APPENDIX 4.10-A: BASICS OF NOISE AND VIBRATION

A. Noise and Vibration Terminology

1. Noise

Noise is unwanted sound. Several noise measurement scales are used to describe noise in a specific location. A decibel (dB) is a unit of measurement that indicates the relative amplitude of a sound. The zero on the decibel scale is based on the lowest sound pressure that the healthy, unimpaired human ear can detect under controlled conditions. Sound levels in decibels are calculated on a logarithmic basis using the ratio of the assumed or measured sound pressure divided by a standardized, reference pressure (for sound, the reference pressure is 20 µPascals). Each 10 dB increase in sound level is perceived as an approximate doubling of loudness over a fairly wide range of amplitudes.

There are several methods of characterizing sound. The A-scale is a filter system that closely approximates the way the human ear perceives sound at different frequencies. Noise levels using A-weighted measurements are denoted with the abbreviation of “dB(A)” or “dBA.” The A-weighting filter system is very commonly used in the measurement and reporting of community noise, as well as in nearly all regulations and ordinances. All sound levels in this report are A-weighted, unless noted otherwise.

Because sound levels can vary markedly over a short period of time, a method for describing either the average character of the sound or the statistical behavior of the variations must be utilized. Most commonly, environmental sounds are described in terms of an average level that has the same acoustical energy as the summation of all the time-varying events. This energy-average or energy-equivalent sound/noise descriptor is abbreviated as L_{eq}. An hour is the most common time period over which energy-average sound is measured, but it can be measured over any duration (and the duration should be specified when the L_{eq} level is reported). Alternately, varying sound levels can be described by their statistical distribution over some fraction of a given observation period. These statistical sound levels are typically abbreviated as “L_n.” For example, the L_{50} noise level represents the noise level that is exceeded n=50 percent of the time. That is, half of the time the noise level exceeds this level and half of the time the noise level is less than this level. For practical implementation, this level is representative of the noise that is exceeded 30 minutes in an hour. Similarly, the L_2, L_8, and L_{25} values represent the noise levels that are exceeded n=2, 8, and 25 percent of the time or, equivalently, 1, 5, and 15 minutes in any given hour. These “n” values are typically used to demonstrate compliance for stationary noise sources with a city’s noise ordinance, as discussed below. Other values typically noted during a noise survey are the L_{min} and L_{max}. These values represent the minimum and maximum root-mean-square noise levels obtained over the measurement period.

Sensitivity to noise is subjective and varies from person to person, with the particular setting, and with the time-of-day. Sensitivity to noise typically increases during the evening and nighttime hours, when excessive noise can interfere with at-home activities and the ability to sleep. To account for these day/evening/night differences in sensitivity, 24-hour descriptors have been developed that incorporate artificial noise penalties that are added to quiet-time noise events. The Day/Night Average Sound Level, abbreviated as “L_{dn}” is a measure of the cumulative noise exposure in a community, with a 10 dB addition applied to nocturnal (10:00 p.m. to 7:00 a.m.) noise levels. A similar 24-hour metric is the Community Noise Equivalent Level, or “CNEL,” which extends the sensitivity adjustment by also applying a 3 dB addition to noise levels in the evening hours (7:00 p.m. to 10:00 p.m.). For typical community noise environments, the L_{dn} and CNEL levels are nearly always within 1 dB of each other and, therefore, are commonly used interchangeably (as will be the case in this document).

Additional technical terms are defined in Table 4.10-A1.

Table 4.10-A1 Definitions of Acoustical Terms

Term	Definitions
Decibel, dB	A unit of level that denotes the ratio between two quantities proportional to power; the number of decibels is 10 times the logarithm (to the base 10) of this ratio. For decibels describing sound pressures, the reference pressure is 20 µPascals.
Frequency, Hz	Of a function periodic in time, the number of times that the quantity repeats itself in one second (i.e., number of cycles per second).
A-Weighted Sound Level, dBA	The sound level obtained by use of the A-weighting filter network. The A-weighting filter de-emphasizes the very low and very high frequency components of the sound in a manner similar to the frequency response of the human ear and correlates well with subjective reactions to noise. All sound levels in this report are A-weighted, unless noted otherwise.
Statistical Sound Level or n-exceedance Sound Level, L_n (e.g., L_{01}, L_{10}, L_{50}, L_{90})	The fast-response, A-weighted noise levels equaled or exceeded by a fluctuating sound level for n-percent of a stated time period. For example, 1 percent, 10 percent, 50 percent, and 90 percent of the stated period. The L_{10} level is commonly called the 'intrusive sound level' and is near the maximum level in that time period, while the L_{90} is commonly called the 'residual sound level' and is near the minimum level in that period.
Equivalent Continuous Noise Level, L_{eq}	The level of a steady sound that, in a stated time period and at a stated location, has the same A-weighted sound energy as the time-varying sound.
Community Noise Equivalent Level*, CNEL	The 24-hour A-weighted average sound level from midnight to midnight, obtained after the addition of five decibels to sound levels occurring in the evening from 7:00 p.m. to 10:00 p.m. and after the addition of 10 decibels to sound levels occurring in the nighttime between 10:00 p.m. and the following 7:00 a.m.
Day/Night Noise Level*, L_{dn}	The 24-hour A-weighted average sound level from midnight to midnight, obtained after the addition of 10 decibels to sound levels occurring in the nighttime between 10:00 p.m. and 7:00 a.m.
L_{max}, L_{min}	The maximum and minimum A-weighted sound levels measured on a sound level meter, during a designated time interval, using fast-response time averaging. The L_{max} is equal to the L_0 and the L_{min} is equal to the L_{100}.
Ambient Noise Level	The all-encompassing noise associated with a given environment at a specified time. It is usually a composite of sounds from many sources and from many directions, both near and far, with no particular sound source being dominant.
Intrusive	The noise that intrudes over and above the existing ambient noise at a given location. The relative intrusiveness of a sound depends upon its amplitude, duration, frequency, time of occurrence, and tonal or informational content, as well as the increment above the ambient noise level.

Source: Harris, Cyril, 1998. Handbook of Acoustical Measurements and Noise Control. Acoustical Society of America, 3rd Edition.

** Note: L_{dn} and CNEL values rarely differ by more than 1 dB. As a matter of practice, CNEL values are considered to be equivalent to and interchangeable with L_{dn} values and are treated as such in this assessment.*

To provide a frame of reference to common experiences, representative outdoor and indoor noise levels are shown in Table 4.10-A2.

Table 4.10-A2 Sound Pressure Levels for Common Sound Sources

Common Outdoor Activities	Noise Level, dBA Perception	Common Indoor Activities
Jet Engine (within 25 feet)	-140- damaging	None
Civil Defense Siren (within 25 feet)	-130- threshold of pain	None
Accelerating noisy motorcycle (within 10 feet)	-120- threshold of feeling	Hard rock band (close to stage)
Power Saw (at 3 feet)	-110- extremely loud	Other concert (close to stage)
Subway; Jet Fly-over (at 100 feet)	-100- very loud	
Gas Lawnmower (at 3 feet)	-95- very loud	Crying Baby (within 3 feet)
Tractor (at 25 feet)	-90- very loud	
Some Construction Equipment (at 50 feet)	-85- loud	Food Blender (at 1 foot)
Diesel Truck going 50 mph (at 50 feet)	-80- loud	Garbage Disposal (at 1 foot)
Noisy Urban Area during Daytime	-75- moderately loud	Busy restaurant
Gas Lawnmower (at 100 feet)	-70- moderately loud	Vacuum Cleaner (at 10 feet)
Commercial Area	-65- moderate	Normal Speech (at 3 feet)
Heavy Traffic (at 300 feet)	-60- moderate	Sewing machine
Air Conditioner	-55- moderate	Large Business Office
Quiet Urban Area during Daytime	-50- quiet	Dishwasher in Next Room
Quiet Urban Area	-45- quiet	Refrigerator
Quiet Urban Area during Nighttime	-40- faint	Theater, Large Conference Room (background)
Quiet Suburban Area during Nighttime	-35- faint	Average residence (without audio or video systems)
Quiet Suburban Area during Nighttime	-30- very faint	Library
Quiet Rural Area	-25- very faint	Bedroom at Night, Concert Hall (background)
Rustling leaves	-20- very quiet	Broadcast/Recording Studio
Very Quiet Remove Area	-15- extremely quiet	Anechoic chamber or sound testing laboratory
Threshold of Human Hearing	-0-	Threshold of Human Hearing

Sources: California Department of Transportation, Noise, Air Quality, and Hazardous Waste Management Office, *Technical Noise Supplement*, November 2009. Alliance Acoustical Consulting, Inc. reference files.

2. *Groundborne Vibration*

Ground vibration consists of rapidly fluctuating motions or waves with an average motion of zero. Several methods are typically used to quantify the amplitude of vibration including Peak Particle Velocity (PPV) and Root Mean Square (RMS) velocity. PPV is defined as the maximum instantaneous positive or negative peak of the vibration wave. RMS velocity is defined as the square root of the arithmetic mean (average) of the squares of the original velocity values. PPV and RMS vibration velocity amplitudes are used to evaluate human response to vibration. Table 4.10-A3 displays human annoyance and the effects on buildings resulting from continuous vibration.

As discussed previously for noise, annoyance to vibration is also subjective and dependent on situational conditions such as the receptor's physical orientation, the frequency content of the vibrational energy, and the impulsiveness of the vibration (described, in part, by the crest factor). Vibrations may be found to be annoying at much lower levels than those shown in the table; depending on the level of activity and/or the sensitivity of the individual. To sensitive individuals, vibrations approaching the threshold of perception can be annoying.

Low-level vibrations frequently cause irritating, secondary vibration, such as a slight rattling of windows, doors, or stacked dishes. The rattling sound can give rise to exaggerated vibration complaints, even though there is very little risk of actual structural damage. In high noise environments, which are more prevalent where groundborne vibration approaches perceptible levels, this rattling phenomenon may also be produced by loud airborne environmental noise which causes induced vibration in exterior doors and windows.

Table 4.10-A3 Reaction of People and Damage to Buildings for Continuous Vibration Levels

Velocity Level, PPV (in/sec)	Human Reaction	Effect on Buildings
0.006 to 0.019	Threshold of perception: Possibility of intrusion	Vibration unlikely to cause damage of any type
0.08	Vibrations readily perceptible	Recommended upper level of the vibration to which ruins and ancient monuments should be subjected
0.10	Level at which continuous vibrations begin to annoy people	Virtually no risk of "architectural" damage to normal buildings
0.20	Vibrations annoying to people in buildings	Threshold at which there is a risk of "architectural" damage to normal dwellings such as plastered walls or ceilings.
0.4 to 0.6	Vibrations considered unpleasant by people subjected to continuous vibrations	Vibration at this level would cause "architectural" damage and possibly minor structural damage.

Source: Transportation Related Earth-borne Vibrations. Caltrans, Technical Advisory, TAV-02-01-R9601, February 2002.