Soundscape Engineering
Practical Solutions from Professional Engineers

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Subject: Ann Arbor Public Schools - Logan Elementary School
Ann Arbor, Michigan
Environmental Noise Impact Analysis

Dear Lindsay,

Soundscape Engineering has completed our assessment for mechanical equipment sound propagation onto nearby residential properties for the future Logan Elementary School in Ann Arbor, Michigan. This report provides the results of our prediction of the mechanical rooftop sound transmission to the nearest residential properties, a description of recommended noise mitigation, and a comparison with the local noise emissions ordinance. A glossary of acoustical terminology is provided in Appendix A in case you wish to refer to it while reading the report.

Noise Target and Local Ordinance

CHPS does not have a requirement for sound from the building site radiating onto adjacent properties. However, all buildings in Ann Arbor must meet the noise ordinance. Ann Arbor has a general noise prohibition in Section 9:362 and maximum limits listed in Section 9:364. While the decibel level is a hard limit, the school district wants to be a good neighbor and thus would like to minimize the possibility of neighborhood noise disturbance related to the school operations.

9:363. Specific prohibitions.

No person shall engage in, assist in, permit, continue or permit the continuance of the following activities if the activity produces clearly audible sound beyond the property line of the property on which it is conducted even if the sound level is equal to or less than the dB(A) specified in section 9:364:

9:364. Maximum permissible sound levels.

No person shall conduct or permit any activity that produces a dB(A) beyond his property line exceeding the levels specified in Table I. Where property is used for both residential and commercial purposes, the residential sound levels shall be used only for measurements made on the portion of the property used solely for residential purposes.

TABLE I

USE OF PROPERTY RECEIVING THE SOUND	7:00 a.m. to 10:00 p.m.	10:00 p.m. to 7:00 a.m.
Residential	61	55
Commercial	71	61

(All limits expressed in dB(A)).

In this report, we first assess the predicted sound from the rooftop air handling units to the noise ordinance. Then to estimate the impact on the neighborhood, we compared the predicted levels to the measured ambient.

Measurement Procedure and Results

Soundscape Engineering installed a sound level meter on the evening of November 3, 2023, to capture the existing ambient exterior sound levels at a location at approximately the future building façade. We also used this location as being representative of the background sound level in the general area.

Figure 1 presents the meter location (blue dot) on an aerial view of the site. Figure 2 shows the installed meter on site. The measurements allow us to estimate the audibility of radiated sound from the rooftop mechanical equipment.

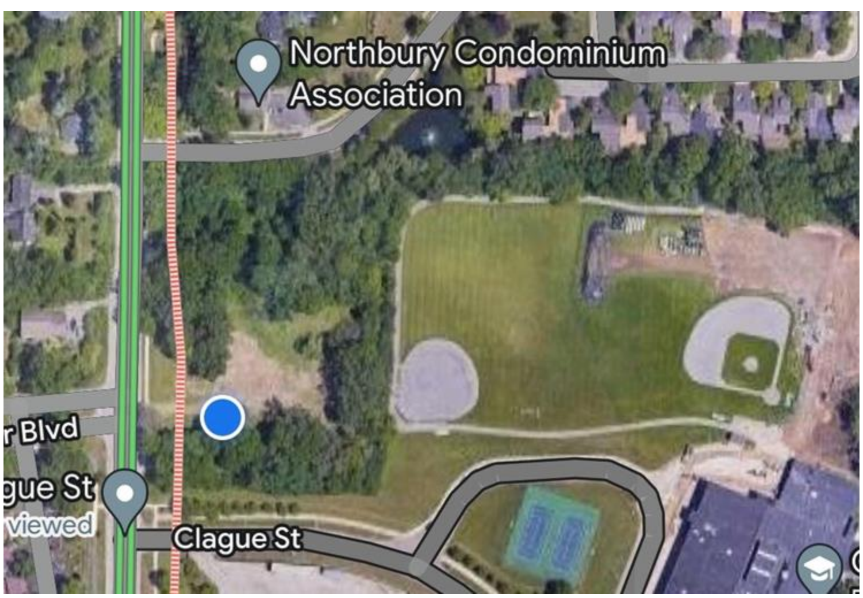

Figure 1: Meter Installation Location (Blue dot)

Figure 2: Installed Meter Placement

<u>Computer Model of Rooftop Units (RTU) Related Sound Levels</u>

The dedicated outside air (RTU) rooftop units will be located on the roof of the school as shown in Figure 3.

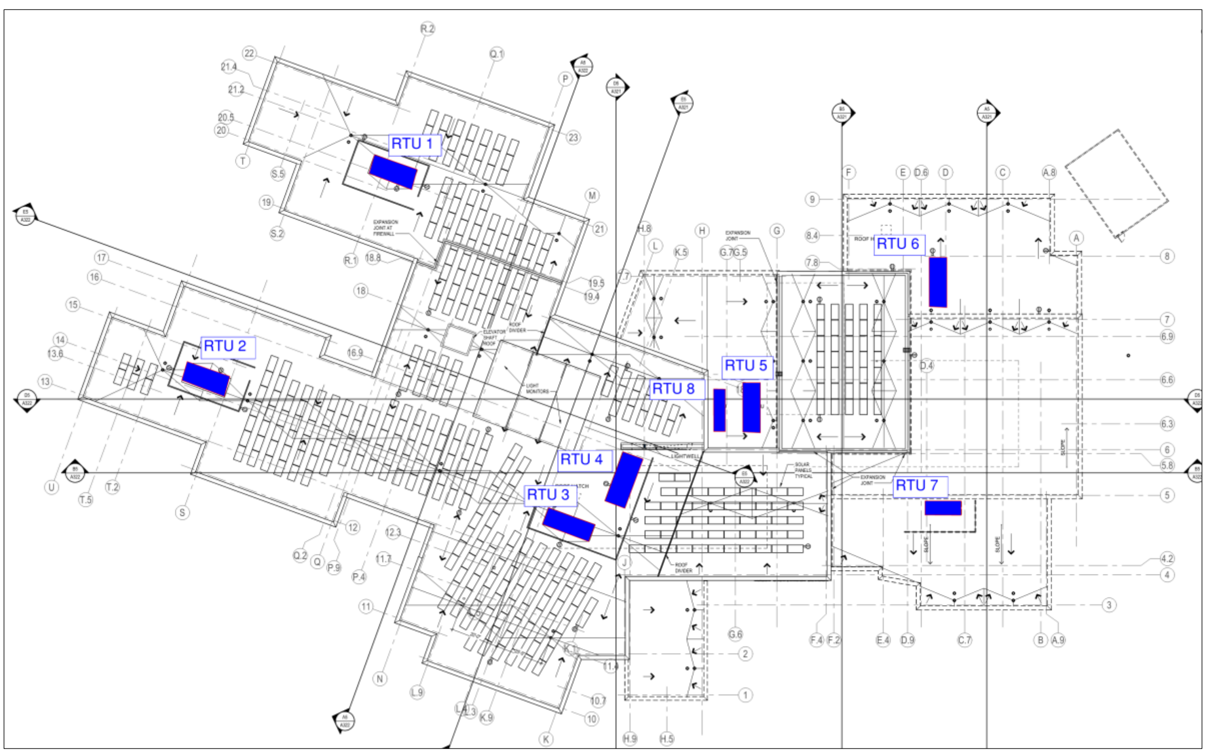

Figure 3: Logan Elementary School Roof Plan

We modeled the Logan Elementary site and surrounding area in the commercial environmental noise modeling software, SoundPLAN. Site topography, ground surface absorption, the proposed school building, nearby buildings, the RTU sound sources, and reflective surfaces were inputted as elements into the computer model. The levels used in the model are listed in Appendix B. We recommend that these levels not be exceeded.

Figure 4 shows a SoundPlan map of the overall sound pressure levels associated with all eight rooftop RTUs operating at 100% of rated capacity. This would be an unusual situation but provides a safety factor in our calculations. The yellow dots with their respective numbers represent receiver locations. The two numbers associated with each dot show the predicted level in dBA for the second story (upper number) and the first story (lower number) of the house but at the property line.

The nighttime ordinance limit of 55 dBA was used as the criterion since we understand that the building systems start conditioning the spaces prior to 7:00 AM, which is the night/day cutoff time, for the arrival of staff and students. The results show **no locations exceed 55 dBA.** The radiated sound levels from the currently specified rooftop units are **predicted to meet the Ann Arbor ordinance requirements** without mitigation steps.

Figure 5 shows how the sound propagates over the property and onto adjacent properties. All green shaded areas are at or under 55 dBA.

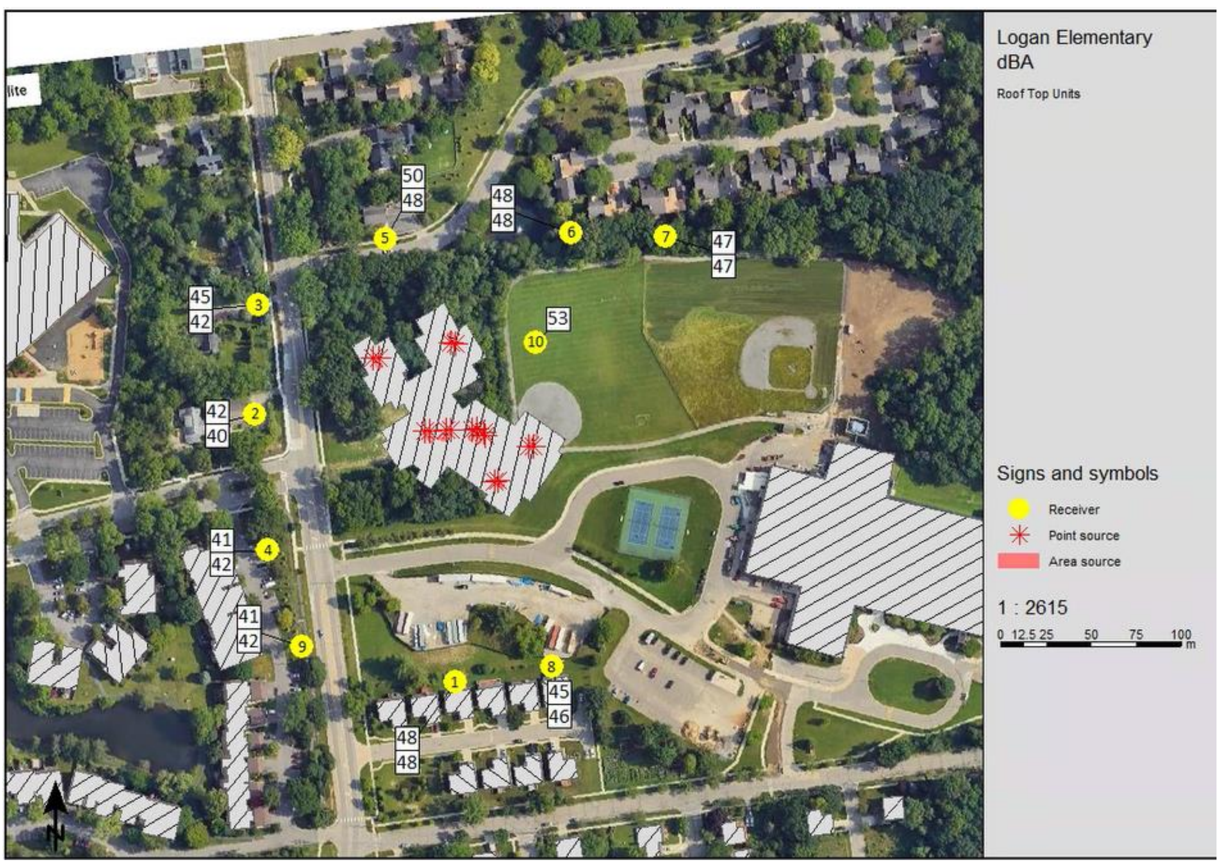

Figure 4: Sound Map – Nighttime

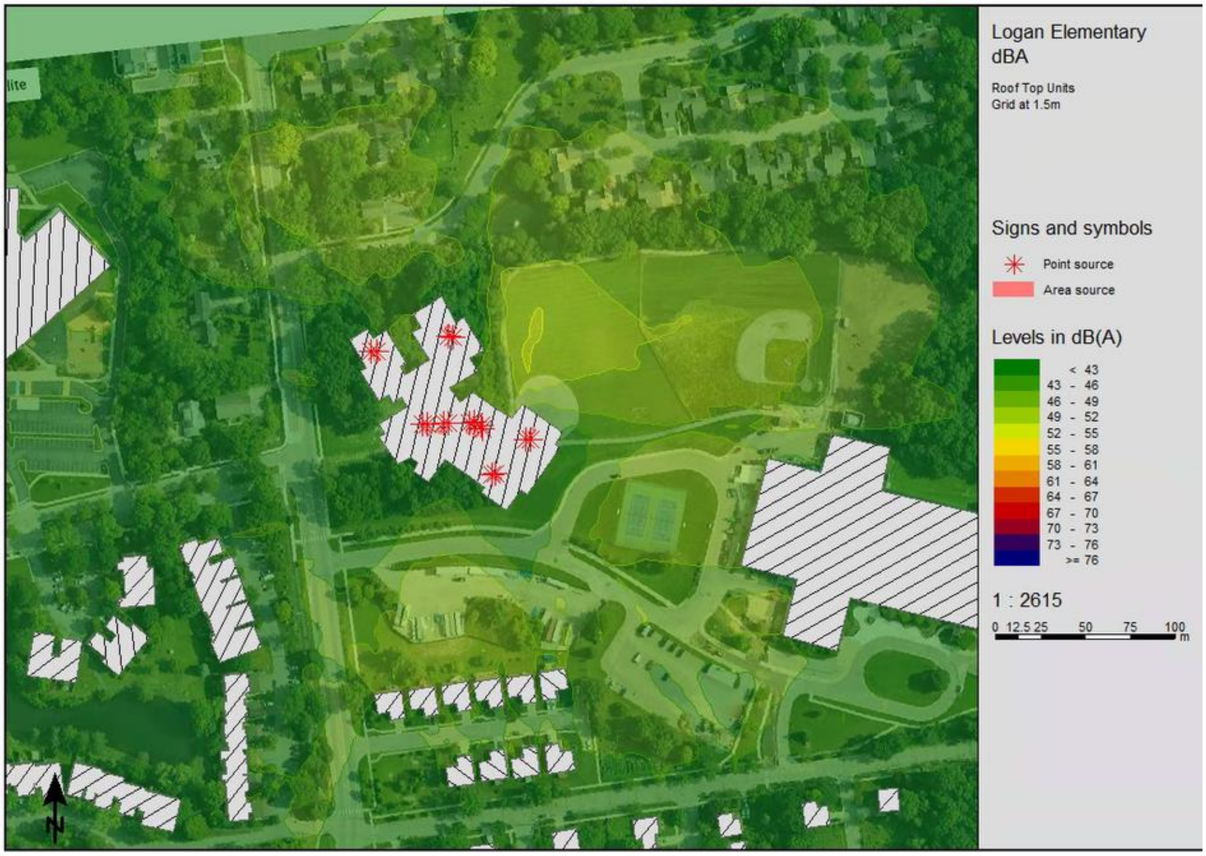

Figure 5: Sound Contour Map (Green Shaded Areas meet the Ordinance)

We have also evaluated the predictions against the measured octave band sound levels during the 6:00 AM hour when the units will typically start cooling the building. The statistical level called L_{90}, which is the sound level exceeded ninety percent of the time, was used for the ambient sound level instead of the average level because it is more representative of what people perceive the ambient to be. This metric is used by the Federal Highway Administration as representative of the constant background sound without influence by transient sounds such as vehicle pass-bys, airplane overflights, people talking, etc.

The highest predicted levels for 100% operation are primarily concentrated to the north on Argonne Drive and Southwick Court, though some of the Nadia Court residences have the same level as the homes on Southwick Court . The highest exposure case, Location 5, is the same distance off Nixon Road as the ambient measurement location, so no adjustments to that level were made for correction to the ambient. Figure 6 presents this receiver location compared to the 6:00 AM octave band average sound level. This hour falls into the "nighttime" category in the ordinance, which has a more restrictive requirement.

The spectral prediction for the RTU units operating at 100% at both the first and second floor of Location #5 is substantially below the measured ambient level at 63 Hz and 125 Hz. At 250 Hz and 500 Hz, the predicted levels are within 3 dBA of the L_{90} ambient, which means that detecting a difference with the RTUs on and off would be difficult. In the upper frequencies, the predicted RTU sound level is above the measured ambient. This means the sound emitted by the RTU units will be most likely audible.

The largest sound source contribution is the exhaust outlet on the rooftop units. Fan noise typically has tonal components, which can be detectable in background sound when the tone is up to ten decibels less than the ambient sound. The prediction indicates that the exhaust fan noise may be detectable when the units are operating at full speed, which presumably would happen during the morning start-up or when experiencing extreme hot and cold temperatures.

Mitigation recommendations are provided in the next section.

Figure 6: Measured and Predicted Sound Levels at Residential Location #5

Mitigation Measures

To reduce the likelihood of neighborhood complaints due to the new school rooftop units, we recommend the following mitigation measure to reduce the sound levels.

- Specify the air handling units to have a 2-inch-thick sound absorbing panels mounted to the walls and ceiling of the exhaust plenum for all RTU units.
    - The panels must have a minimum Noise Reduction Coefficient of NRC 0.90 (surface mounted during testing, referred to as Type A mounting).
    - The face material should be perforated metal with a regularly spaced pattern. The holes should have a maximum diameter of 3/16 inch and achieve a minimum free area of 20%. The metal gauge should be 22 gauge or thinner roll formed galvanized steel that is processed or finished such that the holes do not leave raw metal that can rust. Alternately, aluminum can be used in lieu of steel.
    - Panel framing members can be heavier gauge as needed for structural integrity.
    - The sound absorbing core shall be inert, mildew resistant, vermin-proof glass fiber or mineral wool with a minimum density of 6 lb/ft^3 to suit the sound absorption performance required. The core shall be encapsulated in polyethylene bagging with a spacer to separate the bagging from the perforated face.

Conclusion

Please note that our recommendations and comments are exclusive to acoustics. We cannot comment on such things as local codes, life-safety requirements, or any other non-acoustic issues. Our recommendations should be reviewed by an appropriate design professional for code compliance and constructability before they are implemented.

This concludes our assessment. We are happy to elaborate on anything contained within this report.

Sincerely,
Soundscape Engineering
Per:

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Appendix A: Acoustical Terminology

Sound level is measured in units called decibels (abbreviated dB). Decibels are logarithmic rather than linear quantities and thus a doubling of the sound level does not translate to a mathematical doubling of decibels. Also, our ears do not interpret a doubling of sound energy (two sources instead of one) as a doubling of loudness. The logarithmic nature of dB and our subjective perception of relative sound levels result in the following approximate rules for judging increases in sound.

- 3 dB sound level increase or decrease - just noticeable
  (the addition of one identical sound source to an existing source)
- 5 dB sound level increase or decrease - clearly perceptible and is often considered significant
  (the addition of two identical sound sources to an existing source)
- 10 dB sound level increase or decrease - perceived as twice as loud/half as loud
  (the addition of nine identical sound sources to an existing source)

These perceived changes in the sound level are mostly independent of the absolute sound level. That is, a 35 dB sound will be perceived as approximately twice as loud as a 25 dB sound, and a 60 dB sound will be perceived as approximately twice as loud as a 50 dB sound.

Audible sound occurs over a wide frequency range, from low pitched sounds at approximately 20 hertz (abbreviated as Hz) to high pitched sounds at 20,000 Hz. These frequencies are commonly grouped into octave bands or 1/3 octave bands. Building mechanical systems generally produce sound in the 63 Hz to 1000 Hz octave bands, with the lower frequency sound generated by large fans. Speech is predominantly contained in the 250 Hz to 2000 Hz octave bands.

A-weighted sound level - Humans do not hear equally well at all frequencies. We are especially poor at hearing low frequency sound and are best at hearing sound in the frequency range of speech. A microphone does not have these same characteristics. Therefore, when sound is being measured to determine how well people will be able to hear it, a “weighting” or microphone-to-human correction factor is applied to the sound level measured using a microphone. The most common weighting is the “A-weighting”, and the resulting sound level is expressed in A-weighted decibels (dBA). This weighting reduces the low frequency sound, slightly increases the sound at the dominant frequencies of speech, and slightly lowers the sound level at high frequencies.

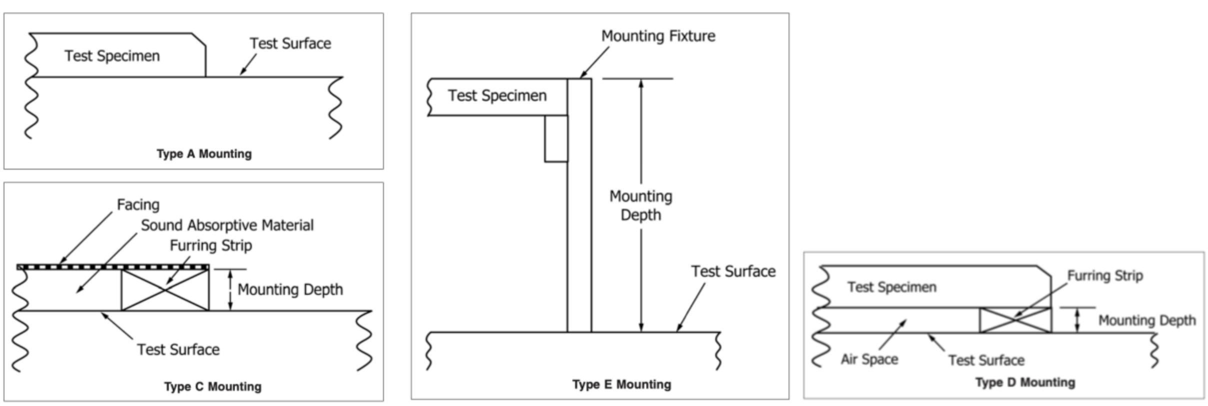
Sound Power and Sound Pressure Levels - Sound pressure can be directly measured by a microphone. Outdoor sound pressure levels are influenced by the distance and orientation of the receiver, obstructions, and ground absorption between the source and receiver, the temperature, and wind gradients. Sound power is a physical property of the source alone and is not influenced by the external environment. It is an important parameter which is used for rating and comparing sound sources. The sound power is calculated by taking sound pressure or sound intensity measurements according to strict standards and calculation procedures. Conversely, the sound pressure level at a particular location can be calculated from the sound power level for a given source and the environmental factors affecting the sound propagation path between the source and receiver.

Sound absorption is the property possessed by materials and objects, including air, that converts sound energy into heat energy. It is measured in sabins with the units of $1/ft^2$ or $1/m^2$. One sabin is the equivalent of 1 square foot or 1 square meter of a perfectly absorptive surface (a material with a sound absorption coefficient of 1.00). Sound absorption is reported by octave band because the absorption of a material varies by frequency. Acoustical baffle performance is often provided in a sound absorption per (material) unit of a given size.

Sound absorption coefficient (α) is a measure of the amount of sound absorbed by a material. It is measured in a reverberation chamber and is specified at octave band center frequencies. In theory, it ranges from 0.00 (perfect reflector) to 1.00 (perfect absorber). In reality, for highly absorptive materials, the test method can result in absorption coefficients higher than 1.00, occasionally as high as 1.20. The absorption coefficient can be used to compare the acoustical performance of sound absorbing materials. It is also used in calculations to estimate sound reverberation time and reverberant sound level in enclosed spaces.

Noise Reduction Coefficient (NRC) is basically the average percentage of incident sound that is absorbed by a material in the speech frequencies. It is a single number rating derived by averaging the measured absorption coefficients for the 250 Hz, 500 Hz, 1000 Hz, and 2000 Hz octave bands. Theoretically, NRC 1.0 (100% of sound absorbed) is the best performance achievable, but NRC’s higher than 1.0 are sometimes encountered as a result of the testing and calculation procedure. Most manufacturers of sound absorbing acoustical products provide the NRC for their products. NRC is mostly used as a convenient means of comparing the acoustical performance of products. If low frequency absorption (125 Hz) is required, then NRC cannot be used and the octave band absorption coefficient at 125 Hz must be evaluated.

Mounting type of acoustical panels affects their sound absorbing properties and thus the NRC rating. The same material could be mounted directly to a reflecting surface, which is called Type A mounting, or suspended on a grid backed by at least a 16 inch deep airspace, which is called Type E-400 mounting. The numerical value is in millimeters. Other mounting types encountered less often are Type C mounting, which calls for furring strips and sound absorptive material behind an acoustically transparent facing (such as perforated metal), and Type D mounting, where an acoustical panel is furred from a hard surface to form an air space behind the acoustical panel. Unless the facing or panel is impact resistent, to avoid damage we generally do not recommend Type C and D mounting for walls where people or objects can come into contact with the panels.



The **ambient or background sound level** often refers to the indoor or outdoor sound level without the sound source of interest but with other sounds that contribute to the level. For example, if the sound level of an outdoor condensing unit is being assessed, the extraneous sound of traffic and other mechanical equipment should also be measured to determine if it affects the measurement of the condensing unit. Indoor background/ambient sound often originates with the air ventilation system. If the background sound does interfere with the measurement of the sound of interest, then most of the time a correction factor can be applied.

Statistical sound levels, as they are most often called, quantify the sound level exceeded during a period of time for the measurement period. For example, the L_{90} sound level is the sound level exceeded during 90% of the measurement period. If the measurement period is 60 minutes long, then the L_{90} is the sound level exceeded during 54 minutes. It is most often lower than the L_{eq}. The L_{90} is generally considered to be the "background" sound level, which is the baseline level that is present most of the time. Another commonly used statistical level is the L_{10}. The L_{10} is the sound level exceeded during 10% of the measurement period. If the measurement period is 60 minutes long, then L_{10} is the sound level exceeded during 6 minutes of the measurement period. L_{10} can be used to quantify the fluctuating sound levels in an environment. L_{01} is often used as the maximum sound level for perceptibility and analysis in the design of interior spaces where music and amplified speech could disturb need to be sound isolated.

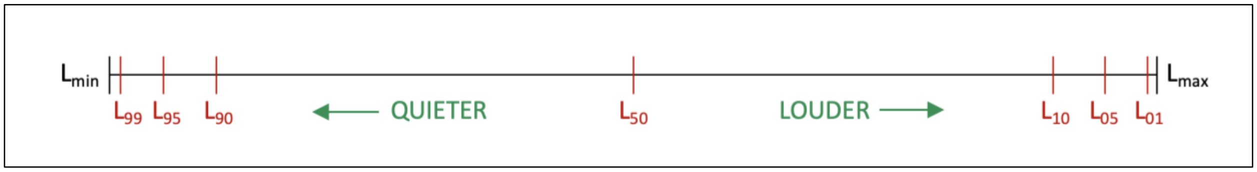


Figure 7: Relative scaling of statistical sound levels

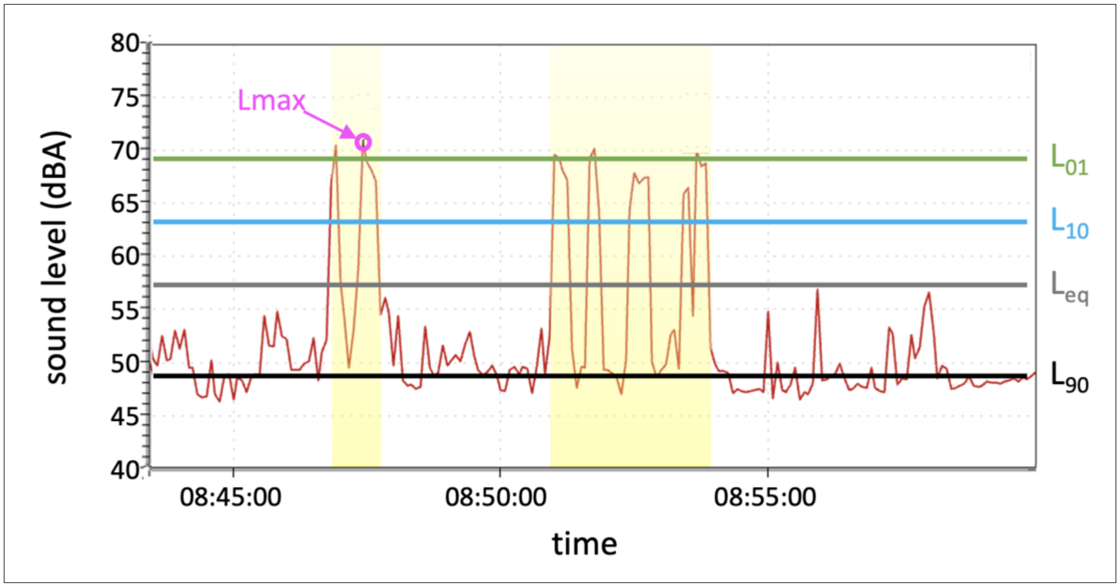


Figure 8: Statistical sound levels, L_{max}, and L_{eq} applied to a sound signal

Appendix B: RTU Rooftop Unit Sound Data

The following tables present the sound level data received from the Innovent manufacturer. Radiated sound levels were not provided, so we calculated it based on the fan sound power and unit openings. If units that exceed these levels are purchased, additional mitigation measures may be necessary.

Table 1: RTU 1 and 2 Sound Power Levels

RTU 1 & 2		Frequency (Hz)							
		63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Supply	Inlet	81	74	83	87	80	80	77	74
	Outlet	85	81	87	90	90	89	84	80
Exhaust	Inlet	83	77	86	85	80	78	75	72
	Outlet	84	81	88	88	89	87	82	79
Calculated Radiated		74	68	77	71	63	52	38	35

Table 2: RTU 3 Sound Power Levels

RTU 3		Frequency (Hz)							
		63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Supply	Inlet	83	81	91	87	84	81	79	77
	Outlet	86	86	97	94	93	90	88	83
Exhaust	Inlet	76	73	88	82	78	77	74	77
	Outlet	80	78	90	87	88	84	80	81
Calculated Radiated		74	74	68	77	71	63	52	38

Table 3: RTU 4 Sound Power Levels

RTU 4		Frequency (Hz)							
		63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Supply	Inlet	83	82	91	89	86	83	81	79
	Outlet	86	87	98	96	96	92	89	85
Exhaust	Inlet	88	83	91	85	80	78	73	77
	Outlet	88	86	93	90	90	85	80	81
Calculated Radiated		74	76	74	85	76	67	54	42

Table 4: RTU 5 Sound Power Levels

RTU 5		Frequency (Hz)							
		63	125	250	500	1000	2000	4000	8000
Supply	Inlet	84	82	91	88	85	83	81	79
	Outlet	86	87	98	95	95	92	89	85
Exhaust	Inlet	83	82	93	89	86	83	79	93
	Outlet	87	87	99	95	96	91	87	95
Calculated Radiated		74	76	74	88	77	69	56	43

Table 5: RTU 6 Sound Power Levels

RTU 6		Frequency (Hz)							
		63	125	250	500	1000	2000	4000	8000
Supply	Inlet	84	79	84	90	83	82	79	77
	Outlet	87	83	88	94	93	91	86	83
Exhaust	Inlet	76	73	88	81	78	77	74	76
	Outlet	80	78	90	87	88	84	80	80
Calculated Radiated		74	74	69	78	74	64	53	39

Table 6: RTU 7 Sound Power Levels

RTU 7		Frequency (Hz)							
		63	125	250	500	1000	2000	4000	8000
Supply	Inlet	94	87	90	85	77	77	75	70
	Outlet	94	93	94	88	88	85	81	76
Exhaust	Inlet	84	79	82	76	69	69	66	61
	Outlet	85	84	87	80	80	77	72	67
Calculated Radiated		74	81	78	81	68	59	47	34

Table 7: RTU 8 Sound Power Levels

RTU 8		Frequency (Hz)							
		63	125	250	500	1000	2000	4000	8000
Supply	Inlet	80	74	81	86	79	78	75	72
	Outlet	83	79	85	89	89	87	82	79
Exhaust	Inlet	81	77	86	85	79	78	74	72
	Outlet	82	80	89	89	89	87	81	79
Calculated Radiated		74	72	67	76	71	62	51	37