algorithms are based on several guidance documents published by the Society of Automotive Engineers (SAE). This SAE-AIR-1845 "Procedure for the Calculation of Airplane Noise in the Vicinity of Airports" directivity pattern function is used to compute noise behind takeoff. The directivity pattern is symmetric around the longitudinal axis of the airplane.

2.3.1 INM Input

The INM calculates noise exposure levels from airport-specific data that are input to the model. This data includes runway coordinates, flight tracks, fleet mix, activity levels, runway utilization, and time of day. The model takes into account arrival, departure, and touch-and-go operations.

The INM user provides the activity and operational data in an input file for each noise impact scenario under evaluation. Activity information includes the level and type of operation. Operations are further defined based upon the fleet mix and time of day. Care is taken to ensure that the file reflects an accurate mix of typical aircraft in use at the Airport.

Fleet mix is determined by observation, operational records, and flight schedules. The time of day specification is an important factor in the calculation of DNL because those operations that occur between 10:00 p.m. and 7:00 a.m. receive a 10-dBA penalty to account for increased noise sensitivity during sleeping hours.

The runway definitions establish the Airport geometry and its relationship to the surrounding area. A flight track is a user-defined flight path projected on the ground from a reference point on a runway. Each flight track is associated with a runway and is used for one type of operation: takeoff, landing, or touch-and-go. Usually, a runway will have several tracks for each type of operation. Because of the limitations of the model, a flight track will typically identify the corridor of flight and not necessarily every path an aircraft has followed.

2.3.2 INM Output

The INM requires both the user input and the model database to operate. This information is processed through a series of algorithms that produce calculations of noise exposure levels. When computer-plotted, these calculations take the form of a line drawing that connects points of equal noise exposure. These drawings are commonly referred to as noise contours.

The INM models "average annual day" aircraft noise impacts, that is, the average level of sound that occurs during a 24-hour period, taking into account times when the airport is busy and times when there is less activity. FAR Part 150 requires analysis of "average annual day" noise levels rather than single-event or peak noise levels.

FAR Part 150 requires the development of DNL 65 dBA, 70 dBA, and 75 dBA noise contours. The INM can also calculate individual noise measurements at specific points or grids at particularly noise-sensitive structures in the airport vicinity, such as hospitals or schools. When the noise contours are overlaid on a map the number of residential areas and total acreage can be calculated.

2.4 COMMUNITY RESPONSE TO NOISE

Individuals in urbanized areas are generally exposed to varying high noise levels from many sources as they go about their daily activities. The degree of disturbance or annoyance of unwanted sound depends on three factors: the amount and nature of the intruding noise, the relationship between the background noise and the intruding noise, and the type of activity occurring when the noise is heard.

Ambient noise is the total background noise in a given place and time consisting of a composite of sounds from varying sources and distances. It is the collection of natural and man-made sounds. People are generally not aware of ambient (background) noise, but normally hear noises (such as fireworks, delivery trucks, or honking horns) that contrast sharply with ambient levels. Because background noise is so familiar, it is less annoying even when it approaches decibel levels considered uncomfortable if generated from a specific source.

It is important to note that individuals have differing sensitivities to noise. Loud noises bother some people more than others. The rhythm of the noise also affects whether or not it is objectionable. Noises occurring during sleeping hours are usually considered to be much more objectionable than the same noise during the daytime.

Individuals tend to judge the annoyance of an unwanted sound in terms of its relationship to background noise. For example, the sound of an aircraft at night when background noise levels are low (approximately 45 dBA) is generally more objectionable than the sound of an aircraft in the afternoon when background noises are higher (approximately 60 dBA).

Another factor to consider is how the noise interferes with activities. In a 60 dBA environment, normal conversation is possible while sleep may be difficult (Noise Levels In Our Environment Fact Sheet; The League for the Hard of Hearing). Work activities requiring high levels of concentration may be interrupted by loud noises, while outside sports activities may not be interrupted at all. In general, community response to noise is based on people's perception of its effects on annoyance, sleep/speech interference, and health.

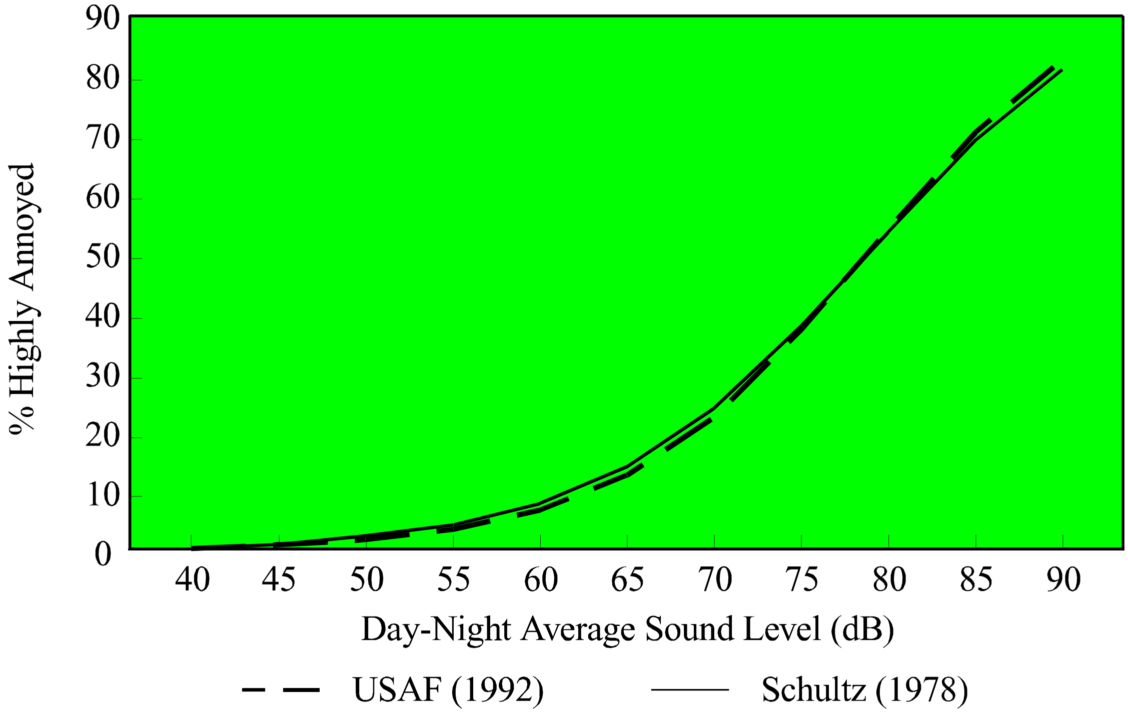
2.4.1 Annoyance

The most common human reaction to aircraft noise is annoyance. People react to noise in different ways, influenced by emotional variables such as feelings about the necessity of the noise and its health effects. They are also influenced by physical factors such as time of day, season of the year, and control over the noise source. The actual intensity and frequency of the noise also influences reaction. **Exhibit 2.4-1** provides a comparison of day-night average sound levels and its general effects on people.[8] As depicted in Exhibit 2.4-1, average community annoyance is expected to be significant at DNL levels of 65 dBA to 70 dBA. Above 70 dBA, community annoyance is expected to be severe.

In analyzing the results of numerous social surveys conducted at major airports in several countries, one researcher noted that when exposed to aircraft noise levels of DNL 65 dBA, 25 percent of residents are seriously annoyed, an additional 35 percent are annoyed, and the remaining 40 percent are not annoyed. With aircraft noise levels of DNL 75 dBA, approximately 60 percent of residents are seriously annoyed, an additional 30 percent are annoyed, and the remaining 10 percent are not annoyed.[9]

2.4.2 Sleep/Speech Interference

Sleep is a necessary part of life with important beneficial effects that any interference can inhibit. There is much debate over the cumulative effects of aircraft noise on sleep. Research indicates that normal residential construction can be expected to provide a Noise Level Reduction (NLR) of 20 dB (FAR 14 CFR Part 150 (1985)), therefore an



	Effects	
Day-Night Average Sound Level (dBA)	Average Community Reaction	General Community Attitude Towards Area
75 and Above	Very Severe	Noise is likely to be the most important of all adverse aspects of the community environment
70 to 75	Severe	Noise is one of the most important adverse aspects of the community environment
65 to 70	Significant	Noise is one of the important of adverse aspects of the community environment
60 to 65	Moderate to Slight	Noise may be considered an adverse aspect of the community environment
Below 60	Moderate to Slight	Noise considered no more important than various other environmental factors

Source: Federal Interagency Committee on Noise (Ficon) Technical Report, August 1992.

CINCINNATI MUNICIPAL-LUNKEN AIRPORT PART 150 STUDY

COMPARATIVE EFFECTS OF NOISE FOR RESIDENTIALAREAS

EXHIBIT 2.4-1

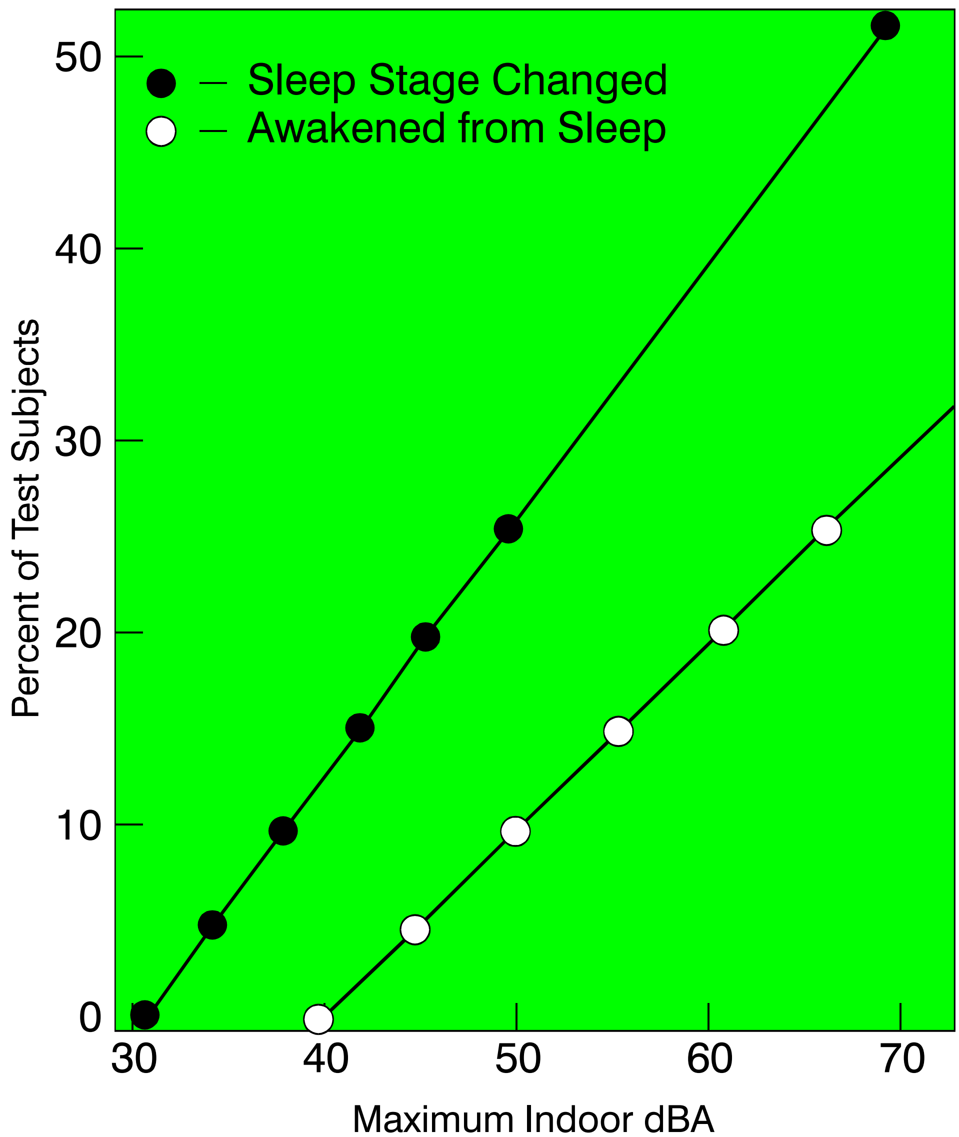
exterior sound level of approximately 72 dBA is an acceptable interference threshold for a windows-closed condition.

A composite of data for sleep interference versus maximum A-weighted indoor noise levels is presented in **Exhibit 2.4-2**.[10] With a maximum interior noise level (Lmax) of 65 dBA, approximately 50 percent of the population will experience a change in sleep state and 25 percent will be awakened. An exterior noise level of 85 dBA corresponds to an interior level of approximately 65 dBA.[11] Normal residential construction can be expected to provide a noise level reduction of 20 dBA and assumes mechanical ventilation and closed window year round. This 20 dBA difference is important in assessing the impacts of nighttime airport operation.

A study conducted in Great Britain concerning aircraft noise and sleep disturbances, concluded that, "aircraft noise has a negligible effect upon overall patterns of arousal from sleep. Even at locations close to airports with higher levels of night aircraft traffic, the additional disturbance caused by the aircraft noise, both wakenings and lesser arousal's, is likely to be very small compared to that occurring "naturally" due to all other causes. Aircraft noise itself is most unlikely to increase sleep disturbance rates to the point at which after-effects upon health or performance would be noticeable".[12]

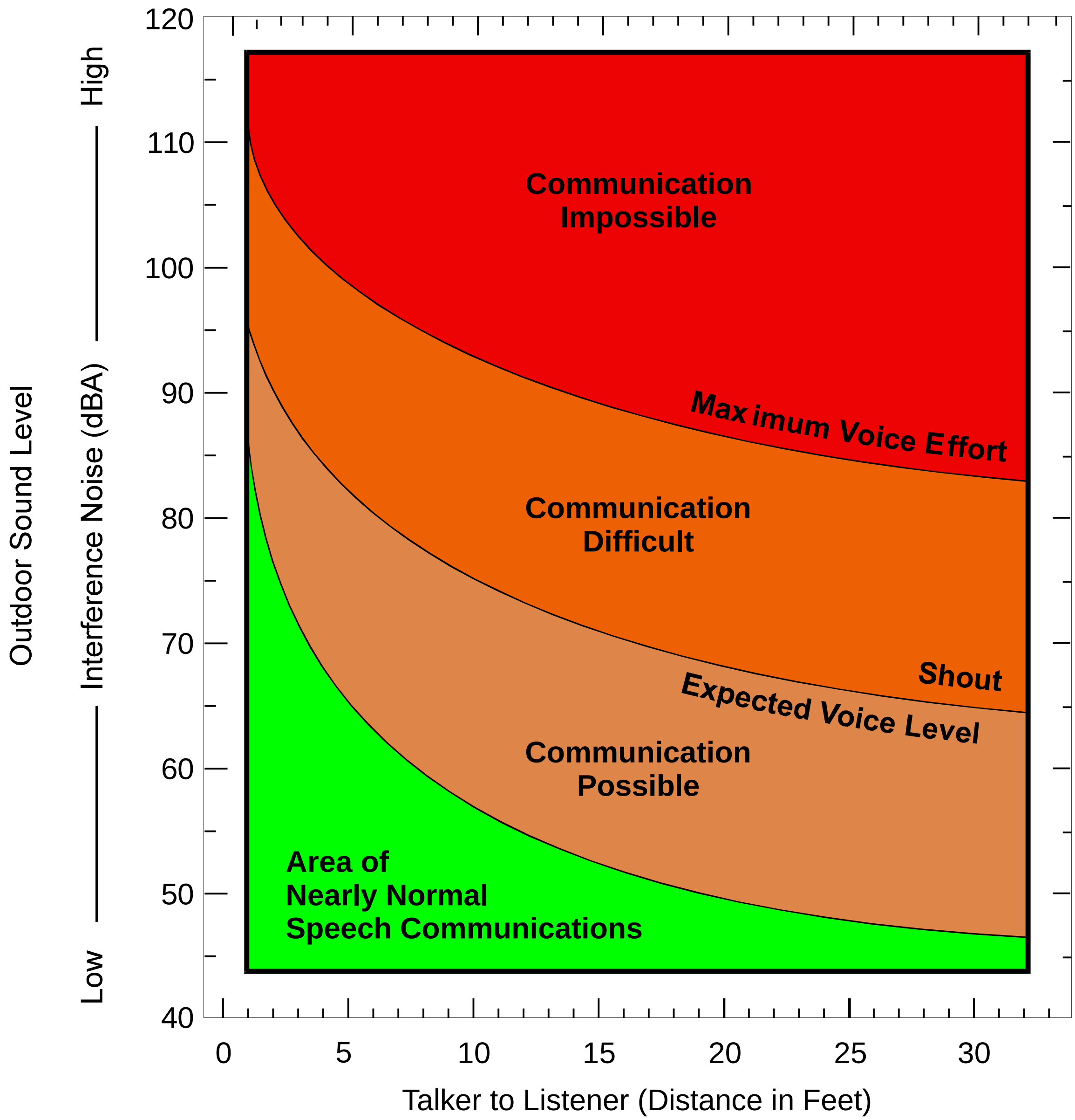
Speech interference is a principal factor in human annoyance response. It is especially critical in situations requiring a high degree of intelligibility for safety. Quality speech communication is important in the classroom, office, and industrial setting. Several factors, including distance from the speaker and loudness of voice, contribute to interference.

Exhibit 2.4-3, developed by the EPA, relates speech interference levels to levels of effective communication. This exhibit shows that at 65 dBA, normal speech communications can continue with individuals who are approximately five feet apart.[13]



Source: J. Steven Newman and Kristy R. Beattie, *Aviation Noise Effects*, Federal Aviation Administration Office of Environment and Energy, Noise Abatement Division, March 1985.

CINCINNATI MUNICIPAL-LUNKEN AIRPORT PART 150 STUDY	SLEEP INTERFERENCE VERSUS MAXIMUM A-WEIGHTED SOUND LEVELS	EXHIBIT 2.4-2



Source: U.S. EPA, Report to the President and Congress on Noise-1972

CINCINNATI MUNICIPAL-
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SPEECH INTERFERENCE LEVELS

EXHIBIT

2.4-3

2.4.3 Health

Response to aviation noise is influenced by the belief that exposure to it will damage health. It is widely believed that continuous exposure to high levels of noise will damage human hearing. At 120 dBA, considered the threshold of discomfort, there may be a sensation of tickling in the middle ear. At 140 dBA, the threshold of pain, sound pressure may cause auditory fatigue or acoustical failure.

One laboratory study conducted, near Los Angeles International Airport, exposed groups of people to recorded aircraft flyover noise consisting of 40 events per hour, each event with a maximum level of 111 dBA, over six one-hour periods.[15] The measured Temporary Threshold Shift (TTS), a constant measure of the effects of a single day's exposure to noise, was negligible for these people. Because TTS is considered to represent a precursor to permanent hearing loss, the study indicated there is no danger of permanent hearing loss resulting from high levels of aircraft noise.

The federal Occupational Safety and Health Administration (OSHA) issues regulations to protect the hearing of industrial workers. These regulations, which prescribe permissible noise limits for various amounts of time, are shown on **Table 2.4-1**.

OSHA standards, while not a requirement of FAR Part 150, are not typically exceeded in the vicinity of an airport.

Nonauditory health issues that have been researched and linked to aircraft noise include cardiovascular effects, achievement scores, birth weight, mortality rates, and psychiatric admissions. While some studies have shown a significant correlation, others have shown none. Research continues, but there are no conclusive studies to corroborate the "cause and effect" theory.[16]

TABLE 2.4-1 Cincinnati Municipal-Lunken Airport PERMISSIBLE NOISE EXPOSURE[1]	
Duration Per Day(Hours)	Sound Level (dBA)
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

Source: OSHA, Code of Federal Regulations, Title 29, Chapter 27, Part 1910.

[1] When the daily exposure is composed of two or more periods of noise exposure of difference levels, their combined effect should be considered, rather than the individual effect of each.

The noise assessment methodologies discussed in this Chapter form the basis for understanding the aircraft noise exposure contours that are presented in Chapter 4.0 *Existing Noise Exposure Map* and Chapter 5.0 *Future Baseline Noise Exposure Map.*

ENDNOTES

[1] Federal Interagency Committee on Noise (FICON), *Federal Agency Review of Selected Airport Noise Analysis Issues, Appendix B Sound Basics*, page B-2, August 1992

[2] J. Steven Newman and Kristy R. Beattie, *Aviation Noise Effects*, Federal Aviation Administration Office of Environment and Energy, Noise Abatement Division, March 1985.

[3] FICON, *Federal Agency Review of Selected Airport Noise Analysis Issues, Appendix B Sound Basics*, pages B-7, B-8, August 1992.

[4] Melville C. Branch, et. al., *Outdoor Noise and the Metropolitan Environment*, Los Angeles Department of City Planning, 1970, p.2.

[5] U.S. Environmental Protection Agency, *Calculation of Day-Night Levels (Ldn) Resulting from Civil Aircraft Operations*, EPA 550/9-77-450, National Technical Information Service PB 266, January 1977.

[6] U.S. Environmental Protection Agency, *Protective Noise Levels, Condensed Version of EPA Levels Document*, November 1978.

[7] FICON, *Federal Agency Review of Selected Airport Noise Analysis Issues, Appendix B Sound Basics*, page B-18, August 1992.

[8] Federal Interagency Committee on Noise (FICON), *Federal Agency Review of Selected Airport Noise Analysis Issues,* pages 3-6 and 3-8, August 1992.

[9] J. Steven Newman and Kristy R. Beattie, *Aviation Noise Effects*, Federal Aviation Administration Office of Environment and Energy, Noise Abatement Division, March 1985.

[10] J. Steven Newman and Kristy R. Beattie, Aviation Noise Effects, Federal Aviation Administration Office of Environment and Energy, Noise Abatement Division, March 1985.

[11] Actual dBA levels may vary from structure to structure; however, FAA guidelines indicate an average difference of 20 dBA with a windows-closed situation.

[12] Great Britain, Department of Transport, *Report of a Field Study of Aircraft Noise and Sleep Disturbance,* December 1992.

[13] U.S. EPA, *Report to the President and Congress on Noise*, 1992.

[15] Ward, Cushing & Burns, *TTS From Neighborhood Aircraft Noise,* Journal of Acoustical Society of America, Vol. 61, No. 1, July 1976.

[16] Occupational Safety and Health Administration, Code of Federal Regulations, Title 29, Chapter 27, Part 1910.