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MAYOR BRANDON JOHNSON

Acoustical Testing to Determine Eligibility for the Residential Sound Insulation Program ("RSIP")

February 27, 2024

CDA
Chicago Department of Aviation

O'HARE & MIDWAY
INTERNATIONAL AIRPORTS

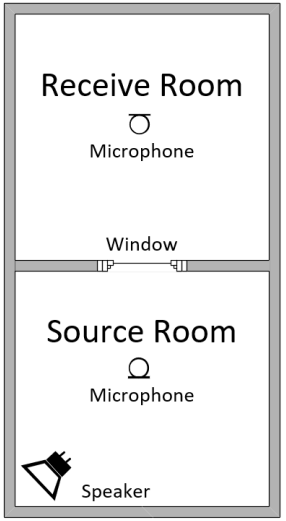
DIFFERENT TYPES OF ACOUSTICAL TESTING

Permanent Noise Monitors

Portable Noise Monitors

School Sound Insulation

Laboratory & Field Testing of Products



RSIP Eligibility

BACKGROUND & TODAY'S OBJECTIVES

1. Under the new Federal Aviation Administration ("FAA") guidelines, the existing noise level of a home plays a critical role in confirming its eligibility for the RSIP.

2. The CDA has updated its eligibility determination process to include acoustical testing, in accordance with FAA guidelines.

3. Today we will walk through an overview of the acoustical testing process so that you have a greater understanding of what is involved.

ELIGIBILITY ACOUSTICAL TEST OVERVIEW

Eligibility Acoustical Test: An in-home sound test that measures how much noise is reduced by the existing conditions (doors, windows, etc.) of a home.

The results of this test will determine if the interior noise level of a home meets an FAA-defined threshold that would justify the need for sound insulation.

Components of an acoustical test:

- Habitable Room Identification
- Equipment
- Conducting Measurements
- Analysis

*Note: The FAA released **Advisory Circular 150/5000-9B ("AC")** in June of 2022, which includes a detailed overview of the process.*

Habitable Room Identification

HABITABLE ROOM IDENTIFICATION

FAA definition of a habitable room: an area that is used for living, sleeping, eating, or cooking, and meets all local building code requirements.

Habitable Rooms:

- Bedroom
- Den
- Dining Room
- Family Room
- Kitchen
- Living Room

Non-Habitable Rooms:

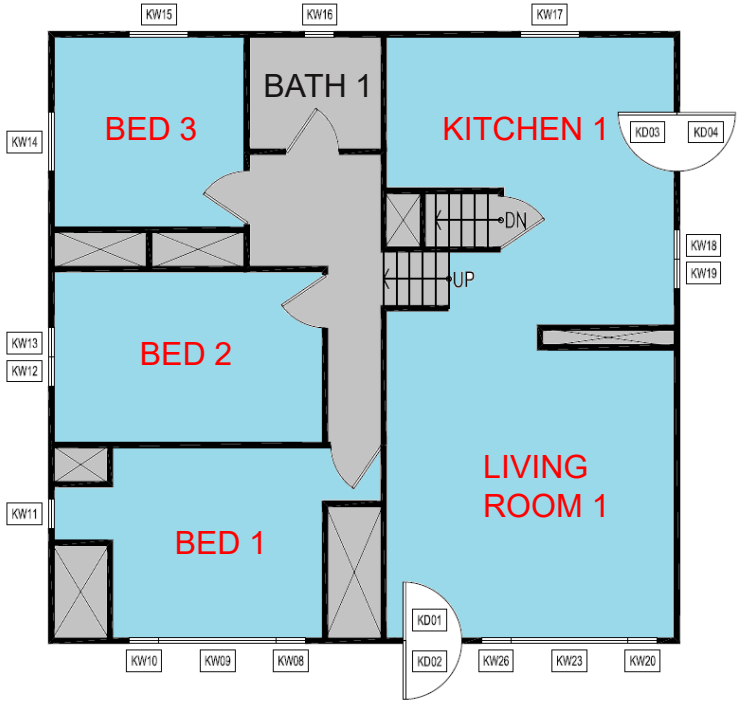
- Attic
- Basement (unfinished)
- Bathroom
- Closet
- Entry
- Garage
- Hallway
- Laundry
- Stairway
- Storage
- Utility

HABITABLE ROOM IDENTIFICATION

Why is it necessary to determine habitability?

1. Only habitable rooms are evaluated when determining the eligibility of a home.
2. Only habitable rooms will receive sound insulation treatments.

The FAA is primarily focused on treating habitable rooms and will only provide funding to sound-insulate a non-habitable room if it is open to an adjacent habitable room creating an entry point for noise.



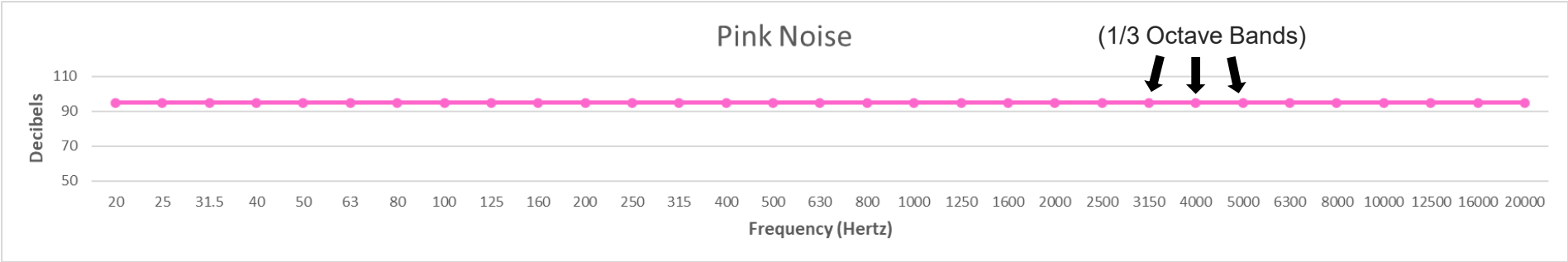
Room names shown in red are habitable

Equipment

EQUIPMENT

Signal Generator → Equalizer → Amplifier → Loudspeaker → Sound Level Meter

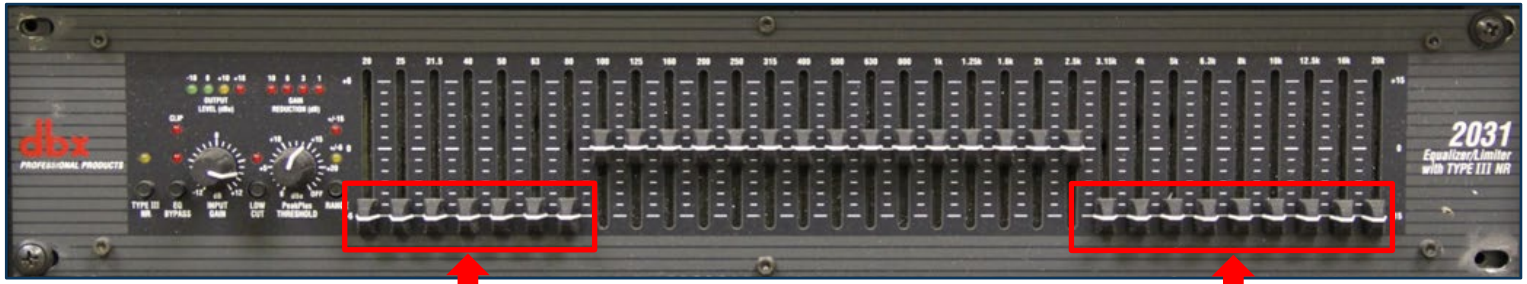
- A signal generator supplies a broadband signal (i.e., a signal that is distributed over a large section of the audible range) called pink noise.
- Pink noise is a form of broadband noise that exhibits equal energy per octave across the entire frequency spectrum.



EQUIPMENT

Signal Generator → **Equalizer** → Amplifier → Loudspeaker → Sound Level Meter

- The FAA's frequency band of interest, as shown in Section 8.2.1 of the AC, is 100 to 2500 Hertz (“Hz”).
- An equalizer splits the full spectrum pink noise signal into smaller segments called one-third octave bands.
- The equalizer reduces the signal level for all frequencies below 100 Hz and above 2500 Hz to provide the loudest signal possible in the frequency band of interest.



Reduced below 100 Hz

Reduced above 2500 Hz

EQUIPMENT

Signal Generator → **Equalizer** → **Amplifier** → Loudspeaker → Sound Level Meter

- An amplifier boosts the equalized signal to a level between 90 to 105 decibels (“dB”) measured at the exterior façade surface.

EQUIPMENT

Signal Generator → **Equalizer** → **Amplifier** → **Loudspeaker** → Sound Level Meter

Ground Wedge Configuration

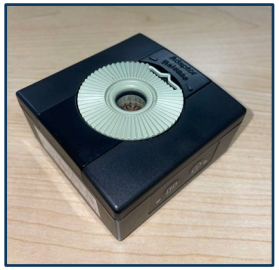
Speaker Stand Configuration

- A loudspeaker provides uniform exposure of the signal over the exterior façade of the habitable room.
- A ground wedge configuration is used for most first and second story rooms.
- A 10-foot speaker stand configuration is used for rooms with vaulted ceilings, and for rooms requiring measurements higher than 24 feet above the ground.

EQUIPMENT

Signal Generator → **Equalizer** → **Amplifier** → **Loudspeaker** → **Sound Level Meter**

- Two sound level meters are used, both of which are classified as Type 1 by American National Standards Institute (“ANSI”) S1.43, to achieve the level of accuracy requested by the FAA.
- A short extension pole is used to take interior measurements, while a long extension pole is used for exterior measurements.
- Both meters are calibrated against a 94 dB 1,000 Hz tone before and after the test.



Acoustic Calibrator

Interior System

Exterior System

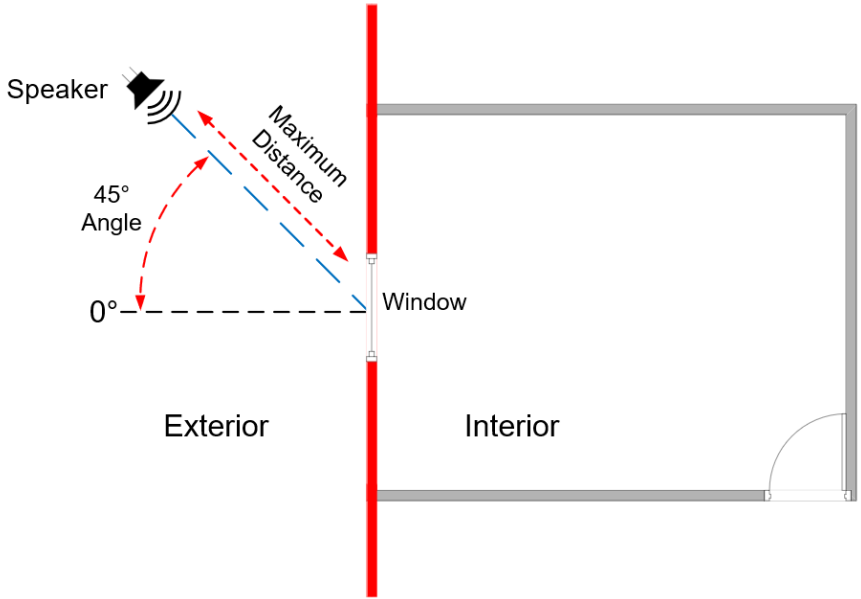
Conducting Measurements

CONDUCTING MEASUREMENTS

- The FAA has developed multiple measurement procedures to address unique habitable room conditions such as the number of exterior façades, measurement height, and exterior accessibility.
    - **1W** - For rooms with one façade and one loudspeaker location.
    - **2W1** - For rooms with two façades and one loudspeaker location that creates even sound coverage on both façades.
    - **2W2** - For rooms with two façades when even sound coverage on both façades cannot be achieved with one loudspeaker location.
- The specific measurement procedure used is determined on a room-by-room basis by evaluating the unique conditions of each habitable room.

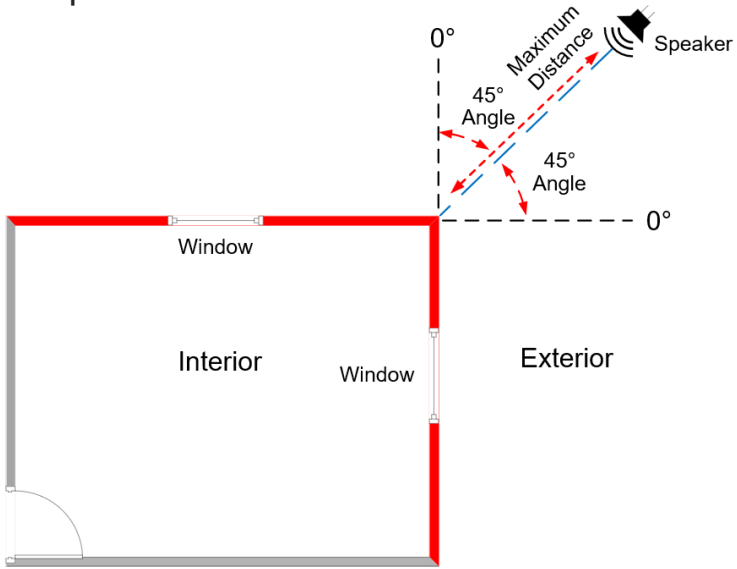
CONDUCTING MEASUREMENTS

1W: Used on habitable rooms with one façade



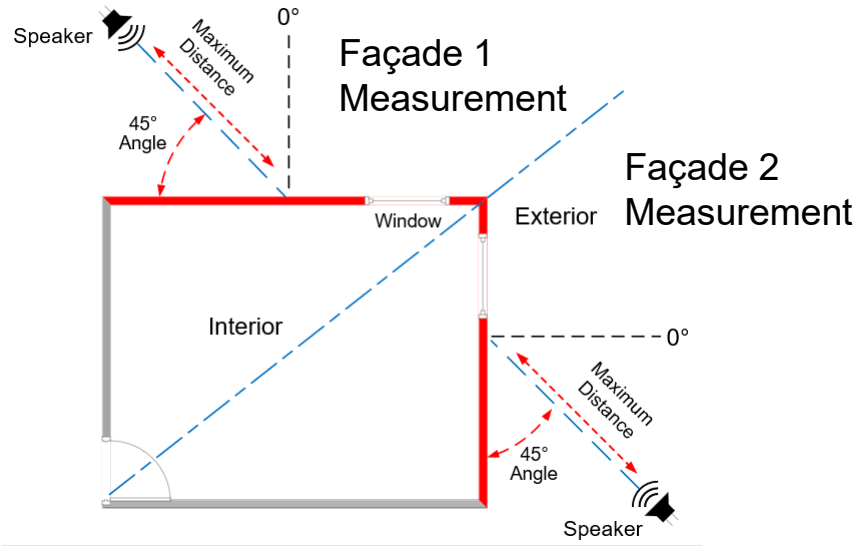
CONDUCTING MEASUREMENTS

2W1: Used on habitable rooms with two façades where even coverage CAN be met across both façades with one loudspeaker location



CONDUCTING MEASUREMENTS

2W2: Used on habitable rooms with two façades where even coverage CANNOT be met across both façades with one loudspeaker location



Tree location prevents the corner access needed to use the 2W1 method

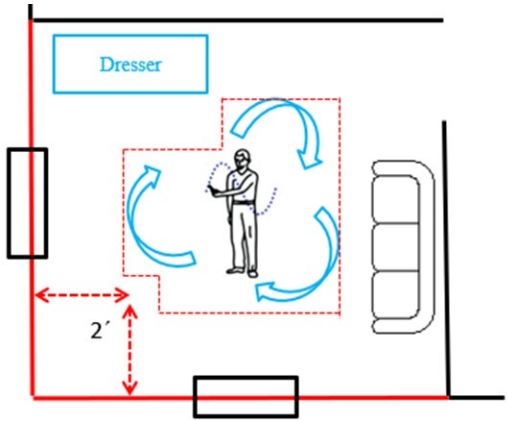
CONDUCTING MEASUREMENTS

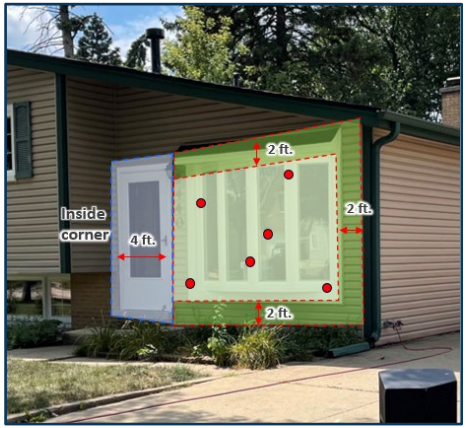
Interior Measurement

- A 30-second 3-D scan is conducted in the central volume of the room.
- The microphone is held at least two feet from the floor, walls, ceiling, and any hard reflective surfaces.

Exterior Measurement

- The RSIP uses the FAA's preferred method known as the flush microphone method.
- The microphone is placed within one and a half inches to the façade surface at six randomly selected points.





Analysis

NOISE REDUCTION EXAMPLE

- One façade room measured with the 1W procedure (1,000 Hz. frequency band):

Measured exterior level: 90.6 - 6 = 84.6 dB **Measured interior level**: 50 dB

Note: As directed in the AC, a -6 dB adjustment is applied to the flush exterior level measurements (i.e., measurements taken with the microphone flush to the exterior façade) to account for sound reflecting back at the microphone from the façade surface.

Noise Reduction ("NR") = Exterior Level – Interior Level

NR = 84.6 - 50

NR @ 1,000 Hz = 34.6 dB

Source: AC section 8.5.9.1

NOISE LEVEL REDUCTION EXAMPLE

Room: Bedroom	Method: 1W														
Frequency (Hz)	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**	**2000**	**2500**	
Exterior Aircraft Noise Spectrum ($L_{ext,ac}$)	48.5	55.0	59.5	61.1	65.8	69.1	70.0	70.8	71.4	73.7	70.0	72.7	71.6	66.4	65.3	
Exterior A-Weighted Total Level ($L_{A,ext}$):																81.0 dBA
Noise Reduction (NR)	21.0	21.5	19.4	16.4	16.8	18.2	20.9	22.4	30.8	31.7	33.8	34.9	35.1	39.1	35.9	
$L_{ext,ac}$ - NR	27.5	33.5	40.1	44.7	49.0	50.9	49.1	48.4	40.6	42.0	36.2	37.8	36.5	27.3	29.4	
Interior A-Weighted Total Level ($L_{A,int}$):																56.4 dBA
Noise Level Reduction (NLR):																24.6 dBA

CALCULATION OF INTERIOR DNL FOR EACH ROOM

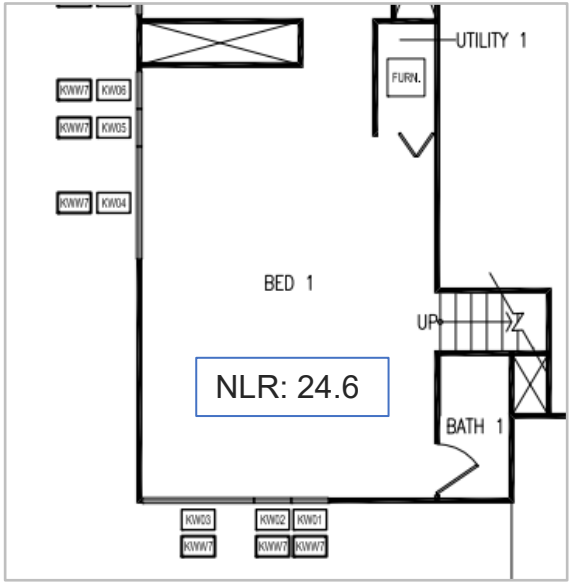
- The interior Day-Night Average Sound Level (“DNL”) of each habitable room is determined by finding the difference between the home’s exterior DNL taken from the airport's FAA-approved noise contour model and the NLR of the habitable room measured during the acoustical testing process:

$$\text{Exterior DNL} - \text{NLR}_{\text{Room}} = \text{Interior DNL}_{\text{Room}}$$

- An example home with an exterior DNL of 70 dB is shown to the right where bedroom 1 has an NLR of 24.6 dB.

- The interior DNL of bedroom 1 would be:

$$70 - 24.6 = 45.4 \text{ dB}$$



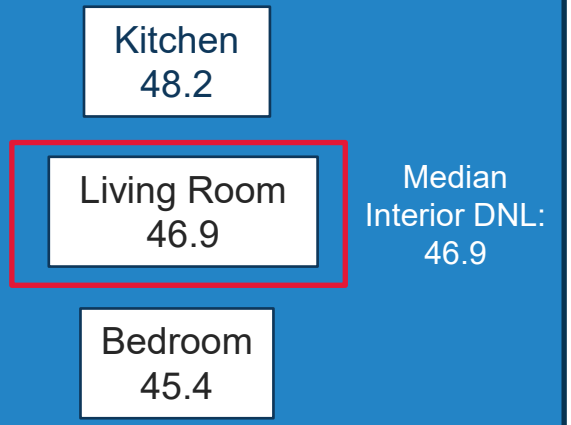
Source: AC section 8.6.7.4

MEDIAN INTERIOR DNL FOR THE HOME

- Identify the **median** value of a dataset containing the interior DNLs of all habitable rooms.
  - Homes with a median interior DNL greater than or equal to 45 dB are considered noise-impacted by the FAA.
  - Homes with a median DNL less than 45 dB are **not** considered noise-impacted by the FAA.
- Per FAA guidelines, in any calculation using interior DNL, the interior DNL value should not be rounded up (for example, an interior DNL of 44.7 dB should not be rounded up to 45 dB).

Source: AC sections 8.6.6.6 and 8.6.7.5

Consider the following example home with the following interior DNLs:



As the median interior DNL is above 45 dB, the home is considered noise-impacted.

KEY TAKEAWAYS

TO RECAP

1. The FAA provides detailed instructions in the AC regarding how to perform an acoustical test, and all acoustical testing completed by the RSIP will need to follow the FAA guidelines.
2. The RSIP uses the FAA-preferred exterior loudspeaker method of conducting an acoustical test, therefore, no direct aircraft overflights are needed to complete this process.
3. Only the habitable rooms of a home are evaluated during an acoustical test.
4. The interior DNL of a habitable room is found by subtracting the measured NLR from the home's exterior DNL taken from the airport's FAA-approved noise contour model.
5. The eligibility of a home is based on the median interior DNL of all habitable rooms obtained through acoustical testing.
6. The same process is used during the post-construction acoustical test on a small number of homes to verify if the two FAA goals of a 5 dB reduction and an interior DNL <45 dB have been achieved.

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APPENDIX

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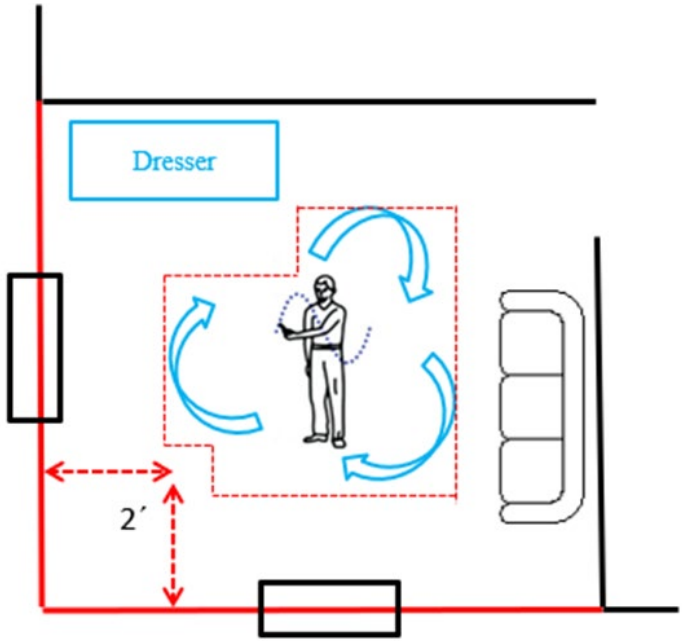
INTERIOR MEASUREMENTS
ADDITIONAL DETAILS FOR SLIDE 19

- For each habitable room, the interior sound level will be measured by manually performing a 30-second spatial 3-D scan of the microphone in a vertical sinusoid pattern at a constant speed of roughly one foot per second over the central volume of the room.
- The microphone will be attached to the end of a short boom pole and held at least an arm's length away from the body.
- During the scan, a minimum distance of two feet will be maintained between the microphone and the floor, ceiling, walls, or any other hard reflective surfaces in the room. The technician will face the exterior façade(s) to avoid shielding the microphone.



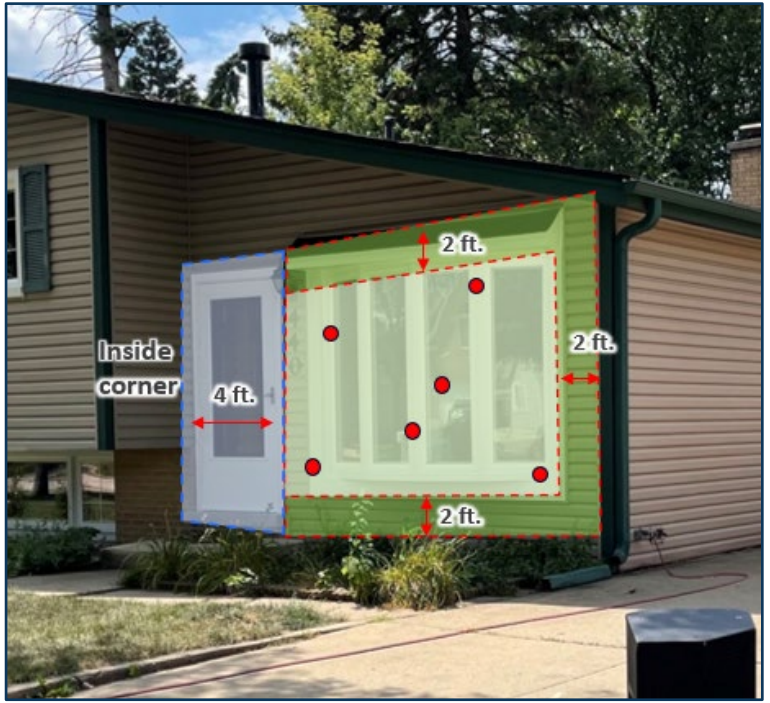
Source: AC section 8.5.7.1.2

EXTERIOR MEASUREMENTS
ADDITIONAL DETAILS FOR SLIDE 19

Exterior measurements are taken using the FAA-preferred flush microphone method as described below:

- Microphone is positioned within one and a half inches of the façade surface at six randomly selected points, where no points are closer than two feet from the horizontal or vertical edges of the façade, and four feet from inside corners.

- One continuous measurement is conducted where:
  - 10 seconds are spent at each of the six random points; and
  - The meter is paused as the technician moves from one point to the next.



Source: AC section 8.5.6.2.1

BACKGROUND NOISE MEASUREMENTS
ADDITIONAL DETAILS FOR SLIDE 21

Interior Background Measurement

- One-third octave bands from 100 to 2500 Hz
- One measurement per habitable room
- At a fixed-point in the center of the room
- Duration of at least 20 seconds

Exterior Background Measurement

- One-third octave bands from 100 to 2500 Hz
- At least one measurement per home
- At a fixed-point flush to the exterior façade surface
- Duration of at least 20 seconds

When a relatively small difference exists between the measured level and the background noise level, a correction factor is applied per Section 8.5.8 of the AC.

Source: AC sections 8.5.6.5 and 8.5.7.3

CALCULATION OF NOISE REDUCTION FOR EACH ROOM: 1W
ADDITIONAL DETAILS FOR SLIDE 21

- NR is the difference between the exterior and interior sound levels measured in one-third octave bands between 100 Hz and 2500 Hz.
- For rooms with a single façade, the NR in each one-third octave band can be determined by a direct difference between the exterior and interior levels:

$$NR(f) = L_{ext}(f) - L_{int}(f)\ dB$$

Frequency band (15 overall)

Exterior level

Interior level

Source: AC section 8.5.9.1

CALCULATION OF NOISE REDUCTION FOR EACH ROOM: 2W1
ADDITIONAL DETAILS FOR SLIDE 21

- When the 2W1 measurement procedure is used on a corner room with two façades, and separate exterior measurements are taken for each façade, it is necessary to first find the average exterior level between the two façades in each one-third octave band using the following equation:

$$L_{ext}(f) = 10log\left(S_1 * 10^{L_1(f)/10} + S_2 * 10^{L_2(f)/10}\right) - 10log(S_1 + S_2)$$

Façade 1 surface area | Exterior level 1 | Façade 2 surface area | Exterior level 2

- Then, the room's NR in each one-third octave band can be found by a direct difference between the exterior and interior levels:

$$NR(f) = L_{ext}(f) - L_{int}(f)\ dB$$

Source: AC section 8.5.9.3.a

CALCULATION OF NOISE REDUCTION FOR EACH ROOM: 2W2
ADDITIONAL DETAILS FOR SLIDE 21

- When the 2W2 measurement procedure is used on a corner room with two façades, a separate NR in each one-third octave band is calculated for each of the two façades. Then, the following equation is used to combine the NR of façade one with the NR of façade two yielding a final NR for the room in each one-third octave band:

Façade 1 NR

$$NR(f) = L_{ext}(f) - L_{int}(f)\ dB$$

Façade 2 NR

$$NR(f) = L_{ext}(f) - L_{int}(f)\ dB$$

Room NR

$$NR(f) = -10log\left(10^{-NR_1(f)/10} + 10^{-NR_2(f)/10}\right)$$

Source: AC section 8.5.9.3.b

ESTABLISHING EXTERIOR AIRCRAFT NOISE SPECTRUM
ADDITIONAL DETAILS FOR SLIDE 22

According to the AC, the exterior aircraft noise spectrum used to calculate the NLR of a habitable room should be as follows: *"…the single aircraft type that is most frequently operated for the runway ends adjacent to a particular community, as identified from the FAA's Aviation Environmental Design Tool ("AEDT")."*

General process to determine the one-third octave band exterior aircraft noise spectrum:

1. Use AEDT operations data from FAA-approved noise contour map to identify runway impacting home.
2. Identify the aircraft type with highest number of operations for the identified runway. (Nighttime operations are emphasized by using a x10 multiplier.)
3. Obtain arrival and departure spectral class data for that aircraft type from the FAA, and scale the arrival and departure spectra to the same overall level.
4. Develop composite spectrum for that aircraft type using a weighted energy average based on the relative number of equivalent annual runway operations and scale to a recognizable A-weighted level.

Source: AC section 8.5.10.1

CALCULATION OF NOISE LEVEL REDUCTION FOR EACH ROOM
ADDITIONAL DETAILS FOR SLIDE 22

- NLR is a single-number metric determined for each room representing the difference between the exterior total level and interior total level.

$$L_{int,ac}(f) = L_{ext,ac}(f) - NR(f)$$

$$L_{A,ext} = 10log \sum_{i=1}^{k} 10^{\frac{L_{ext,ac}(f)+A(f)}{10}}$$

$$L_{A,int} = 10log \sum_{i=1}^{k} 10^{\frac{L_{int,ac}(f)+A(f)}{10}}$$

$$NLR = L_{A,ext} - L_{A,int}$$

$L_{A,ext}$: Exterior A-weighted Total Level

$L_{A,int}$: Interior A-weighted Total Level

$L_{ext,ac}$: 1/3-Octave Exterior Aircraft Spectrum

$L_{int,ac}$: 1/3-Octave Interior Aircraft Spectrum

NR: Noise Reduction

A(f): A-weighted Frequency Correction

Source: AC section 8.5.10.2

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