

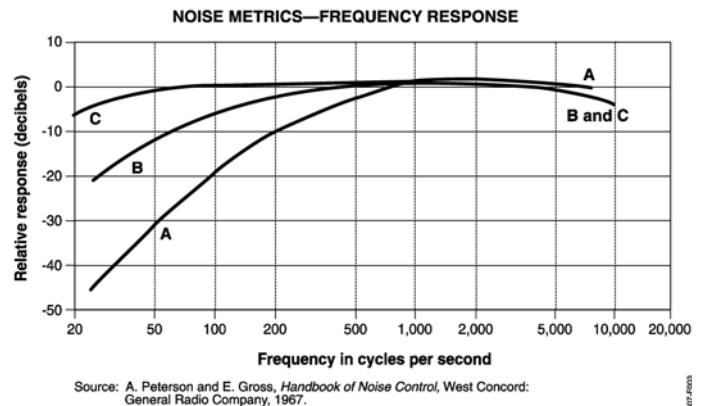
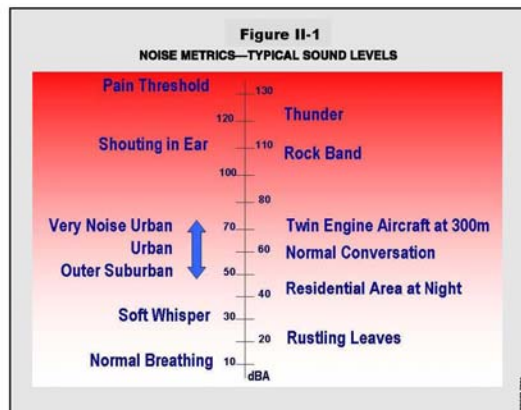
## Background:

### Understanding noise and noise metrics

Sound can technically be described in terms of the sound pressure and frequency. Sound pressure is a direct measure of the magnitude of a sound without consideration for other factors that may influence its perception.

There is a wide variation of sound pressures that we experience in our day-to-day lives. In order to understand sound pressures better, it is convenient to express them as sound pressure levels on a logarithmic scale that compresses the wide range of sound pressures to a more usable range of numbers. The standard unit of measurement of sound is the Decibel (dB) that describes the pressure of a sound relative to a reference pressure.

The frequency (pitch) of a sound is expressed as Hertz (Hz) or cycles per second. The normal audible frequency for young adults is 20 Hz to 20,000 Hz. Community noise, including aircraft and motor vehicles, typically ranges between 50 Hz and 5,000 Hz. The human ear is not equally sensitive to all frequencies, with some frequencies judged to be louder for a given signal than others. As a result of this, various methods of frequency weighting have been developed. The most common weighting is the A-weighted noise curve (dBA). The A-weighted decibel scale (dBA) performs this compensation by discriminating against frequencies in a manner approximating the sensitivity of the human ear. In the A-weighted decibel, the human ear is capable of hearing sounds from 0 dBA to about 130 dBA. Everyday sounds normally range from 30 dBA (very quiet) to 100 dBA (very loud). Refer to figure below. Thunder is approximately 120 dBA; a rock band is 105 dBA; a dense urban environment is typically between 60-70 dB; and a suburban residential area at night is typically between 45-55 dB. Most community noise analyses are based upon the A-weighted decibel scale.



The figure above shows the A-weighted scale compared to other scales such as the C-weighted scale, which is more sensitive to low frequency noise and used in assessing hearing loss in occupational or recreational exposures to noise. The C-weighted scale has also been used to quantify low frequency noise in the environment, but such use is crude and can be misleading. Changes in C-weighted scale noise do not mean changes in low frequency noise. The C-weighted scale also measures higher frequency sounds, and therefore a change in the C-weighted scale measurement could be due to low or high frequency sounds. If low frequency noise impacts are to be identified, measurements in low frequency noise. The C-weighted scale also measures higher frequency sounds, and therefore a change in the C-weighted scale measurement could be due to low or high frequency sounds. If low frequency noise impacts are to be identified, measurements in frequency bands are the best method of defining low frequency noise.

## Background: Understanding Noise and Noise Metrics (Cont'd)

The noise generated by an aircraft flight is quite complex. The sound sources can be described in three broad categories: combustor noise (the noise associated with the rapid combustion of fuel and the associated release of energy), turbomachinery noise (often noticed as an aircraft is coming towards you), and aerodynamic noise (the noise associated with rapid air movement over the airframe and control surfaces). New technologies in modern aircraft have achieved significant reductions in engine noise. Turbomachinery noise has also been reduced in newer aircraft. Aerodynamic noise is a current area of acoustic research to reduce aircraft noise.

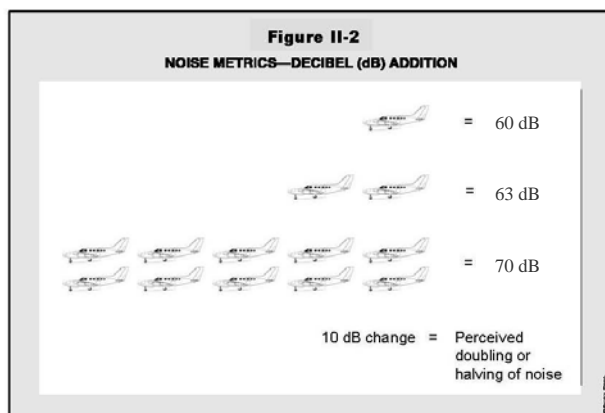
Outdoor sound levels decrease as the distance from the source increases, and as a result of wave divergence, atmospheric absorption and ground attenuation. Sound radiating from a source in a homogeneous and undisturbed manner travels in spherical waves. As the sound wave travels away from the source, the sound energy is dispersed over a greater area decreasing the sound power of the wave. Spherical spreading of the sound wave reduces the noise level at a rate of 6 dB per doubling of the distance.

Atmospheric absorption also influences the levels received by the observer. The greater the distance traveled, the greater the influence of the atmosphere and the resultant fluctuations. Atmospheric absorption becomes important at distances of greater than 1,000 feet. The degree of absorption varies depending on the frequency of the sound as well as the humidity and temperature of the air. For example, atmospheric absorption is lowest (i.e., sound carries farther) at high humidity and high temperatures. Turbulence and gradients of wind, temperature and humidity play a significant role in determining the propagation of sound over a large distance. At short distances between the source and receiver, atmospheric effects are minimal. Certain conditions, such as inversions, can channel or focus the sound waves resulting in higher noise levels than would result from simple spherical spreading. Absorption effects in the atmosphere vary with frequency. The higher frequencies are more readily absorbed than the lower frequencies. Over large distances, the lower frequencies become the dominant sound as the higher frequencies are attenuated.

The effect of sound reflecting across a water surface has an even more profound effect than weather. Sound propagating over water is louder than propagating over land as the result of the reflective characteristics of water. Shielding of noise by a structure also can have significant effects on noise. Structures such as buildings, homes, barrier walls, block the straight line propagation of sound. Homes shielded by these structures receive a lower noise level than without.

Annoyance from a noise event increases with increased duration of the noise event (i.e., the longer the noise event, the more annoying it is). The “effective duration” of a sound is the time between when a sound rises above the background sound level until it drops back below the background level. Psycho-acoustic studies have determined the relationship between duration and annoyance and the amount by which a sound must be reduced to be judged equally annoying for increased duration. Duration is an important factor in describing sound in a community setting.

The relationship between duration and noise level is the basis of the equivalent energy principle of sound exposure. Because of the way the ear hears sound, if two equally loud sounds occur at the same time, the increase in decibels is only 3 dB (as opposed to double). Likewise, if two sounds with different loudness are heard at the same time, the ear hears the sound at a decibel level only slightly higher than the loudest sound (for example,  $60\text{ dB} + 70\text{ dB} = 70.4\text{ dB}$ ). This equivalent energy principle is based upon the premise that the potential for a noise to impact a person is dependent on the total acoustical energy content of the noise. Defined in the Sound Rating Scales section below, noise metrics such as CNEL, DNL, Leq and SEL are all based upon the equal energy principles.



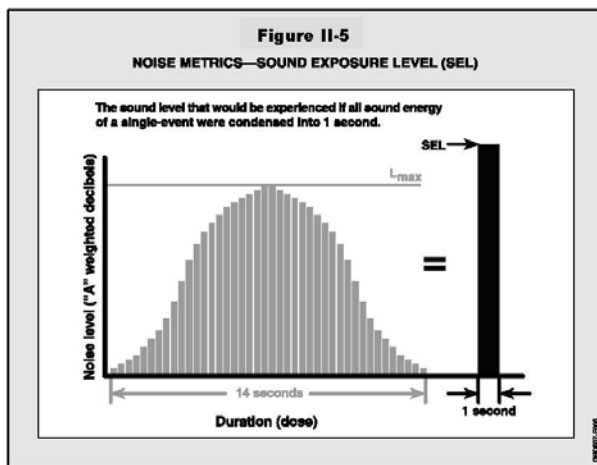
## Background: Understanding Noise and Noise Metrics (Cont'd)

The description, analysis, and reporting of community sound levels is made difficult by the complexity of human response to sound and myriad of sound-rating scales and metrics developed to describe acoustic effects. Various rating scales approximate the human subjective assessment to the “loudness” or “noisiness” of a sound. Noise metrics have been developed to account for additional parameters such as duration and cumulative effect of multiple events.

**Frequency Weighted Metrics (dBA)** — In order to simplify the measurement and computation of sound loudness levels, frequency weighted networks have obtained wide acceptance. The A-weighting (dBA) scale has become the most prominent of these scales and is widely used in community noise analysis. Its advantages are that it has shown good correlation with community response and is easily measured. The metrics used in most aircraft noise studies are all based upon the dBA scale.

**Maximum Noise Level** — The highest noise level reached during a noise event is called the “Maximum Noise Level,” or L<sub>max</sub>. For example, as an aircraft approaches, the sound of the aircraft begins to rise above ambient noise levels. The closer the aircraft gets, the louder it is until the aircraft is at its closest point directly overhead. Then as the aircraft passes, the noise level decreases until the sound level again settles to ambient levels. It is this metric to which people generally instantaneously respond when an aircraft flyover occurs.

**Single Event Noise Exposure Level (SENEL) or Sound Exposure Level (SEL)** — Another metric that is reported for aircraft flyovers is the Sound Exposure Level (SEL). This metric is essentially equivalent to the metric Single Event Noise Exposure Level (SENEL). It is computed from dBA sound levels. Referring to the figure below, the shaded area, or the area within the maximum noise level, is the area from which the SEL is computed. The SEL value is the integration of all the acoustic energy contained within the event.

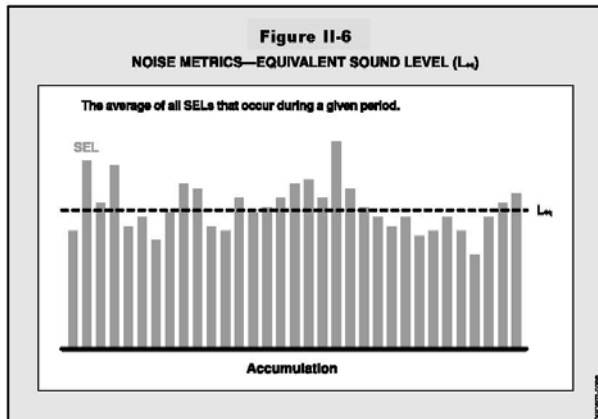


To properly reflect community noise levels, Jacobs Consultancy measured sound intensity over time, and plotted it on a graph. It is important to measure sound over time because a quieter sound over a longer period of time may be more annoying than a short but loud sound. This measurement of “annoyance” sound levels is called the Sound Exposure Level, or “SEL”. The SEL metric takes into account the maximum noise level of the event and the duration of the event. For aircraft flyovers, the SEL value is typically about 10 dBA higher than the maximum noise level. Single event metrics are a convenient method for describing noise from individual aircraft events. This metric is useful in that airport noise models contain aircraft noise curve data based upon the SEL metric. In addition, cumulative noise metrics such as Leq, CNEL and DNL can be computed from SEL data.

**Cumulative Metric** - Cumulative noise metrics assess community response to noise by including the loudness of the noise, the duration of the noise, the total number of noise events, and the time of day these events occur into on single number rating scale.

## Background: Understanding Noise and Noise Metrics (Cont'd)

**Equivalent Noise Level (Leq)** — Leq is the sound level corresponding to a steady-state A-weighted sound level containing the same total energy as several SEL events during a given sample period. Leq is the “energy” average noise level during the time period of the sample. It is based on the observation that the potential for noise annoyance is dependent on the total acoustical energy content of the noise. This is graphically illustrated in the figure below. Leq can be measured for any time period, but is typically measured for 15 minutes, 1 hour, or 24 hours. Leq for a 1-hour period is generally used for assessing highway noise impacts.



**Community Noise Equivalent Level (CNEL)** — CNEL is a 24-hour, time-weighted energy average noise level based on the A-weighted decibel. It is a measure of the overall noise experienced during an entire day. The term “time-weighted” refers to the penalties attached to noise events occurring during certain sensitive time periods. In the CNEL scale, noise occurring between 7 PM and 10 PM is penalized by approximately 5 dB. This penalty accounts for the greater potential for noise to cause communication interference during these hours, as well as typically lower ambient noise levels during these hours. Noise that takes place during the night (10 PM to 7 AM) is penalized by 10 dB. This penalty was selected to attempt to account for the higher sensitivity to noise in the nighttime and the expected further decrease in background noise levels that typically occur in the nighttime.

**Day-Night Noise Level (DNL)** — The DNL index is very similar to CNEL but does not include the evening (7 PM to 10 PM) penalty that is included in CNEL. It does however include the nighttime (10 PM to 7 AM) penalty. Typically DNL is about 1 dB lower than CNEL, although the difference may be greater if there is an abnormal concentration of noise events in the 7 AM to 10 PM time period. In addition, the United States Federal Aviation Administration adds a 10 dB “penalty” to sound that occurs between 10 PM and 7 AM. This adjusted number is called the Day-Night Average Sound Level (or “DNL”). Because of its ability to combine a number of important measurements into a single number, the DNL measurement is the best available method to describe aircraft noise levels.

In Canada, we use a measurement system similar to the DNL called the Noise Exposure Forecast (“NEF”) when we measure aircraft noise. It combines the noise levels of individual aircraft with the total number of aircraft. As with the DNL, Transport Canada requires the addition of a 12.2 dB “penalty” for night-time sound — this penalty is higher than the FAA’s 10 dB. The NEF, with some adjustment, can be substituted for the DNL in many cases.