Solving Mechanical Noise Complaints in an Office Building

Walid Tikriti, Acoustonica, LLC, Brookline, Massachusetts

This article discusses noise impact from HVAC and mechanical systems in an office building. The project discusses noise impact related to mechanical systems. The mechanical noise relates to the air distribution system and vibration from rooftop package systems. Noise measurements were recorded in all cases. Sound analyses and noise mitigation solutions are also discussed.

When the headquarters of a Tulsa-based company opened, the client experienced severe noise levels that could be related to the air conditioning system. The noise impact from the mechanical equipment was evaluated. The equipment is located on the roof of the newly constructed building.

The purpose of the sound measurements was to assess the noise impact on the top floor executive offices. The measurements took place in March 2015 to collect noise data at different locations in the building and on the roof next to the air units.

Objective. Identify the impact of various noise sources and levels from the air-handling units located on the roof and determine the action required to reduce the intrusive noise levels.

Field Observations. Noise from the air-handling units could be heard in the open office area located on the top floor of the building. The noise is audible in the close proximity to the footprint of the air-handling units. The closer the receiver got to the perimeter of the building next to the windows, the less audible the noise became.

Instrumentation. Here is a description of the equipment used in the field measurements:

- Type 1 Brüel & Kjær Type 2250 sound level meter
- Utility Software, Brüel & Kjær BZ5503

Noise Measurements. During the site visit, air-handling units were operational and running at the time of the measurements. Various noise sources from the air-handling units were noted, and the general noise source from the air-handling units were described as constant. Noise levels were measured on the roof and on the top-floor office area. Ambient noise measurements were also taken in the office space and compared to the noise sources.

The difference between the ambient noise levels in the office space (with and without noise source) was the intrusive noise. So the goal was to reduce the intrusive noise to below the ambient so that it could not be heard. Most of the noise sources on the roof were structure borne, or vibration and re-radiated noise into the top floor. Some of the noise was airborne noise getting to the building via ducts and pipe penetrations through the roof.

The data are presented in dBA for noise level and NC level; NC ratings are determined for each bandwidth in the audible sound spectrum (63 Hz to 8,000 Hz). The NC curves define the limits that the octave-band spectrum of a noise source must not exceed to achieve a level of occupant acceptance.

Equipment Installation Observations – Air-Handling Units. The roof noise level averaged 72 dBA. The fan pointed down (not horizontal discharge), and the discharge plenum was not lined.

- The air-handling units were internally isolated from the structure with spring vibration isolators.
- The air-handling units and all components connected to it were rigidly connected to the structure (see Photos 1 and 2).
- Pipes did not appear to have flexible connections to the air-handling units.
- Vibration from the air-handling units could be felt next to the air-handling units and at the pipes connected to it and to the slab (floor of the roof).

Based on a paper presented at Noise-Con 2016, Conference on Noise Control Engineering, Providence, RI, June 2016.

Photo 1. Return duct elbow connected directly to the fourth-floor units located directly above sensitive spaces.

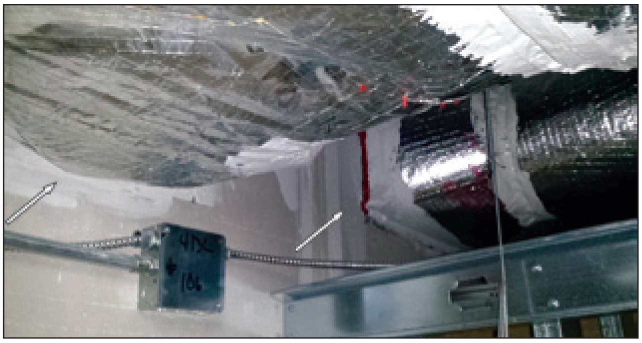

Photo 2. Ducts in direct contact with walls and pipes above ceiling,

- Ducts penetrated the roof in many locations and were rigidly connected to those areas (see Photos 3a and 3b).

Fourth-Floor (Top Executive Floor) Observations. Air-handling unit noise was clearly audible on the fourth floor (see Figures 1 and 2).

- Air-handling units (AHU 5.4A and 5.4B) serving the fourth floor were located above the center of the floor. The two units supplied air directly to the ducts in the ceiling plenum.
- Air-handling units serving the lower floors were located on the roof on the north and south sides. Some units were ducted, and some units supplied air directly.
- Noise from AHU 5.4A and 5.4B was audible in the center of the fourth floor.
- Noise level on the fourth floor with units running averaged 46 dBA in the middle of the floor.
- Noise from air-handling units on the south and north end of the building was audible with vibration that could be felt on the walls.
- When two air-handling units on the north side were running (AHU 5.3A and 5.1A), the noise level in the copy room averaged 54 dBA. The noise is characterized as pulsating and loud.
- When AHU 5.3A (first unit from the north side) was turned off and only AHU 5.1A was on, the noise level in the copy room dropped noticeably. The noise averaged 41 dBA, meaning that AHU 5.3A contributed 13 dB to the overall background noise.
- Above the ceiling of the copy room, the noise level averaged 67 dBA with air-handling units 5.3A and 5.1A both running. See Table 1 for a summary of the copy room noise levels.
- Breakout noise above the ceiling from the main supply and return ducts was dominant.
- There is a rigid connection between the main ducts and the

Photo 3. Pipes and ducts are rigidly connected to units and roof with potential vibration and noise transfer.

walls; in some cases, ducts are resting on the wall.
- Noise level averaged 54 dBA in the break room when AHU 5.1B is on and AHU 5.2B if off.
- The noise dropped to 45 dBA when AHU 5.1B was turned off while AHU 5.2 B is on. This means that AHU 5.1B is contributing 9 dB to the overall background noise.
- Noise level in the break room averaged 59 dBA when both units (5.1B and 5.2B) are on. See Table 2 for a summary of the copy room noise levels.

Noise Control Discussion. In general, the noise control problem can be divided into three parts:
- Noise source – air-handling units and distribution systems
- Noise Path – ducts and pipe supports
- Noise receiver – office space

The majority of the noise from air-handling units is believed to be transmitted throughout the air and the ducting system connected to them. The main supply fan system exhibits a high pulsation as a result of discharge airflow turbulence. The AHU fan is configured as a down-blast, with the air immediately entering the duct system. The ducts and their supports are rigidly connected to the structure, possibly transmitting vibration from the air-handling units into the floor below.

Proper operation of air-handling units and airflow is greatly dependent on the entire system, which includes the duct geometry and the system operating conditions. There are too many elbows or transitions in a short distance between the air-handling units and the ceiling. So there can be turbulent energy from the airflow in the ducting system that can possibly excite acoustical resonances in the ducting system. This is believed to be a major contributor to the noise especially in the low-frequency range of 31-125 Hz.

We observed several locations on the roof where the ducting system was in contact with the air-handling units' frame and structure, causing the vibration to be possibly transmitted from the units to the ducting system.

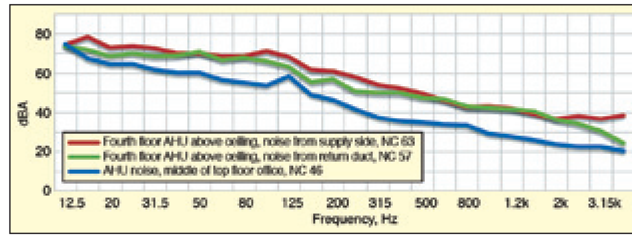

Figure 1. Building noise level from air-handling units serving fourth floor of Building D4.

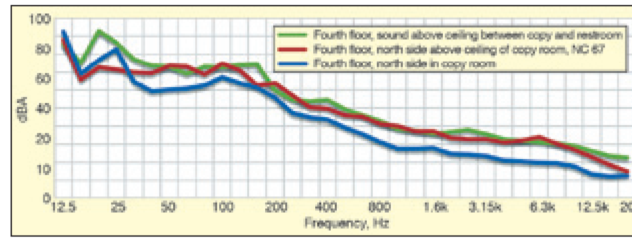

Figure 2. Noise level from air-handling unit in copy room of Building D4.

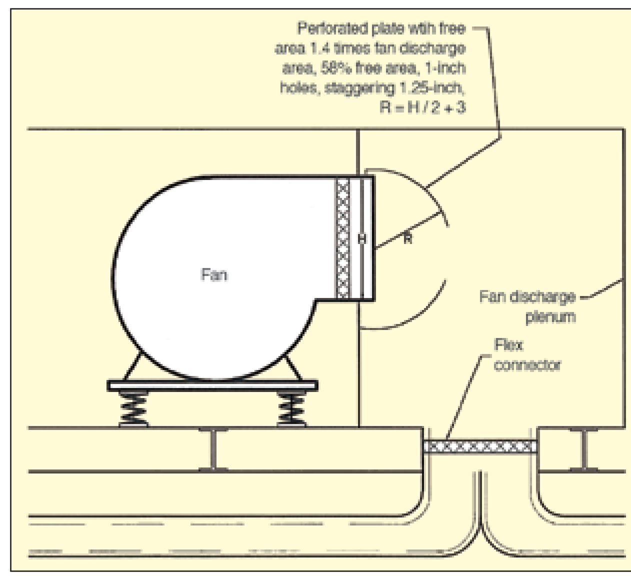

Figure 3. Perforated diffuser.

Table 1. Copy room noise level.

Air-handling Unit (AHU) Turned On	Noise Level, dBA	Comments
AHU 5.1A	41	AHU 5.3A off
AHU 5.3A and 5.1A	54	Both copy room AHUs on
AHU 5.3A and 5.1A	61	Above ceiling of copy room, both AHUs on

Table 2. Break room noise level.

Air-handling Unit (AHU) Turned On	Noise Level, dBA	Comments
AHU 5.1B	54	AHU 5.2B off
AHU 5.2B	45	AHU 5.1B off
AHU 5.1B and 5.2B	59	Both units on

Recommendations

Since it may not be possible to fully change the duct system, as in this case, the solution could involve implementing a method to diffuse the air before it reaches the main elbow and turning vanes. The goal was to allow the air to enter the elbow and turning vanes at lower velocity. So, we recommended the following two strategies to reduce the noise level from the air-handling units:
- Install mufflers at each main supply and return ducts.
- Provide lagging to the ducting system and a combination of vibration isolation for the ducts and chilled water pipes on the roof. The following paragraphs detail the recommendations:
- Provide duct silencers for each air-handling unit at the main supply and return ducts. Elbow silencers can be considered as an option. The duct silencers will help reduce the in-duct noise but will require four to five duct lengths downstream the silencer.
- Apply a perforated diffuser at the main supply, as shown in

Figure 3. This forces the high-velocity fan discharge air through the perforations and disperses the airflow to eliminate turbulence that occurs as the high-velocity air impinges on the opposite plenum wall, creating rolling turbulence and resulting unwanted low-frequency noise created by the turbulence and vibration in the duct system. Using a duct silencer was proven effective in further reducing the broadband noise spectrum. This option should be discussed directly with the mechanical engineer and the manufacturer, since they may have items and parts suitable for the air-handling units' model number.
- Wrap all supply and return ducts with acoustical lagging material. This step will help reduce radiated "breakout noise" from the discharge ductwork. There were several manufactures that can supply acoustical lagging products.
- The ducts should not be connected rigidly to the air-handling units, and there should be flexible connections at each supply and return side. All ducts and pipes should be free from touching any component of the air-handling units.
- There should be flexible connections of the reinforced spherical rubber between the air-handling units and the connecting piping. The connectors should be applied to the inlet and discharge sides.
- Isolate and support all pipes from the floor. The chilled water pipes were in direct contact with the roof slab.
- Provide spring isolation to the duct supports above the ceiling. Springs should be selected or neoprene hangers as an alternative. This spring option may be complicated to implement due to limited space above the ceiling.
- The duct penetrations should have better noise-blocking material between the ducts and the slab on the roof. We believed that some of the noise energy was being transmitted into the building directly through the penetration area.
- In the ceiling cavity below the foot print of the air-handling units, add 6-inch batt insulation with foil backing facing down to the cavity.

Summary

The steps outlined here could reduce the system noise and vibration levels but might not eliminate the noise problem. When designing air distribution systems, mechanical engineers should conduct analyses with the help of acoustical consultants to help verify smooth airflow and the impact of duct breakout noise. Proper noise analyses should be conducted during the design phase to allow for noise control items to be implemented into the construction documents.

Acknowledgments

This project was completed with the help and support from Howard K. Pelton of Pelton Associates who provided reviews and feedback on this project. S/V

The author can be reached at: wtikriti@acoustonica.com.