Pier 3 Condominiums – Philadelphia, PA

Rooftop Mechanical Sound Study – Revision 1

February 22, 2022

PREPARED FOR
Cathy Proctor
Community Association Manager
First Service Residential

PREPARED BY
Robert M. Tanen | Member, INCE-USA
Associate Principal

Alexander M. Aquila
Associate Consultant

Maeve Cantwell
Staff Consultant

metropolitan
acoustics

1628 JFK Blvd.
8 Penn Center, Suite 1902
Philadelphia, PA 19103
215.248.4352
www.metro-acoustics.com

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Cathy Proctor
Community Association Manager
First Service Residential
Pier 3 Condominium Association
3 North Columbus Boulevard
Philadelphia, PA 19106

Re: Pier 3 Condominiums – Philadelphia, PA
Rooftop Mechanical Sound Study – Revision 1

Dear Cathy:

Metropolitan Acoustics has completed a rooftop mechanical sound study for the Pier 3 Condominium building in Philadelphia, PA. We understand that there are presently concerns with sound and vibration transmission from rooftop mechanical equipment to top floor residential spaces. Our scope of work included conducting a site visit to document the existing conditions, identifying possible transmission paths, and comparing our results to relevant standards.

The information provided herein is a summary of our testing procedures, measurement results, and observations. Our findings are based on our February 2, 2022 site visit, and ongoing correspondence with First Service Residential.

For the readers' convenience, blue text indicates an external link to a product and the *blue italicized text* indicates an internal link to another section of this document. Please let us know if you have any questions regarding this information.

Best regards,

metropolitan acoustics, llc

Robert M. Tanen | Member, INCE-USA
Associate Principal
r.tanen@metro-acoustics.com
MA#210440

Alexander M. Aquila
Associate Consultant
a.aquila@metro-acoustics.com

Maeve Cantwell
Staff Consultant
m.cantwell@metro-acoustics.com

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EXECUTIVE SUMMARY

Sound and vibration measurements confirm the presence of perceptible noise intrusion into the 4th floor condominiums. Tonal characteristics (hum and pulsing), and a clearly noticeable change in level with condensing units (CU) on vs. off contribute to the perceptibility of the rooftop equipment. Lack of vibration isolation is likely a major contributor to measured intrusion.

Per a common industry standard, *The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) – Chapter 49: Noise and Vibration Control*, the Design Guidelines for HVAC-Related Background Sound in Rooms are as follows:

- NC 30 / 35 dBA (overall sound levels)
- Ideally, HVAC-related background noise should have the following characteristics:
  - Balanced contributions from all parts of the sound spectrum with no predominant frequency bands of noise
  - No audible tones such as hum or whine
  - No fluctuations in sound level such as throbbing or pulsing

Unit 407 and Unit 434 satisfied the NC 30 / 35 dBA guideline but contained non-ideal characteristics.
Unit 403 exceeded the NC 30 / 35 dBA guideline and contained non-ideal characteristics.

Not meeting the ideal characteristics, as defined by ASHRAE above, can lead to complaints. As such, it is recommended to implement mitigation measures (such as, but not limited to, vibration isolation and equipment maintenance) to reduce the perceptibility of *Prominent Discrete Tones* and to minimize fluctuations in sound level to 6 dB or less.

Acoustical Terminology

Sound Level
Sound pressure levels (SPL) are commonly expressed on a logarithmic scale in decibels (dB). The human ear is most sensitive at mid-frequencies (speech) and less sensitive at high and low frequencies at typical listening levels. To account for this, sound pressure can be expressed in units of A-weighted decibels (dBA).

Background sound levels in unoccupied rooms from mechanical and exterior sources are typically specified in terms of Noise Criteria (NC) ratings. The NC is a single-number rating derived from octave band sound pressure levels from 63 to 8000 Hz.

For dBA and NC ratings, a higher number corresponds to louder sound levels. For reference, a 3-point difference in decibels represents a just-noticeable difference, a change of 5-6 decibels is clearly noticeable, and a sound level that is 10 decibels higher is perceived to be twice as loud.

Background Sound
Background sound is the total sound from all sources other than a particular sound that is of interest (e.g., other than the sound being measured or other than the speech or music being listened to).

Prominent Discrete Tone
A prominent discrete tone is a sound, often perceived as a whine or hum, that can be heard distinctly as a single pitch or a set of pitches. A prominent discrete tone exists if the 1/3 octave band sound pressure level in the band with the tone exceeds the arithmetic average of the sound pressure levels of the two contiguous 1/3 octave bands by:

- 5 dB for center frequencies of 500 Hz and above;
- 8 dB for center frequencies between 160 and 400 Hz; or
- 15 dB for center frequencies less than or equal to 125 Hz.

Vibration
Root-mean-square (RMS) acceleration is typically measured as a multiple of the acceleration due to Earth's gravity (*g*). One *g* is approximately equal to 9.8 m/s² or 386 in./s². The *g* is one of the most common units for vibration measurements with accelerometers in buildings. RMS amplitude is used to describe the "smoothed" vibration amplitude of acceleration and velocity.

EXISTING CONDITIONS & TESTING PROCEDURES

EXISTING CONDITIONS & OBSERVATIONS

Based on discussions with the residents of Unit 407, we understand noise and vibration transmission into their second level is a concern. The noise source is assumed to be from the operation of rooftop condensing units (CUs), and occurs even when the equipment serving Unit 407 is not operational. Several other residents have observed similar sound and vibration intrusion but have not been concerned enough to issue a complaint. Measurements were taken in three condominiums: Unit 403, Unit 407, and Unit 434. Units 403 and 407 are located along the northern portion of the building, while Unit 434 is located along the southern portion of the building.

Additionally, it is our understanding that the rooftop of the building has been recently renovated. The rooftop previously consisted of approximately 3" of river rock on top of metal decking; however, the river rock has been removed and replaced with 5" to 6" of rigid insulation beneath 6mm EPDM roof membrane.

The following observations were made while onsite:

- The rooftop CUs are all different makes and models, as each condominium owner is responsible for supplying and maintaining their own mechanical systems independently of the building.
    - The mounting of all rooftop CUs to their respective dunnage is inconsistent.
- In general, it was noted that attempts were made to install vibration isolation for the northern row of CUs that span the entire length of the building from east to west. The southern row of units was not provided with vibration isolation.
- Vibration isolation, where installed, appeared to be neoprene pads such as Mason Super W.
- In several instances, vibration isolation was not properly installed/loaded or was short-circuited through rigid connections, as shown in the figures below.
    - CU piping or other conduit was rigidly contacting the unit, the dunnage, and the rooftop structure in many locations.
    - Qualitatively, vibration was felt in the dunnage and roof structure with the CUs on.
    - Sound ("low-hum") was also observed to radiate in the wall cavities of the office spaces in Units 403 and 407 when the CUs were on.
- The worst-case location for sound and vibration transmission from the rooftop CUs in each condo was the offices, which are located directly below the rows of CUs.
- When ten or more CUs directly above the tested units were powered down, it was noted that the transmission of sound and vibration appeared to decrease substantially.

The following figures show the existing site conditions.

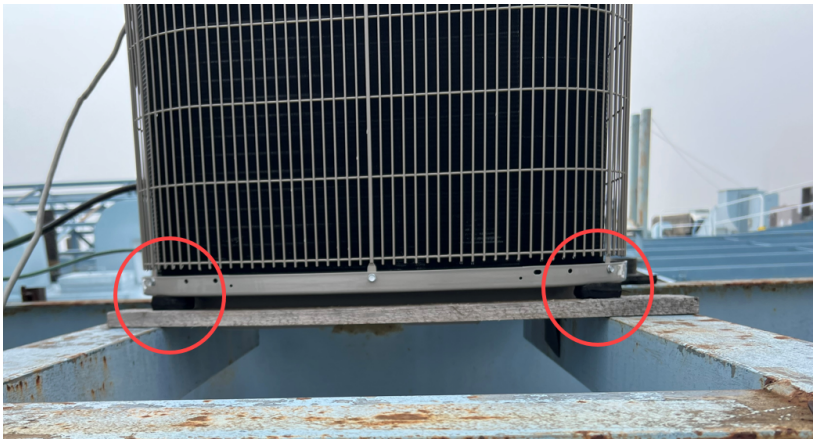

Figure 1. Example of vibration isolator installation beneath CU

Figure 2. Example of vibration isolator installation beneath CU

Figure 3. Northern row of rooftop CUs

Figure 4. Example CU above Unit 434 rigidly bolted to dunnage

Figure 5. Example rigid connections to rooftop CU and dunnage

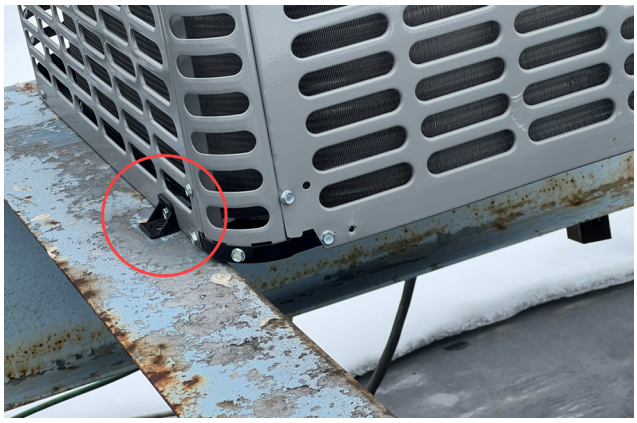

Figure 6. Example rigid connections to rooftop CU and dunnage

Figure 7. Unit 403 living room existing conditions

DESIGN CRITERIA

Airborne Sound Design Goals

Based upon the ASHRAE Applications Handbook guidelines, Table 1 displays a relevant industry standard for background sound level design goals resulting from intruding mechanical, electrical, or plumbing noise.

Table 1. Background Sound Level Design Goals Pier 3 Condominiums – Philadelphia, PA		
Space		*Design Goal*
Residential Units	Bedroom	NC 30 / 35 dBA
	Office	
	Living Room	

- (Per ASHRAE) Ideally, HVAC-related background noise should have the following characteristics:
  - Balanced contributions from all parts of the sound spectrum with no predominant frequency bands of noise
  - No audible tones such as hum or whine
  - No fluctuations in sound level such as throbbing or pulsing

Vibration Transmission Design Goals

Vibration criteria for various space types and its relationship to human perceptibility and comfort is outlined by the International Organization for Standardization (ISO) ISO-2631-2 "Evaluations of Human Exposure to Whole-Body Vibration – Continuous and Shock-Induced Vibration in Buildings (1 to 80 Hz)." Supporting and supplementary criteria and definitions are provided in ISO-2631-1 and the British Standard (BS) BS-6472 "Evaluation of Human Exposure to Vibration in Buildings 1 Hz to 80 Hz". The following is an excerpt from these standards:

- "The base curves represent magnitudes of approximately equal human response with respect to human annoyance and/or complaints about interference with activities."
  - Measured vibration magnitudes below the values corresponding to the base curves, in general, result in no adverse comments, sensations, or complaints being reported.

Figure 8 outlines the base curves (vibration criteria) provided by ISO-2631 for continuous vibration in residential spaces. It outlines the combined limits for the horizontal "x,y" (side-to-side) and vertical "z" directions (from head-to-toe/up-and-down).

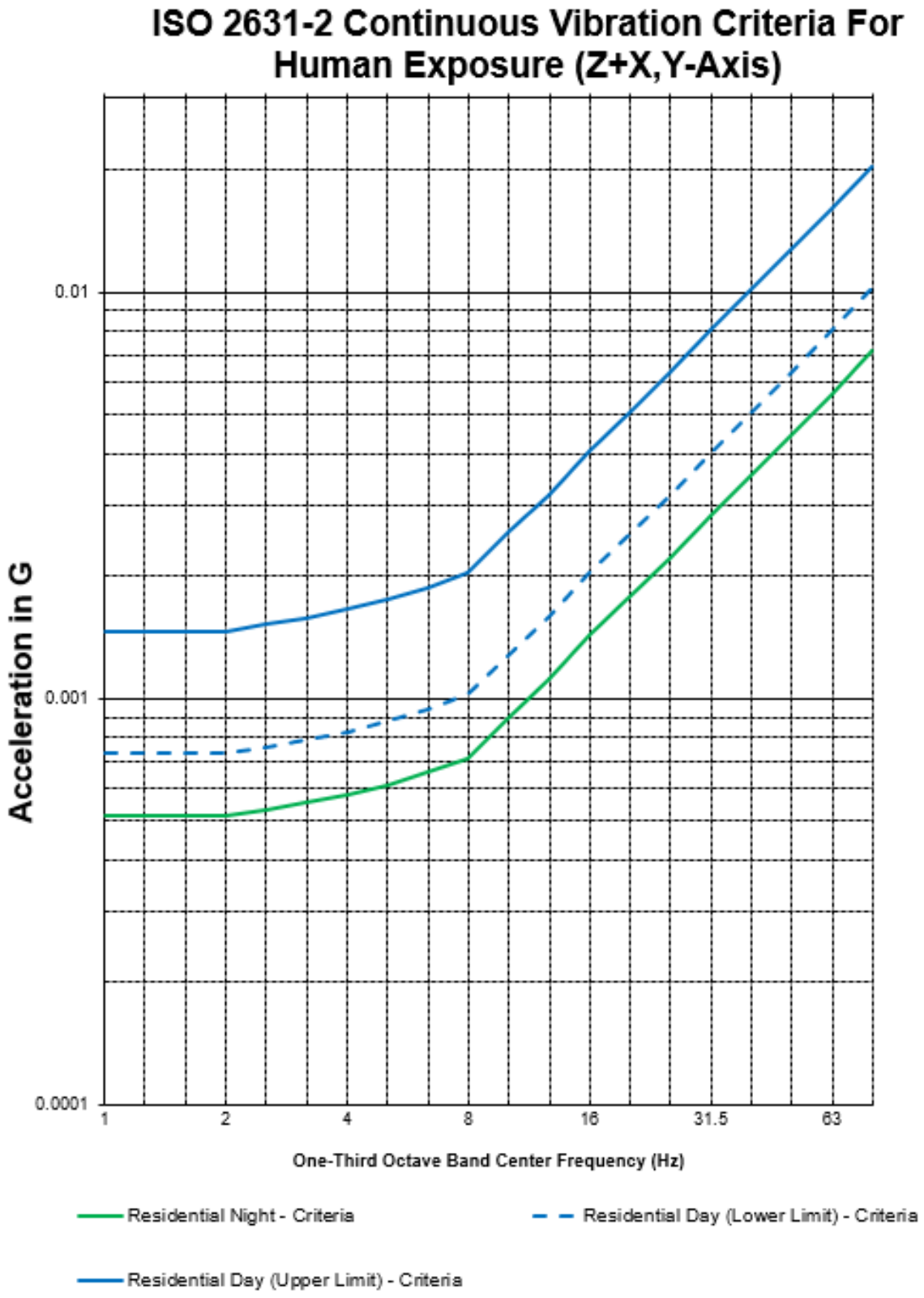

Figure 8. Vibration Criteria Z+X,Y-Axis (Combined)

TEST PROCEDURES

Airborne Sound Level Testing

Measurements were conducted on February 2, 2022 between 9:30am and 11:30am utilizing an NTi XL2 Audio Analyzer, which meets ANSI S1.4 criteria for a Type 1 sound level meter. Decibel levels were measured on fast response in 1/3 octave bands from 6.3 Hz to 20,000 Hz. Each measurement was averaged over a period of 30 seconds. Measurement locations included various rooms in each of the three residential units tested, including Unit 403, Unit 407, and Unit 434.

Vibration Testing

Vibration measurements were made using several tri-axial piezoelectric accelerometers, model G-Link 200 manufactured by LORD MicroStrain. Data were transferred wirelessly through a LORD MicroStrain WSDA-200-USB Wireless USB Gateway. The frequency response of the sensors was set from 0.5 Hz to 128 Hz with amplitude resolution from 0.00000002 *g* to 2 *g*. Fourier transforms were applied to determine the amplitude of frequency peaks in the measurements.

Table 2 outlines the locations of the accelerometers.

Table 2. Accelerometer Locations
Pier 3 Condominiums – Philadelphia, PA

Accelerometer Number	*Location*
3866	Unit 403 – attached to steel ceiling structure
3874	Unit 407 – attached to steel ceiling structure
3874	Rooftop – attached to steel CU dunnage
3874	Unit 434 – attached to steel ceiling structure

The following figures display example installations of the accelerometers onsite.

Figure 9. Node 3874 attached to CU dunnage

Figure 10. Node 3866 attached to Unit 403 ceiling structure

RESULTS

SURVEY RESULTS

Airborne Sound Testing

Table 3 below shows the measured sound levels in Units 403, 407, and 434 with and without CUs operational; these measurements are compared to our airborne design goal. Cells highlighted in red indicate where the overall design goal clearly exceeded; the 1 dB overall exceedance is Unit 407 is considered negligible for this analysis.

Table 3. Measured Sound Levels
Pier 3 Condominiums – Philadelphia, PA

Measurement Number	Unit Number	Measurement Location	Measurement Description	Measured Sound Level (dBA)	Overall Design Goal
1	Unit 403	Office	CUs On	NC 38 / 45 dBA	NC 30 / 35 dBA
2	Unit 403		CUs Off	NC 24 / 32 dBA	
3	Unit 407	Office	CUs On	NC 28 / 36 dBA	
4	Unit 407		CUs Off	NC 17 / 28 dBA	
5	Unit 434	Office	CUs On	NC 26 / 34 dBA	
6	Unit 434		CUs Off	NC 19 / 29 dBA	

As shown in the table above, the airborne sound levels measured in the residential units when the CUs are powered down meet the overall design goal. When the CUs are operating, the overall design goal is met in all units, except for Unit 403, where the goal is exceeded by 10 dB. The 'ideal characteristics' of the sound, per ASHRAE however, were not satisfied in any space when the CUs were operating.

Figure 11 shows the measured sound levels vs. the NC curves; the dashed green line being the goal.

Figure 12 shows the one-third octave band spectrum measured in Unit 407; tonal characteristic highlighted.

The following summarizes our analysis of the measured data:

- While the rooftop CUs were operating, the measured sound levels in the 63 Hz and 125 Hz 1/3 octave bands were measured to be 6-9 dB louder than when the CUs were not operating.
  - This would ideally be less than 6 dB to reduce perceptibility of these tonal characteristics.
- The overall difference in sound level (CUs on vs. off) in Unit 407 and Unit 403 was 8 dB or greater.
  - This would ideally be less than 6 dB to reduce awareness of units being on vs. off.
  - The less than 6 dB difference should still not exceed NC 30/35 dBA when the units are on.
- The increase in sound and vibration levels was experienced in all areas tested; this is not exclusive to Unit 407.

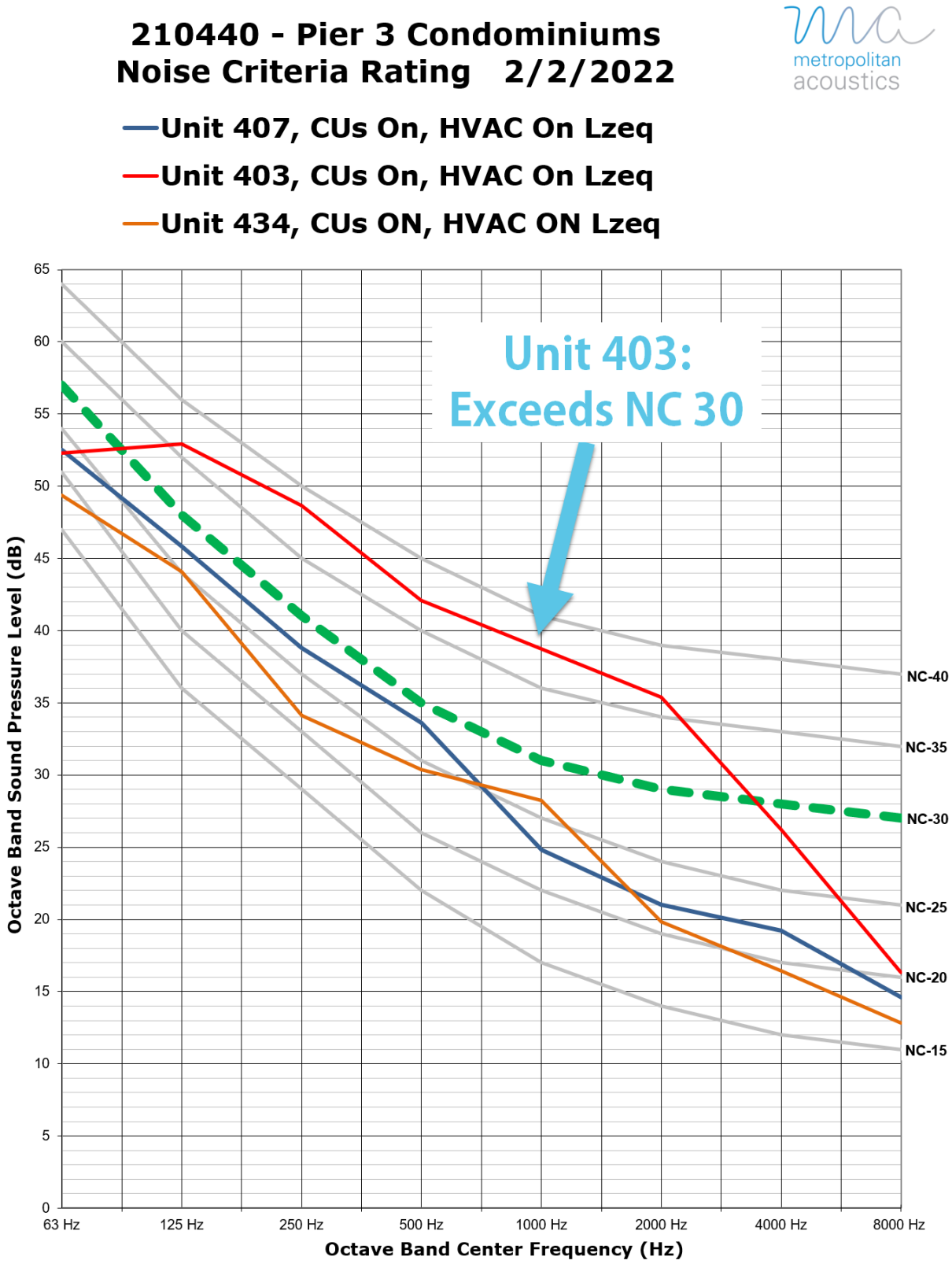

Figure 11. Noise Criteria (NC) Level in Each Unit with CUs Operational

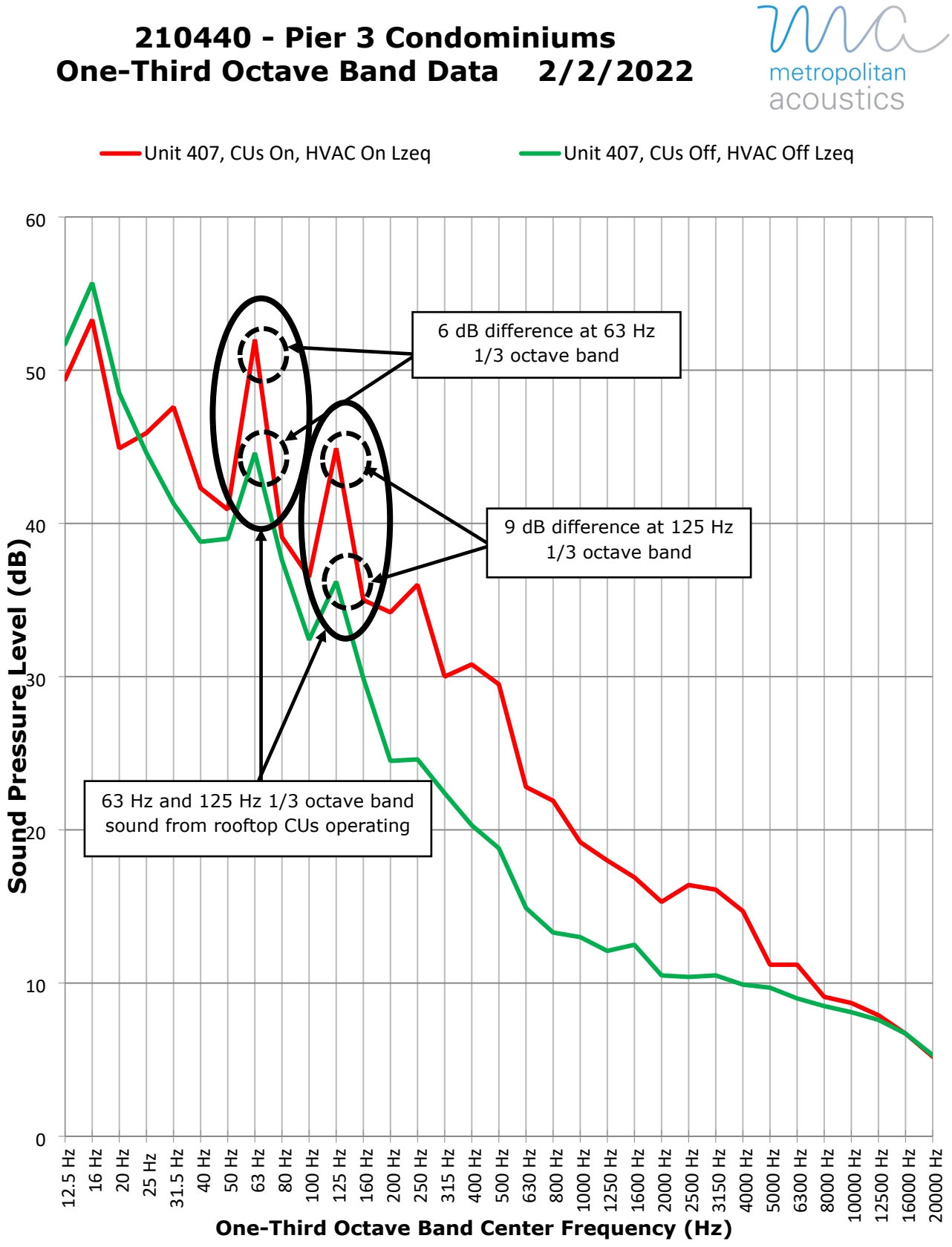

Figure 12. Sound Level Measurement Comparison – Unit 407

Vibration Testing

Figure 13 shows the vibration criteria for residential spaces and the measured vibration on the office ceiling in Units 403, 407, and 434. A measurement from the CU dunnage is included for reference with the CU on/CU off conditions.

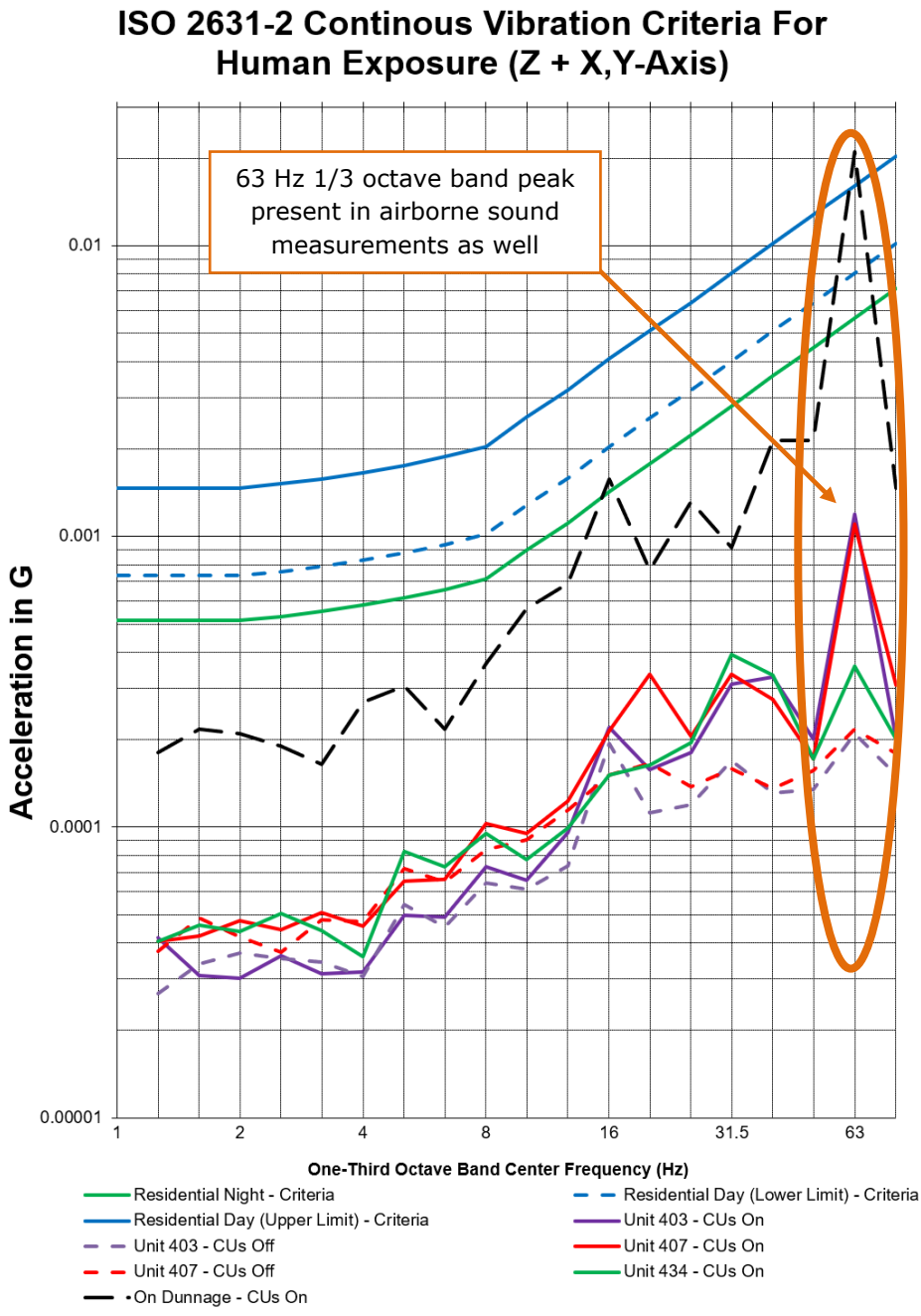

Figure 13. Vibration Transmission –Rooftop CUs On vs Off

As shown in Figure 13, there is a clear vibrational peak at 63 Hz, which is the same peak frequency from the airborne measurements. The measurements indicate that vibration is present in the structure.