Aircraft Noise Terminology & Metric

Supplement

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To assist in understanding the noise measurement results and the metric used in evaluating airport noise, this supplement provides a brief introduction to various acoustic terminologies used to express sound level. The terms discussed are the decibel (dB), A-weighted decibel (dBA), Maximum Noise Level (Lmax), Sound Exposure Level (SEL) and time-weighted, cumulative metric known as Community Noise Equivalent Level (CNEL).

The **decibel (dB)** is the unit used to represent the change in sound pressure as a direct measurement of changes in amplitudes on array of frequencies. Decibels measure a scale from the threshold of human hearing – 0 dB, towards the threshold of pain about 120-140 dB. Because decibels are such a small measure, they are computed logarithmically and cannot be added arithmetically. An increase of 10 dB is perceived by our ears as a doubling of noise. Most sounds we experience in our day-to-day lives vary between 30 dB and 100 dB. Figure 1 depicts decibel levels of common sounds.

A-weighted decibel (dBA) is sound pressure levels filtered with an "A" weighted filter de-emphasizing level changes that occur at lower frequencies (those below 500 Hertz) and also at very high frequencies above 10,0000 Hertz where people generally do not hear as well. The normal frequency range of hearing for most people is from a low of 500 Hertz to a high of 10,000 Hertz. This filter closely matches our ears' sensitivity to sound. As a result, an aircraft noise event with a higher A-weighted sound level is perceived to be louder than an aircraft noise event with a lower A-weighted sound level. This correlation with our perception of loudness is the reason that A-weighted sound levels are used to evaluate environmental noise sources.

The sound level heard during an arrival or departure of an aircraft varies as a function of the distance from the aircraft to the person hearing the noise and as a function of the direction of the aircraft noise source. As the aircraft approaches the person, the sound level increases and as the aircraft moves away from the person, the sound level decreases. The effect of noise exposure during such an event can be described in terms of either the Maximum Sound Level or the Sound Exposure Level of an individual aircraft noise event.

The **Maximum Sound Level (Lmax)** represents the highest instantaneous noise level heard during a single aircraft overflight. However, it provides no information on the duration (length) of the noise exposure. Thus, two events with the exact Lmax may produce completely different total exposures. While some people will be annoyed by events having shorter duration, majority of people are more likely to be highly annoyed with longer events continuing for extended period of time. To account for differing durations of an event, Sound Exposure Level is used to quantify total noise exposure for a single aircraft overflight.

The **Sound Exposure Level (SEL)** is the total sound energy above an established threshold for a single event considering both intensity and length of the event all compressed into 1 second. The SEL of any noise event is the entire event's total energy expressed in a reference period time as though it had occurred within one second. A noise event having a Lmax of 80 dbA and lasting 1 second would have a SEL of 80 dBA. But if that event lasted 2 seconds long, the SEL would be 83 dBA. Two events with the same intensity but different durations can be differentiated with the longer duration event having a higher SEL. For locations relatively close to an airport, the SEL for most aircraft departures will usually be about 10 decibels higher than the corresponding Lmax. For example, an aircraft departure producing a maximum sound level of 70 dB at a particular location would be expected to produce an SEL value of about 80 dB at the same location. SEL gives us a common basis for comparing noise events that matches our instinctive impression – the higher the SEL, the more annoying it is likely to be. Figure 2 is a graphic representation of a typical aircraft noise event along with these terminologies.

In the example below, the SEL is calculated for an aircraft noise event that has a duration of 5 seconds and a Lmax of 65 dBA. This noise event is numerically equivalent to a SEL of 69.6 dBA.

Sound Exposure Level Formula:

$$SEL = 10 * \log_{10}\left(\sum_{i=1}^{n} 10^{L_i/10}\right)$$

Where SEL = sound exposure level
L_i = sound level for a given one second time period
n = number of seconds during the measurement period

SEL calculation example:

The rows below list the 1 second decibel levels and the corresponding energy levels of the 5 seconds duration aircraft noise event. The energy levels are summed together in order to calculate the SEL value of the aircraft noise event.

Seconds	Sound Level	Energy
1	60 dB	1000000.0
2	63 dB	1995262.3
3	65 dB (LMax)	3162277.7
4	63 dB	1995262.3
5	60 dB	1000000.0
	Total Energy	9152802.3
	Aircraft Noise Event's SEL	**69.6 dB**

The **Community Noise Equivalent Level (CNEL)** metric is used to assess and regulate aircraft noise exposure in communities surrounding airports located in California. Federal Government approved and defined in the California Airport Noise Standards, this cumulative metric represents the average daytime noise level during a 24-hour day and adjusted to an equivalent level to account for increased sensitivity to aircraft noise during evening and nighttime periods relative to the daytime. CNEL applies a 4.77 dBA weighting to all aircraft events occurring during the 3 evening hours from 7:00 p.m. to 9:59:59 p.m. and a 10 dBA weighting to all aircraft events during the 9 nighttime hours from 10:00 p.m. to 6:59:59 a.m.

Aircraft CNEL is then derived using the SELs from all aircraft events for the 24 hour day. The Total CNEL will include all aircraft events as well as other noise events generated in the community during the corresponding time period. Typically, Total CNEL in our environment ranges from a low of 40-45 dBA in very quiet locations to 80-85 dBA immediately adjacent to an active noise source – busy traffic route or active airport. Figure 3 shows representative values of CNEL in typically different environments. Aircraft CNEL greater than 65 dBA CNEL within a residential property line is incompatible to airport operations. CNEL is calculated using the following formula:

$$CNEL = 10 * \log_{10}\left(\left[\sum_{i=1}^{n} 10^{SEL_i/10} + \sum_{i=n+1}^{m} 10^{(SEL_i+4.8)/10} + \sum_{i=m+1}^{r} 10^{(SEL_i+10)/10}\right]\right) - 49.4$$

Day Evening Night

CNEL calculation example showing 10 aircraft noise events in a 24 hour period:

Time of Day	Hour	SEL (dB)	Weighting (dB)	Weighted SEL (dB)	Energy
Night	Midnight	86.1	10	96.1	4073802778.0
Night	1:00 a.m.		10		
Night	2:00 a.m.		10		
Night	3:00 a.m.		10		
Night	4:00 a.m.		10		
Night	5:00 a.m.	90.0	10	100.0	10000000000.0
Night	6:00 a.m.	86.1	10	96.1	4073802778.0
Day	7:00 a.m.		0		
Day	8:00 a.m.	93.6	0	93.6	2290867652.8
Day	9:00 a.m.		0		
Day	10:00 a.m.	82.6	0	82.6	181970085.9
Day	11:00 a.m.		0		
Day	Noon	90.3	0	90.3	1071519305.2
Day	1:00 p.m.		0		
Day	2:00 p.m.		0		
Day	3:00 p.m.		0		
Day	4:00 p.m.		0		
Day	5:00 p.m.	94.8	0	94.8	3019951720.4
Day	6:00 p.m.		0		
Evening	7:00 p.m.		4.77		
Evening	8:00 p.m.		4.77		
Evening	9:00 p.m.	86.1	4.77	90.9	1221799660.2
Night	10:00 p.m.	85.2	10	95.2	3311311214.8
Night	11:00 p.m.	89.5	10	99.5	8912509381.3
				Total Energy	38157534576.7
				Aircraft CNEL	**56.4 dB**

Figure 1 – Common Sound Levels

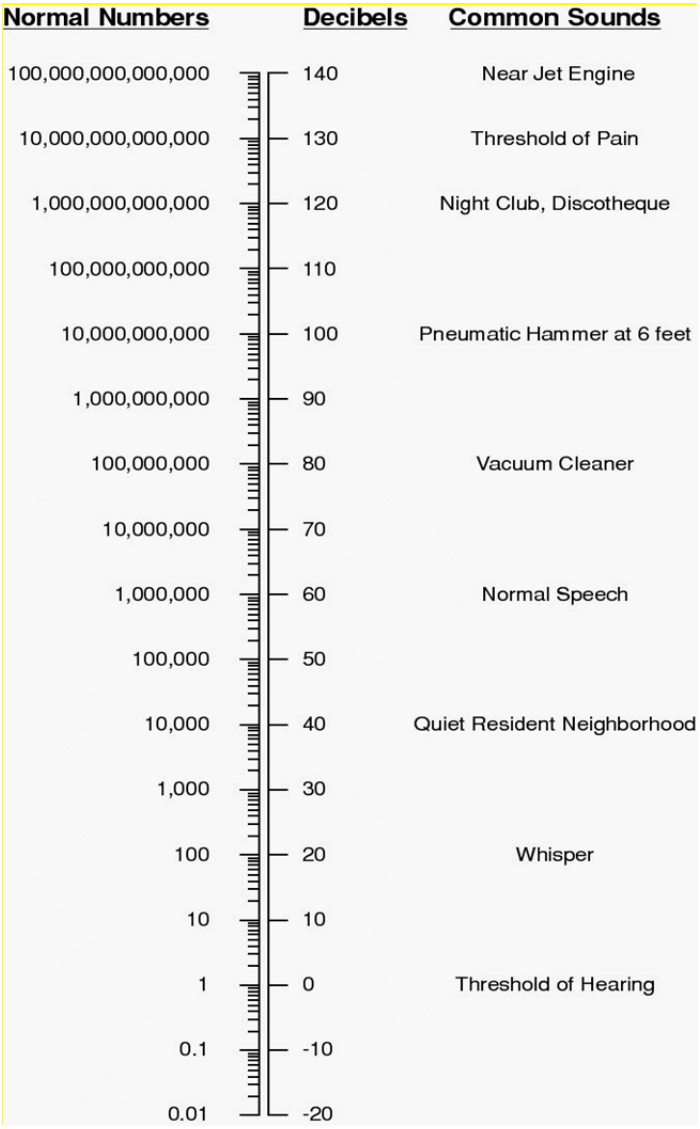

Figure 2 – Typical Aircraft Noise Event

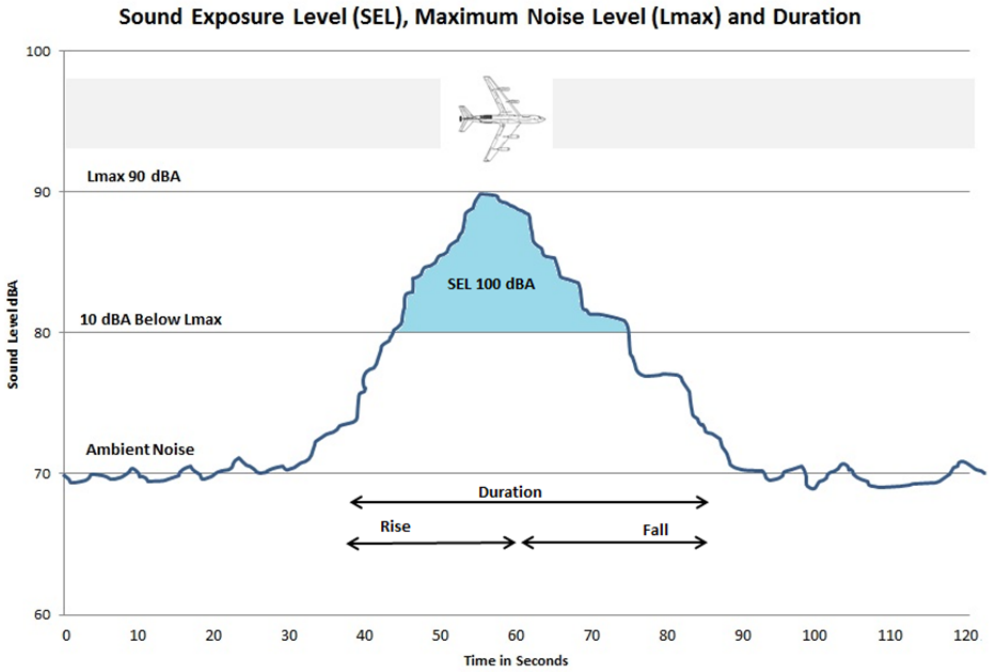
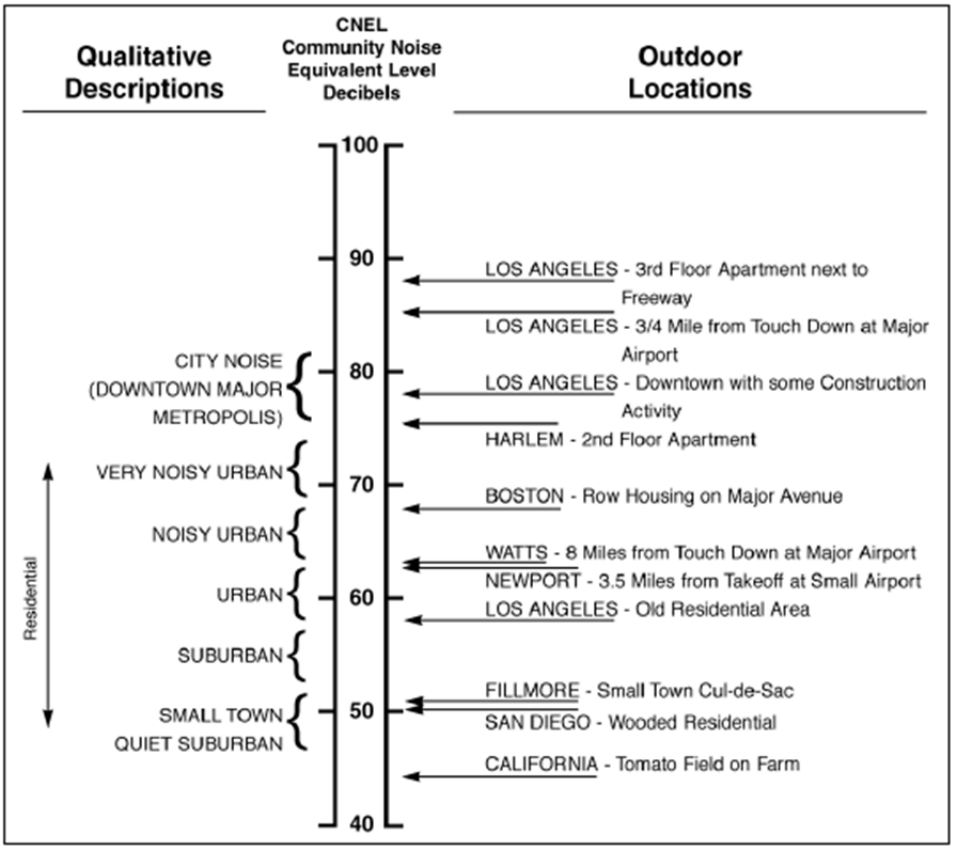
Figure 3 – Representative Cumulative Sound Levels