San Leandro Sound Insulation Program
Introductory Phase Sound Insulation Testing

Prepared for the

City of San Leandro

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July 6, 2006

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1. Introduction

The purpose of this report is to present the results of the pre-construction and post-construction testing for the test homes in the Introductory Phase of the San Leandro Airport Noise Insulation Program. The Introductory Phase consists of 10 homes. Following the Introductory Phase, there will be two additional phases, each consisting of as many as 95 homes. All homes are located within the City of San Leandro. The sound insulation program is funded by the Port of Oakland, but implemented as a City of San Leandro Public Works project pursuant to the Settlement Agreement between the Port of Oakland and the City of San Leandro. The homes are located south of Oakland International Airport, and according to the noise contours published by the Port of Oakland, the area is subject to aircraft noise in the range of 53 to 61 dB CNEL. The project area and Oakland noise contours are shown in Exhibit 1.

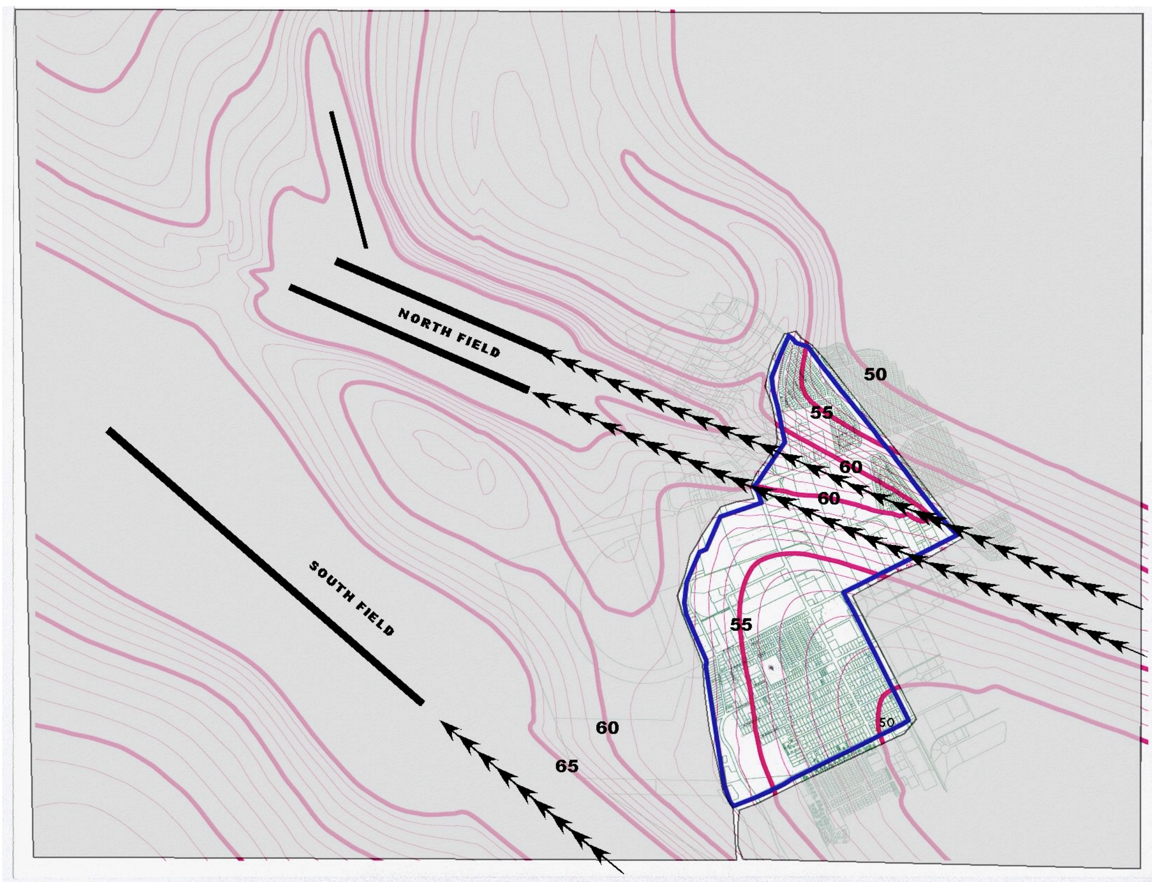


Exhibit 1: Project Area and CNEL Contours for Oakland International Airport

Of the 10 homes that were included in the Introductory Phase, four were chosen for pre-construction testing. Pre-construction testing was completed on these four homes. Two of the homes later dropped out of the program. After sound insulation was completed on the remaining homes, the two homes that had been tested prior to construction were re-tested after sound insulation construction. This report presents the results of that testing.

2. Location of the Noise Measurements

The location of the pre-construction measurements are shown in Exhibit 2. The following are the addresses for each location.

12960 Neptune
2092 Laura
1365 Marybelle
2029 Marina Court

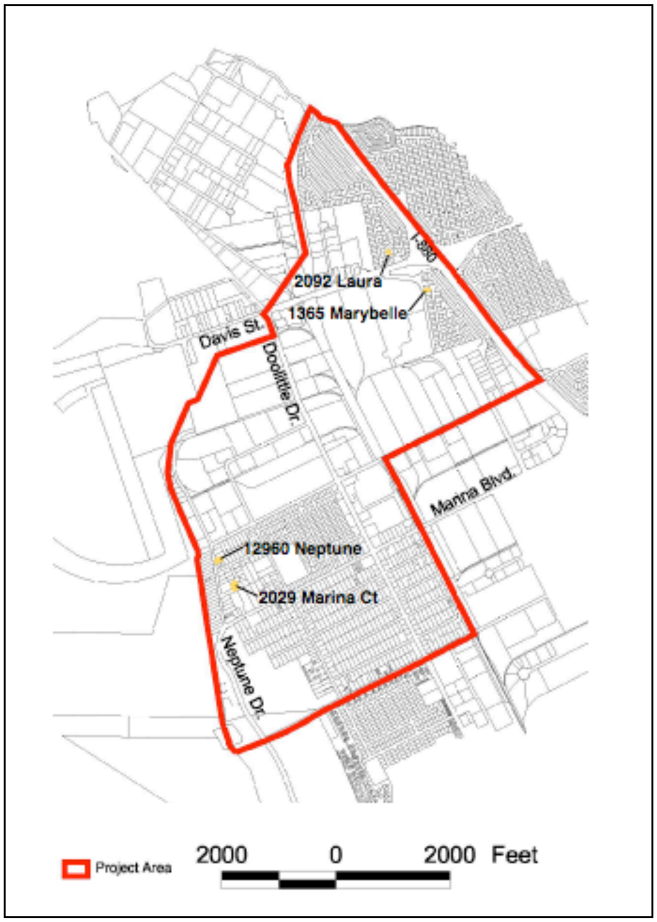
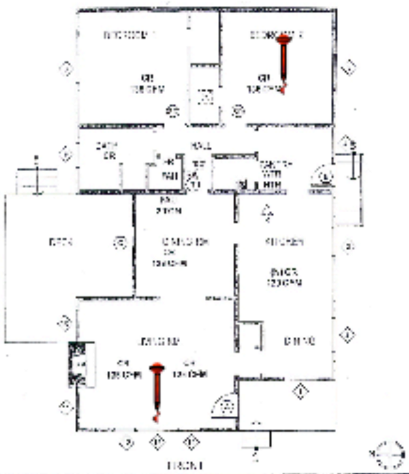


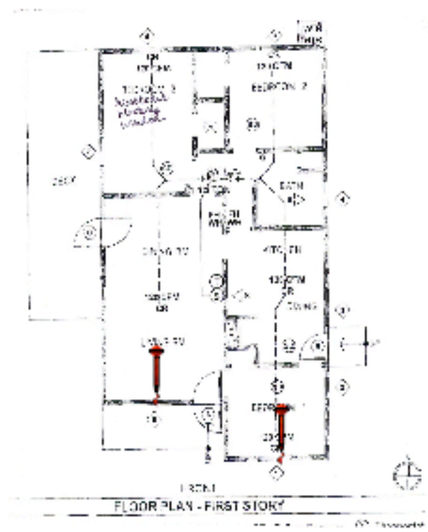
Exhibit 2: Noise Measurement Locations

The floor plans for each of the four homes is shown in Exhibit 3 showing the location of the rooms that were measured.

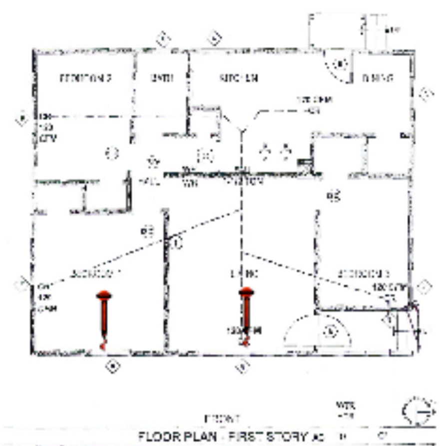
Photographs of the four homes are shown in Exhibit 4.



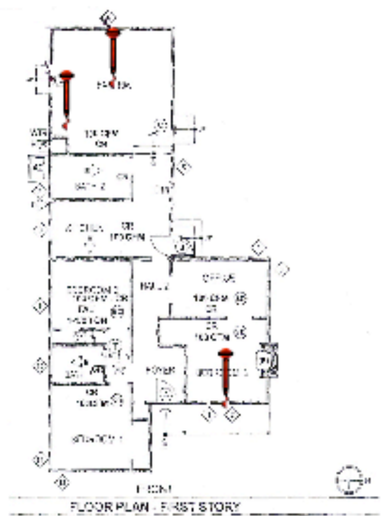
12960 Neptune



2092 Laura



1365 Marybelle



2029 Marina Court

Exhibit 3: Floor Plans (Microphone Location Shown)

12960 Neptune

2092 Laura

1365 Marybelle

2029 Marina Court

Exhibit 4: Photographs of Test Homes

3. Noise Measurement Methodology

The noise measurements were made by measuring interior and exterior noise levels simultaneously using a sound level meter indoors and a sound level meter outdoors. There are two methods available to perform these measurements. The first uses the actual aircraft flyover noise as the noise source. The second method uses a loudspeaker as an artificial sound source. The former method could not be used in San Leandro because of the low signal to noise ratio that results from the ambient noise level and aircraft noise level. That is not to say that aircraft are not audible, but that the difference between the aircraft and ambient noises makes the measurement of outdoor to indoor transmission loss very difficult. For that reason an outdoor artificial sound source was used for these tests. The test methodology used was that described in "Standard Guide for Field Measurement of Airborne Sound Insulation of Building Facades and Façade Elements," American Society of Testing and Materials (ASTM), E 966-92. The test method used involves reproducing a recorded sound through a loudspeaker and measuring a time averaged noise level indoors and outdoors and calculating the Outdoor Indoor Level Reduction (OILR). The loudspeaker was set up at specific location relative to the room being tested. A time average sound level was measured by moving a microphone slowly and carefully just outside and just inside the window of the room being tested. Detailed descriptions of the methodology are provided in the appendix. The measurement equipment included the following:

Sound Level Meters:
- Bruel and Kjaer Model 2238 Precision Sound Level Meters
- Bruel and Kjaer Model 2260 Real Time Analyzer

Calibrator:
- Bruel and Kjaer Model 4231
- Bruel and Kjaer Model 4220

Amplifier:
- QSC PLX1602

Loudspeaker:
- Yamaha S1121V

CD Player:
- Sony Model No. D-E356CK

Source:
- CD recording of BBA aircraft noise continuous loop

The location of the speaker was documented in photographs and located by tape measure.

Three sets of measurements were made for each room. The one minute A-weighted slow equivalent sound level (LEQ) moving time average was recorded twice and then the 1/3 octave band frequency noise levels were recorded using a fixed microphone position.

The spectra of the sound source used for each test is shown in Exhibit 5a and 5b. The spectra in the pre-construction testing was low in the low frequencies so the 1/3 octave frequency data recorded during the pre-construction tests was used to provide a frequency adjustment to the pre-construction tests.

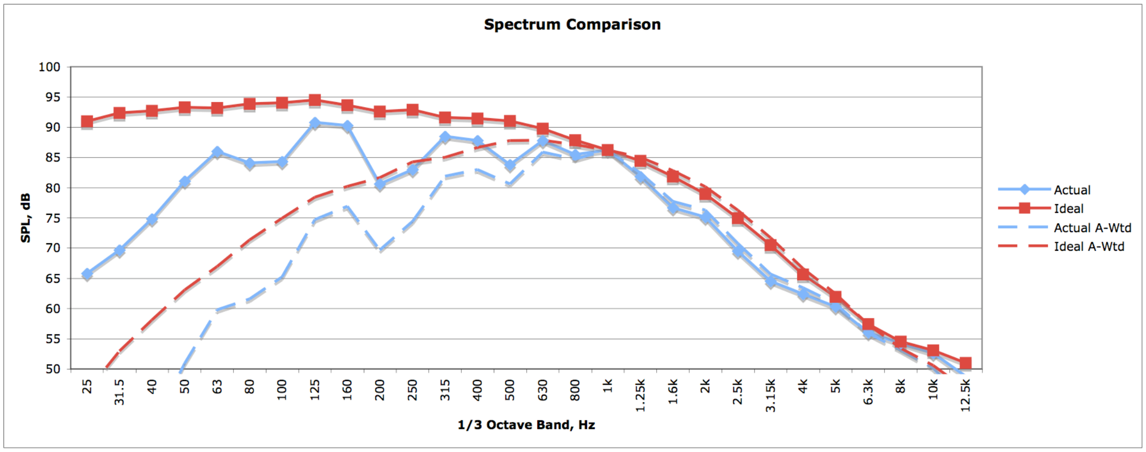


Exhibit 5a: Pre-Construction Source Spectra

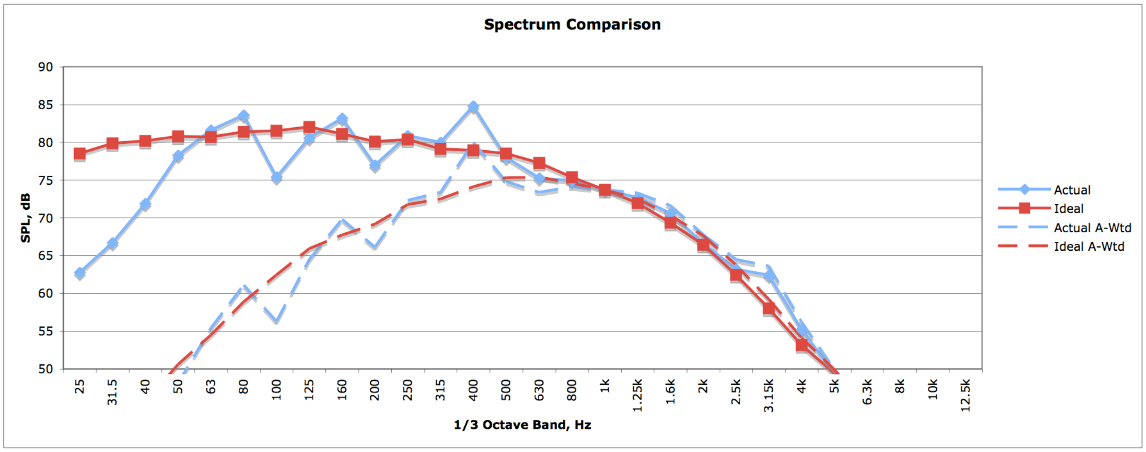


Exhibit 5b: Post-Construction Source Spectra

4. Pre-Construction and Post-Construction Noise Measurement Results

Address	Room	OILR, dBA		Noise Level
		Pre	Post	Reduction, dBA
12960 Neptune	Living Room	20.3	27.3	7.0
	Bedroom 2	24.5	31.5	7.0
2092 Laura	Living Room	23.6	25.8	2.2
	Bedroom 1	22.5	28.2	5.7
1365 Marybelle	Living Room	19.2	withdrew	-
	Bedroom 3	15.1	withdrew	-
	Bedroom 1	19.2	withdrew	-
2029 Marina Ct	Bedroom 2	19.1	withdrew	-
	Family Room Slider	19.1	withdrew	-
	Family Room Window	20.8	withdrew	-

Table 1: Noise Measurement Results

The noise measurement results at 12960 Neptune exceed the design goal 5 dBA noise level reduction improvement.

The results for the home at 2092 Laura show a 2.2 dBA improvement in the living room and 5.7 dBA improvement in the bedroom. This home is unique in that the homeowner had already installed dual glazed insulating windows in his home. Further, the owner of this home did not want to change his living room front door to a new sound-rated solid core door. The old door included a stain glass window that was installed over a dual glazed insert. While this appeared to be a fairly good installation, it is not as good as a new sound rated solid core door and that may be the reason that the living room did not achieve the 5 dBA improvement goal. Overall, the average noise level reduction improvement was 5.5 dBA.

Appendix: Equipment List and Detailed Procedures

Equipment List and Test Procedures

These test procedures are intended to be consistent with ASTM Standard Guide E 966-92 using a loudspeaker source and the "nearby average method" (see Figure 2b and Equation 8a). Refer to the ASTM Standard Guide for further details and clarification.

Equipment List (w/o spares)

1. BBA CD-ROM with continuous, recorded aircraft noise
2. Portable CD player with output cable
3. AudioSource Model EQ 100 graphic spectrum analyzer/equalizer
4. QSC PLX1602 audio power amplifier
5. Yamaha S1121V loudspeaker
6. Folding table for CD player, equalizer and power amplifier
7. Cables between equalizer, amplifier and loudspeaker
8. Speaker stand to elevate loudspeaker about 6 feet above ground
9. Honda portable generator
10. 50-foot extension cord with 3-prong, grounded connectors
11. Two B&K Model 2238 sound level meters
12. Two microphone extension cables
13. B&K sound level calibrator
14. Two large windscreens
15. Two tripods with base clip for mounting sound level meter
16. Two 25-foot tape measures
17. Two 30-inch lengths of PVC pipe for "wands"
18. One roll of tape for securing microphone extension cable to "wand"
19. B&K Model 2260 sound level meter for initial spectral balancing
20. Straight-line ultrasonic "laser tape" for measuring interior room dimensions
21. Casio Wave Ceptor watch or GPS unit or Internet connection for time standard
22. Two clipboards with data sheets
23. Laptop computer with serial cable for downloading data and Excel spreadsheet for plotting OILR curves
24. Digital camera for photographing house exterior and yard, room interior and equipment setup
25. Extra AA batteries for CD player, camera and sound level meters
26. Ear protection for person working outside

<u>Preliminary Set-up and Testing of Equipment (before leaving office)</u>

1. Set dip switches at rear panel of QSC power amplifier (clip limiter ON, bridge mono ON, LF filter OFF) for maximum output.
2. With CD player and QSC amplifier at full scale, the free-field sound pressure level at 15 feet is approximately 95 dBA.

3. Confirm off-axis sound pressure is within 3 dB of on-axis sound pressure up to an angle of 45 degrees.
4. Confirm that the settings for both B&K 2238 sound level meters are as given below. There are separate settings for the Basic SLM and Frequency Analysis applications. In the list of settings, an underlined word (e.g., Weightings) refers to a major heading under "Settings".
5. Set-up B&K 2260 sound level meter on tripod 15 feet from loudspeaker. Adjust equalizer settings so measured noise spectrum approximates the known spectrum of aircraft noise. Analyzer settings used were (30 Hz, +12 dB; 60 Hz, +12 dB; 125 Hz, +10 dB; 250 Hz, -4 dB; 500 Hz, +3 dB; 1 kHz, 0 dB; 2 kHz, +3 dB; 4 kHz, -3 dB; 8 kHz, -3 dB; 16 kHz, 0 dB). These settings should be further adjusted to give a closer match to the known spectrum of aircraft noise, especially between 200 and 800 Hz. As with most loudspeakers, there is reduced output from the amplifier-loudspeaker combination below 50 Hz. Using the maximum low-frequency equalizer settings (+12 dB), the sound level at 31 Hz is about 20 dB below the desired spectral level for aircraft noise.

Field Test Procedures

1. Adjust watches, sound level meters and camera to within two seconds of time standard.
2. Calibrate B&K 2238 sound level meters using same calibrator. Select Basic SLM application for initial measurements of time- and spatial-averaged, A-weighted LEQ.
3. Set-up CD player, equalizer and QSC amplifier on folding table, with AC power from Honda generator.
4. Use two tape measures to position loudspeaker stand at 15 feet perpendicular distance from the façade and at an angle of 45 degrees. The slant distance is near 21 feet. Loudspeaker is about 6 feet above ground and aimed at the center of the façade.
5. For a room with two corner windows or sliding doors, loudspeaker is positioned so as to be approximately 21 feet from the center of each façade. X-Y measurements are taken to calculate the angle of incidence for each façade.
6. For use in the later spectral measurements, set-up the exterior tripod four feet from façade being tested, and the interior tripod one meter from the center of the facade. Note the window type and construction while measuring the window's dimensions. Record the average ambient interior and exterior noise levels. Record the average wind speed.
7. Measure interior room dimensions using ultrasonic "laser tape."
8. Use digital camera to photograph the residence exterior and yard, the room interior, the façade(s) being tested and the loudspeaker placement.
9. Close all doors and windows before starting test.
10. Person working outside needs to wear ear protection before turning on loudspeaker. Person working inside does not wear ear protection in order to hear any other noise sources.
11. Turn on loudspeaker with CD player and power amplifier (bridge mono mode) at full-scale. Turn on the loudspeaker about 15 seconds before the next whole minute to signal the test is about to begin.

12. Measure the noise level outside the façade for 60 seconds at a distance of 4 to 8 feet from the façade. Four feet was used except where a greater distance was needed to avoid hitting the landscaping. Slowly move the microphone (taped to PVC "wand") across the glazed area (not the wall) in a pattern that time- and spatially-averages the sound field incident upon the façade. Stop the sound level meter and turn-off the loudspeaker. Record the start/end times, the measured LEQ, and the file number on the data sheet.
13. Simultaneously, measure the interior noise level for 60 seconds at a distance of about one meter from the façade. Orient the microphone toward the window and slowly move the microphone (taped to PVC "wand") across the glazed area in a pattern that averages the transmitted sound field, being careful not to hit the ceiling or adjacent furniture. Stop the sound level meter and record the start/end times, the measured LEQ, and file number on the data sheet.
14. To ensure data integrity, repeat steps 11 through 13 and compare the measured LEQ values. The measured values are generally repeatable to within several tenths of a decibel.
15. Change the 2238 sound level meters to run the frequency analysis application. Set the instrument settings to record the 1/3-octave spectrum from 25 Hz to 12.5 kHz. Using these parameters, the total frequency sweep time is three minutes and seven seconds.
16. The frequency spectra are recorded using stationary, tripod-mounted microphones positioned near the center of the façade at the distances given in step 6. With the 2238 sound level meter already mounted on a tripod, this step simply involves removing the microphone extension cable and connecting the microphone directly to the sound level meter.
17. Turn on loudspeaker with CD player and power amplifier (bridge mono mode) at full-scale. Turn on loudspeaker about 15 seconds before the next whole minute to signal the test is about to start.
18. At the next whole minute, start both noise level meters so as to record simultaneous frequency sweeps. After the meter stops, record the start/end times, the A-weighted measured LEQ, and the file number on the data sheet. Compare the LEQ value calculated from the frequency sweep with the spatially-averaged results obtained in steps11 through 13. The LEQ values generally agree within 1 dB. Any minor differences can be attributed to the placement of the stationary microphone.
19. While breaking down the test equipment, and before leaving the site, download the recorded files from the sound level meters to a laptop computer. Scan the recorded files for completeness.
20. As soon as convenient, transfer the recorded spectral data to an Excel spreadsheet that calculates and plots the outdoor-indoor level reduction (OILR) versus log (frequency) for each façade at a given residence. The 1/3-octave OILR curves generally show a linear trend with a sequence of local minima that correspond to the complicated resonances of the window assembly.

2238 Meter Settings

Basic SLM Application

Meter display: Lasp, Laeq and LasMax
General Range: 30-110 dB (interior)
General Range: 40-120 dB (exterior)
Peaks Over: 140 dB
2nd Exch. Rate: either 4 or 5 dB
Weightings Detector 1(RMS) Bandwidth: BB/S
Freq. Wgt.: A
Detector 2 (Br.Band)
Weighting: Peak/C
Meas. Control Sequence: Off
Correction Filters Sound Incidence: Random
Windscreen Correction: On
Input/Output: not used
Auto Start No.: 1
Application: None
Occ. Health: not used
Save Setup: Save in no.: 1
Recall Setup no.: Default

Frequency Analysis Application

Weightings Bandwidth: 1/3 Octave
Limits: 25-12.5 kHz
Broadband Wgt.: A
Time Weighting: S
Meas. Control No. of Scans: 1
Dwell Time: Optimized
Tolerance: 0.5 dB
Auto Save: either Off or On
Correction Filters Sound Incidence: Random
Windscreen Correction: On
Input/Output: not used
Auto Start No.: 1
Application: None
Save Setup: Save in no.: 1
Recall Setup no.: Default

Glossary

Community Noise Equivalent Level (CNEL): Cumulative noise metrics have been developed to assess community response to noise. They are useful because these scales attempt to include the loudness of each event, the duration of these events, the total number of events and the time of day these events occur into one single number rating scale. 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 phrase "time-weighted," refers to the fact that noise that occurs during certain sensitive time periods is penalized for occurring at these times. In the CNEL scale, those events that take place during the night (10 p.m. to 7 a.m.) are penalized by 10 dB. This penalty was selected to attempt to account for the higher sensitivity to noise in the nighttime and the expected decrease in background noise levels that typically occur in the nighttime. There is also an evening 5 dB penalty that is used between the hours of 7 p.m. and 10 p.m. This penalty is included to account for the evening hours being a more sensitive time for in-home communication.

Equivalent Noise Level (LEQ): LEQ is the sound level corresponding to a steady-state A-weighted sound level containing the same total energy as a time-varying signal over 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 a noise to impact people is dependent on the total acoustical energy content of the noise.

Noise Contours: Noise contours are lines of equal loudness that are drawn around an airport. Contours are typically drawn using a cumulative noise metric such as CNEL, but can also be drawn for single event noise.

Noise Level Reduction (NLR): The difference between the outdoor and indoor noise level for a specific room in a structure. Includes the effect of the transmission loss through the wall and the sound absorption of the room.

Sound Transmission Class (STC): A specific measurement of the sound reducing capabilities of a building element such as a window or a door. It is a single number rating that describes the difference in sound level for that building element. The overall difference between indoor and outdoor noise levels is based on combining the transmission loss characteristics of each building element and the area of those building elements.