Appendix B

Acoustical Terminology and Concepts Used in Noise Modeling

Noise Definitions

Noise

Noise is generally defined as loud, unpleasant, unexpected, or undesired sound that interferes or disrupts normal activities. Although exposure to high noise levels has been demonstrated to cause hearing loss, the principal human response to environmental noise is annoyance. Reaction of individuals to similar noise events is diverse and influenced by numerous factors, such as the type of noise, its perceived importance, the time of day during which the noise occurs, its duration, frequency, level, etc.

Sound Level Meters

Noise is measured using a standardized instrument called a 'sound level meter'. All sound level meters are equipped with small microphones that detect minute changes in atmospheric pressure caused by the mechanical vibration of air molecules. Healthy human hearing can detect pressures as low as 0.00002 Pascals (threshold of hearing) and as high as 100 Pascals (threshold of pain).[1] Since this dynamic range is enormous (greater than one million to one), sound pressures are instead reported using a logarithmic scale, which compresses the numbers to keep them more manageable. Once converted, they are referred to as sound pressure levels, followed by 'decibels' (abbreviated dB) as the unit of measure. On a logarithmic scale, the threshold of hearing and the threshold of pain become 0 and about 130 decibels, respectively.

A-Weighted Levels

Noise is generally characterized by amplitude (level) and by frequency (pitch). Amplitude can be reported using various human-perception scales, similar to reporting temperature in terms of wind chill or heat index, or humidity in terms of dew point. The latter are better indicators of perceived cold, warmth or dampness, respectively. Similarly, sound level measurements are often reported using the 'A-weighting' scale of a sound level meter. A-weighting slightly boosts high frequency sound, while reducing low frequency components (similar to the way stereo bass and treble controls work), providing a better indicator of perceived loudness at relatively modest volumes. These measures are called A-weighted levels (abbreviated dBA). Table B-1 provides A-weighted noise levels of familiar noise sources and activities.

[1] A Pascal is a unit of pressure (one Pascal is equivalent to about 0.02 lbs/ft^2). A single Pascal of pressure will produce a sound pressure level of about 94 dB.

TABLE B-1
COMMON SOURCES OF NOISE AND SUBJECTIVE HUMAN RESPONSES

Thresholds/ Noise Sources	Noise Level (dBA)	Subjective Evaluations
Human Threshold of Pain Carrier jet takeoff (50 ft)	140	Deafening
Siren (100 ft) Loud rock band	130	
Jet takeoff (200 ft) Auto horn (3 ft)	120	
Chain saw Noisy snowmobile	110	Very Loud
Lawn mower (3 ft) Noisy motorcycle (50 feet)	100	
Heavy truck (50 feet)	90	
Pneumatic drill (50 feet) Busy urban street, daytime	80	Loud
Normal automobile at 50 mph Vacuum cleaner (3 ft)	70	
Large air conditioning unit (20 feet) Conversation (3 feet)	60	Moderate
Quiet residential area Light auto traffic (100 ft)	50	
Library Quiet home	40	Faint
Soft whisper	30	
Slight rustling of leaves	20	Very Faint
Broadcasting Studio	10	
Threshold of Human Hearing	0	
Note that the subjective evaluations are continuous without true threshold boundaries. Consequently, there are overlaps among categories of response that depend on the sensitivity of the noise receivers.		

Frequency Analysis

To better approximate the response of human hearing, sound level meters are often equipped with octave band filters. Octave band filters divide the audible hearing range into nine separate ‘frequency-bins’ much like a prism separates white-light into bands of different color or wavelengths. Imagining a piano with only nine keys to represent the full range of sound is a good analogy. Sound levels are sometimes measured using one-third octave band filters. As the name implies, one-third octave band filters further divide each octave band into three additional ‘bins’ for greater resolution. An analogous piano would have twenty-seven keys representing the full musical range (rather than only nine).

Percentile Levels

Environmental noise levels constantly change over time and at any given moment are often combinations of natural sounds from birds, insects or tree rustle; noise from local or distant traffic; and/or from industrial, commercial and residential activities. In order to separate low-level constant noise sources (the din of distant traffic, for example) from louder, short-duration events (such as aircraft flyovers or vehicle passbys) percentile or 'exceedance' measurements are often used. These measures help describe the 'average' noise level as well as the range of highs to lows for any given measurement period. As shown in Figure B-1:

L_{10} ('L-Ten') is the level exceeded 10% of the time, that is, levels are higher than this value only 10% of the measurement time. The L_{10} typically represents
the loudest and shortest noise events occurring in the environment, such as car
and truck pass-bys or aircraft flyovers.

L_{50} ('L-Fifty') is the sound level exceeded 50% of the time. Levels will be above and below this value exactly one-half of the measurement time, and therefore the L_{50} is sometimes referred to as the 'median' sound level.

L_{90} ('L-Ninety') is the sound level exceeded 90% of the time and is often called the 'background' sound level. Measured levels are higher than this value
most of the measurement time, so the L_{90} represents the relatively low-level, constant noise present in the environment, discernable only when temporary or varying noises such as bird calls, car pass-bys or aircraft flyovers cease.

Equivalent Energy Level

Noise levels may also be reported in terms of 'equivalent energy levels' or L_{EQ}. An L_{EQ} is a single, calculated value that is 'equal' in energy to the actual fluctuating noise for any given measurement period. As shown in Figure B-1, a noise level of 50 dBA (L_{EQ}) for a period of one minute is equivalent in energy to the fluctuating noise level for the same period produced by the car and truck passes, which range in level from less than 30 dBA to more than 60 dBA. The L_{EQ} typically falls between the L_{10} and L_{50}, and was used to quantify existing noise levels in the vicinity of the project site.

Sound Power and Sound Pressure Levels

Sound power level (PWL) is a single number that ranks how much sound energy is produced by a piece of equipment, independent of the surroundings or environment, and allows one piece of equipment to be directly compared with another. As discussed in Section 4.1, sound power levels for each major piece of equipment were used in a computer-generated acoustical model of the Project to predict property boundary and off-site noise levels.

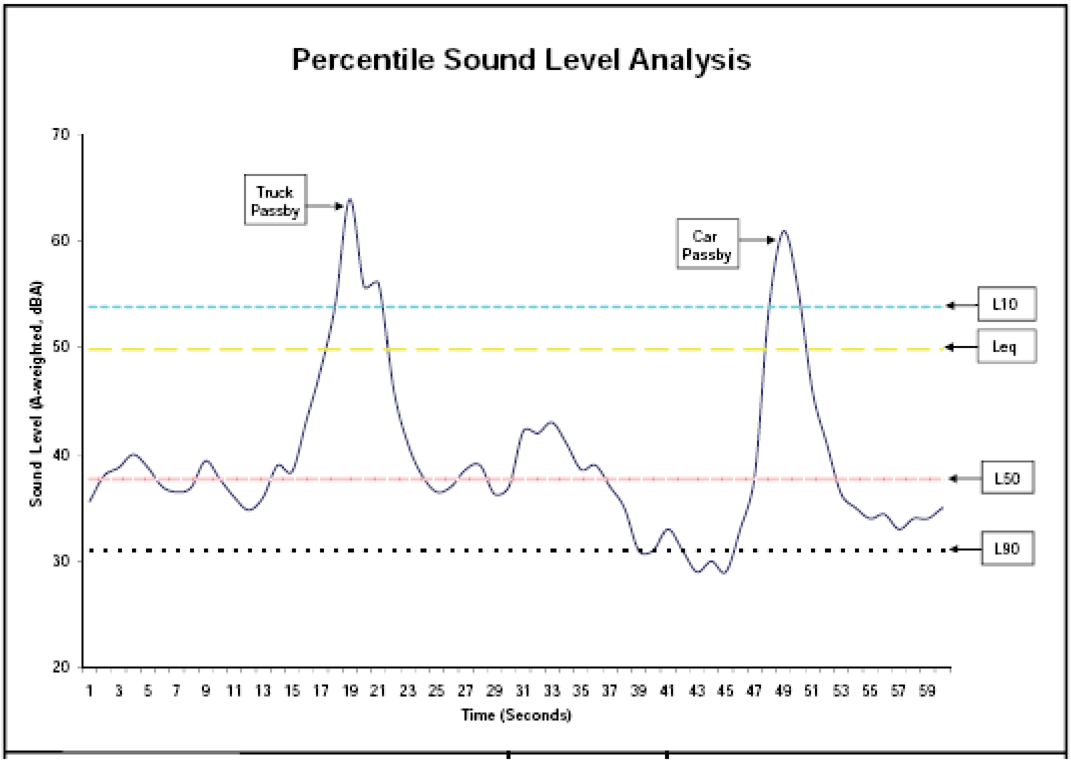

Figure B-1
Example Percentile Analysis

Sound power level is analogous to the wattage of a light bulb, whereas sound level is analogous to brightness. Sound power is *independent* of the environment; sound pressure is *dependent* on the environment. When a 75-watt light bulb is placed in a room painted white or black, it still radiates the same amount of energy. However, the apparent brightness of the light bulb changes as the room environment changes. In the room painted white, many reflections are causing the apparent brightness of the bulb to increase, and in the room painted black, much of the light is being absorbed, so the apparent brightness decreases.

For sound, a room painted white is analogous to a contemporary home with sparse furnishings and hardwood floors, i.e., little absorbing material and many reflections. A room painted black is analogous to a colonial home with rugs, overstuffed chairs, and paintings on the wall, i.e., many absorbing materials and few reflections. A blender or vacuum cleaner would tend to have a higher sound pressure level in the contemporary home versus the colonial one. Similar to light bulb wattage however, the sound power level of either appliance would remain the same regardless of the home it was placed in.

Acoustical Model

In order to evaluate expected noise levels and identify any need for mitigation measures, a three-dimensional, computer-generated acoustical model of the Project was developed using SoundPlan[7] 6.5, to predict property line and off-site noise levels, based on plan and general arrangements provided by Invenergy (see Figure B-2). SoundPlan[7] 6.5 is a computer-based acoustical analysis package specially designed for estimating noise levels from industrial facilities.

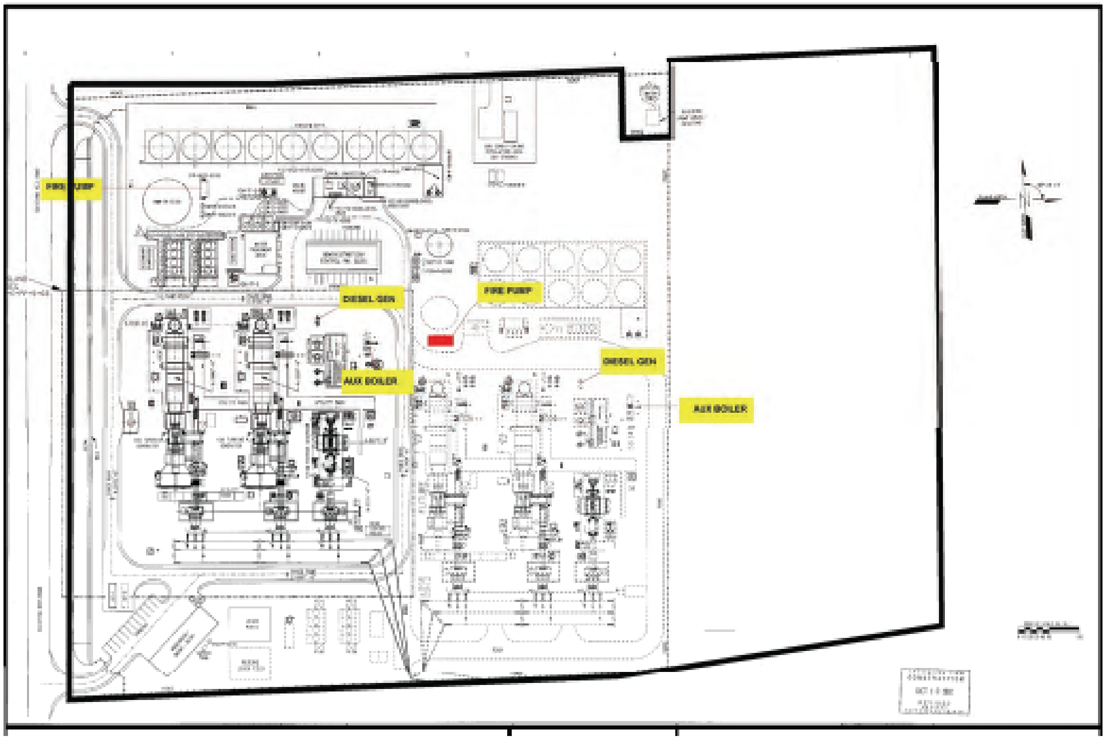

Figure B-2
Facility General Arrangement

Sound power levels (PWL) for all major noise sources (existing plus proposed equipment, including combustion turbine generators, cooling tower inlets and fans, HRSG exhausts, etc.) were estimated using octave band data from manufacturers; field-obtained data; and data from industry-standard prediction algorithms.[2]

Equipment power levels were adjusted for the reduction of sound by distance (*geometrical spreading);* the molecular absorption of sound by air (*air absorption*); and the absorption and reflection of sound by the ground (*ground effect).* Sound levels were further modified by the effects of shielding, (i.e., via tanks, buildings, equipment, etc.); and by changes in source levels with direction (*directivity)* to estimate property boundary and off-site receiver noise levels.

Acoustical Modeling Parameters

The acoustical model used for the analysis is based on ISO 9613-2, “Attenuation of Sound During Propagation Outdoors” adopted by the International Organization for

2 Edison Electric Institute, “Electric Power Plant Environmental Noise Guide”, 1978.

Standardization (ISO) in 1996. This standard provides a widely-accepted engineering method for calculating outdoor environmental noise levels from sources of known sound emission. The following sections briefly discuss the conditions under which the predictions are considered valid.

Meteorology

ISO 9613 is designed to estimate far-field noise levels under favorable sound-propagation conditions, (that is, when wind is blowing from the site towards receivers, or under well-developed temperature inversions, which commonly occur on clear, calm nights[3]). For other weather patterns, such as during upwind conditions, or for ground based temperature lapses, observed noise levels would generally be less than predicted.

Air Absorption

Absorption/attenuation of sound by air is dependent on the frequency of sound as well as on temperature and relative humidity. In general, low temperatures and low humidity increase high-frequency sound absorption, which tends to reduce far-field predicted noise levels. 'Standard' values were used for temperature, relative humidity, and barometric pressure, resulting in a generally conservative estimate of atmospheric attenuation.

Ground Absorption

Noise level predictions are largely dependent on both the type and extent of ground condition assumed for the site and receiver areas. Areas of ground at the Project site were modeled as 'hard', or completely reflective, which is typical of paving, concrete, tamped ground, water and other ground surfaces commonly found at industrial sites. Off-site ground areas were assumed to be 50% absorptive, which is characterized as semi-porous ground, and is typical of moderately vegetated land.

Reflections

For complex industrial installations with a large number of obstacles (such as buildings, tanks, equipment, etc.), reflected energy components can be considerable. Therefore, the number of reflections for the model was conservatively set at two, allowing for the effects of multiple acoustic ray paths from a single source to be considered.

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3 Temperature inversions typically develop during calm, cloudless nights, when the ground is no longer being heated by the sun. As a result, air near the ground begins to cool, forming a thicker and thicker 'blanket' as the evening progresses. In practical terms, this means that temperature is ***increasing*** with elevation, (i.e., the air is actually warmer at higher elevations, as compared to near the ground) and hence the term Atemperature inversion.@ The effect of temperature inversion on sound propagation is to 'bend' sound waves back towards the ground, producing near worst-case sound levels at a receiver. In contrast, Atemperature lapse@ commonly develops during calm, cloudless ***daytime*** periods, when the ground is being heated by the sun, which in turn produces a warm layer of air next to the ground, as opposed to at higher elevations. This means that temperature ***decreases*** with elevation, causing sound waves to bend upwards and reducing sound levels observed at a far-field observer.

Directivity

A vertical directivity correction was used to account for changes in source levels with direction. This vertical directivity was used with sources including the HRSG stack exhausts, cooling tower fans, and gas turbine compartment ventilation fans.