# DUCT LINER ACOUSTICS — IT'S ALL THE SAME... RIGHT?

Hello, and welcome back to the second installment of our duct liner blog. In the first installment, we talked about thermal performance between fiberglass and elastomeric rubber foam duct liner. Today, we're talking about the acoustic performance of these two products.

**The Importance of an Air Handling Unit (AHU)**

Have you ever found yourself interrupted by activity or conversations in the next room or by mechanical system noise when the building Air Handling Unit (AHU) starts up, or needing to put earbuds in to avoid noise distractions? Have you ever heard the all too familiar sound of the bass drum from the duct system as the sheet metal expands or contracts to the air temperature flowing through it when the AHU cycles on? I know I've personally caught myself speaking quite loudly to overcome AHU system noise, only to be embarrassed when the HVAC system cycles off and others in the building notice I'm talking loudly.

Another interesting aspect of an untreated or poorly treated acoustic environment is one's inability to focus effectively because of background noise, which can be caused by the building's HVAC system as well as worker activity in open plan office spaces. Several studies have been commissioned over the years to capture the actual impact of louder noises, like those related to an HVAC system, within workspaces and classrooms.

One such investigation found that workers or students can be "...up to 66% less productive when exposed to just one nearby conversation."[1] It's been shown that interruptive sounds, or noise, can cause psychological stresses, including an increase in blood pressure and heart rate.[2] Another study by David M. Sykes, PhD[3] speaks to an approximation that 73% of the U.S. workforce work in open office environments. Continuing Education Course material[4] indicates that the dominant complaints from people in the workplace involve the HVAC systems, with the most frequent problem being excessive noise and vibration.

These studies highlight that a large portion of the workforce is exposed to an acoustic environment that is known to affect health and productivity. So, if you've found yourself stressed, irritable, or less productive, the recommendation is to determine if you are in an untreated or poorly treated acoustic environment. But, there's good news: this is a problem that can be fixed!

In a building, sound is generated by HVAC equipment, people, and office equipment. Sound generated by

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[1] https://information.insulationinstitute.org/blog/noise-affects-productivity-and-well-being.
[2] Harvard Medicine: *The Effects of Noise on Health.* https://hms.harvard.edu/magazine/viral-world/effects-noise-health.
[3] *Productivity: How Acoustics Affect Worker's Performance in Offices & Open Areas.* https://mpsacoustics.com/wp-content/uploads/2009/10/Productivity.pdf.
[4] *HVAC Systems Noise Control* – A. Bhatia.

Air Handling Units (AHUs) and air movement, which can be carried great distances through the ducts without appropriate and effective reduction, can create communication and productivity issues for the building occupants. Have you ever heard the all too familiar sound of the bass drum when the AHU cycles on? That sound is the duct system as the sheet metal expands or contracts to the air temperature flowing through it. Uninsulated air ducts connecting two rooms may freely transfer sound between rooms. These types of sounds can become a nuisance, disrupt production, or become a privacy concern. To minimize the effects of the sound traveling within the ducts, contractors and building designers can add materials to line the ducts and reduce the sound levels.

**Ways to Reduce HVAC Noise**

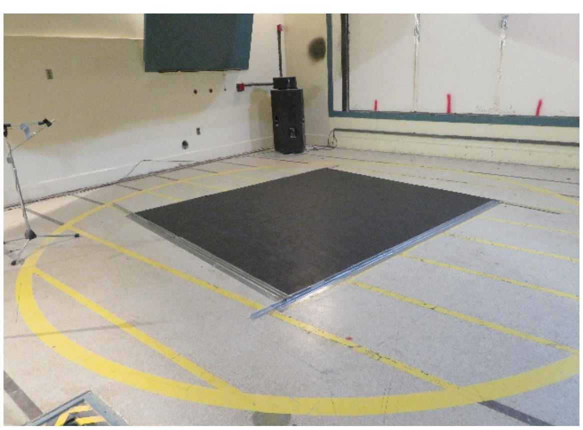
While thermal performance is usually the primary driver for duct insulation specification, noise control is also an important feature to be considered. The data used to select materials to insulate the ducts is critical to the overall building noise control design. Today, we'll compare the different methods to identify the acoustic performance of acoustic ducts and linings and discuss their differences and why these methods are used.

Sound in ducts is produced through the turbulence of the air flow and by vibrations in the HVAC unit and VAVs that transfer to the air inside the ducts. Both the turbulent flow and vibration cause sound travel in the duct system as sound waves. Unless there is something to reduce the amplitude of the sound waves, the amplitude typically does not decrease as the wave moves away from the source. To reduce the sound levels within the ducts, the employment of sound absorption materials is utilized. There are many manufacturers that offer materials to reduce sound levels in ducts. These include fibrous materials such as fiberglass as well as elastomeric rubber foam. Each material has advantages and disadvantages for the duct application. Many of those can be related to temperature control, sound control, condensation control, and energy conservation.

**Testing ASTM C423: Fiberglass Duct Liner vs. Elastomeric Rubber**

A review of duct liner product brochures revealed that, for sound control, the manufacturers rely on sound absorption data to demonstrate the acoustic performance of their products. If a test of the product installed as it actually is used in the field did not exist, sound absorption would provide a comparison between products to determine which one had a higher probability of reducing the sound level within the duct. Sound absorption testing is typically conducted in a large reverberation chamber per ASTM C423: *Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method* or ISO 354: *Acoustics — Measurement of sound absorption in a reverberation room*. These tests are typically conducted utilizing a band of random noise between the frequencies 80 and 5000 Hz to excite the reverberation chamber long enough to reach a steady state, if the sound field is diffused. The signal is then turned off and the sound pressure level decay rate in each one third octave or octave band frequency is determined by measuring the slope of the average decay curve for the sound pressure level.

*Figure 1a and 1b: Pictures of a sample duct liner being tested in reverberation chamber per ASTM C423.*



Unfortunately, this method is only useful for estimating attenuation at low frequencies where the acoustical waves behave as plane waves. Measuring the actual performance of the duct liner products would provide the most practical solution to comparing the effectiveness of different duct lining materials. By the ASTM C423 Sound Absorption Test Method, it appears that fiberglass and foam perform similarly in the lower frequency range where structural and mechanical noise reside with foam showing better performance in at least one frequency band.

*Table 1*

| | **Sound Absorption Coefficients by Frequency (Hz) (ASTM C423)** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Product** | 125 | 250 | 500 | 1000 | 2000 | 4000 | NRC |
| 1" armacell® AP ArmaFlex® * | 0.01 | 0.13 | 0.39 | 0.69 | 0.29 | 0.26 | 0.40 |
| 1" K-Flex® Duct® Liner Gray ** | 0.06 | 0.17 | 1.06 | 0.32 | 0.67 | 0.54 | 0.55 |
| 1" Owens Corning QuietR® Rotary Duct Liner *** | 0.04 | 0.26 | 0.63 | 0.91 | 0.99 | 0.99 | 0.70 |
| | | | | | | | |
| 1.5" armacell® AP ArmaFlex® * | 0.07 | 0.26 | 0.92 | 0.31 | 0.49 | 0.53 | 0.50 |
| 1.5" Owens Corning QuietR® Rotary Duct Liner *** | 0.19 | 0.55 | 0.84 | 1.00 | 1.01 | 0.98 | 0.85 |
| | | | | | | | |
| 2" armacell® AP ArmaFlex® * | 0.14 | 0.62 | 0.44 | 0.43 | 0.51 | 0.45 | 0.50 |
| 2" K-Flex® Duct® Liner Gray ** | 0.23 | 0.84 | 0.32 | 0.60 | 0.39 | 0.31 | 0.55 |
| 2" Owens Corning QuietR® Rotary Duct Liner *** | 0.16 | 0.61 | 0.94 | 1.04 | 0.95 | 0.99 | 0.90 |

*AP ArmaFlex and AP ArmaFlex FS | Duct Liner and Wrap TDS | 112020 | NA | EN-A | 019

** K-Flex document - K-FLEX US_LEA_DUCT LINER GRAY_V1_0619

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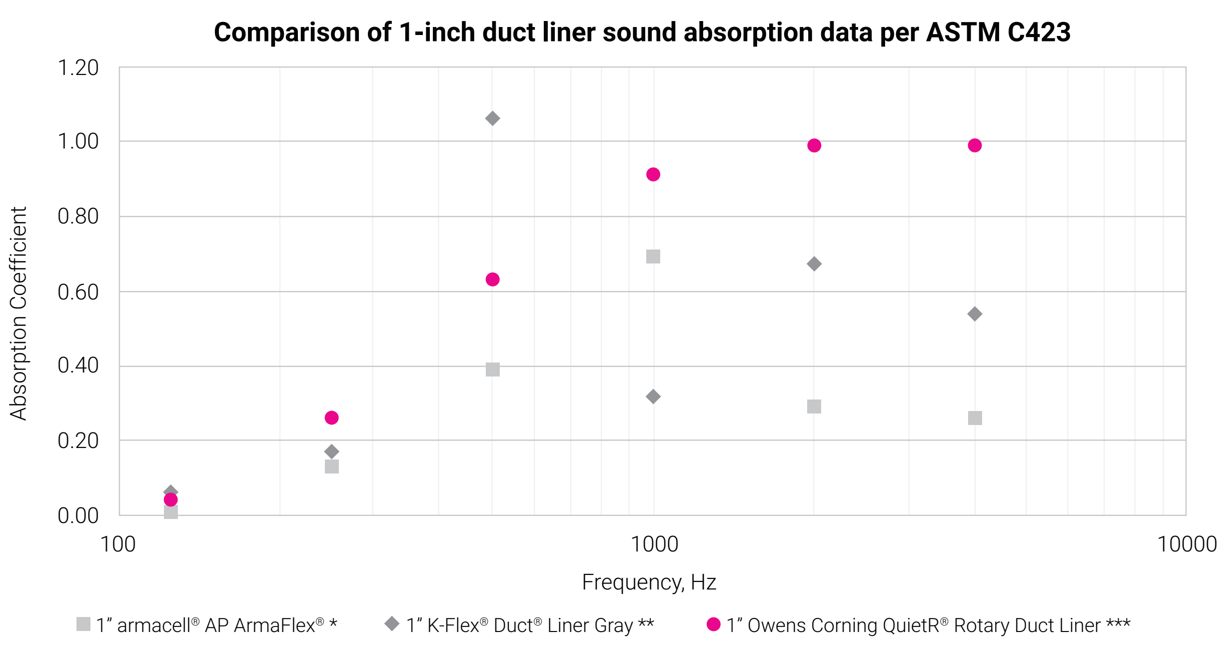
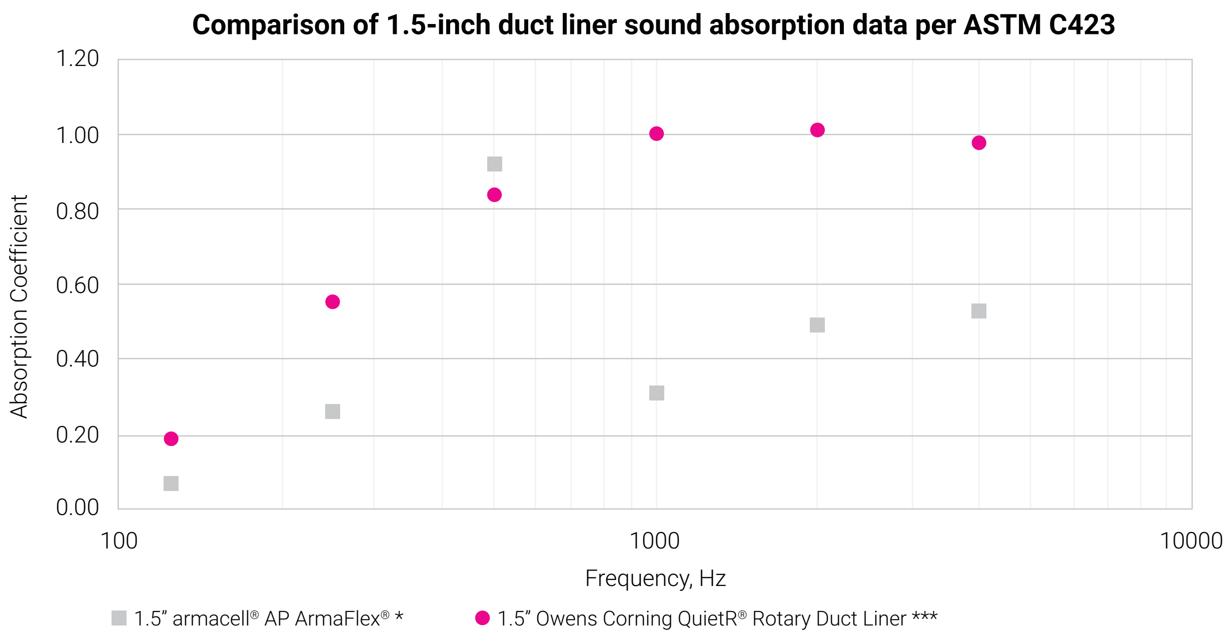
A plot of the absorption coefficients taken from Table 1 for each material at one-inch thickness is shown in Figure 2a. The materials have similar performance for frequencies below 250 Hz. K-Flex® has better performance at 500 Hz, but then both elastomeric foam products have lower performance over the remainder of the frequencies.

*Figure 2a*



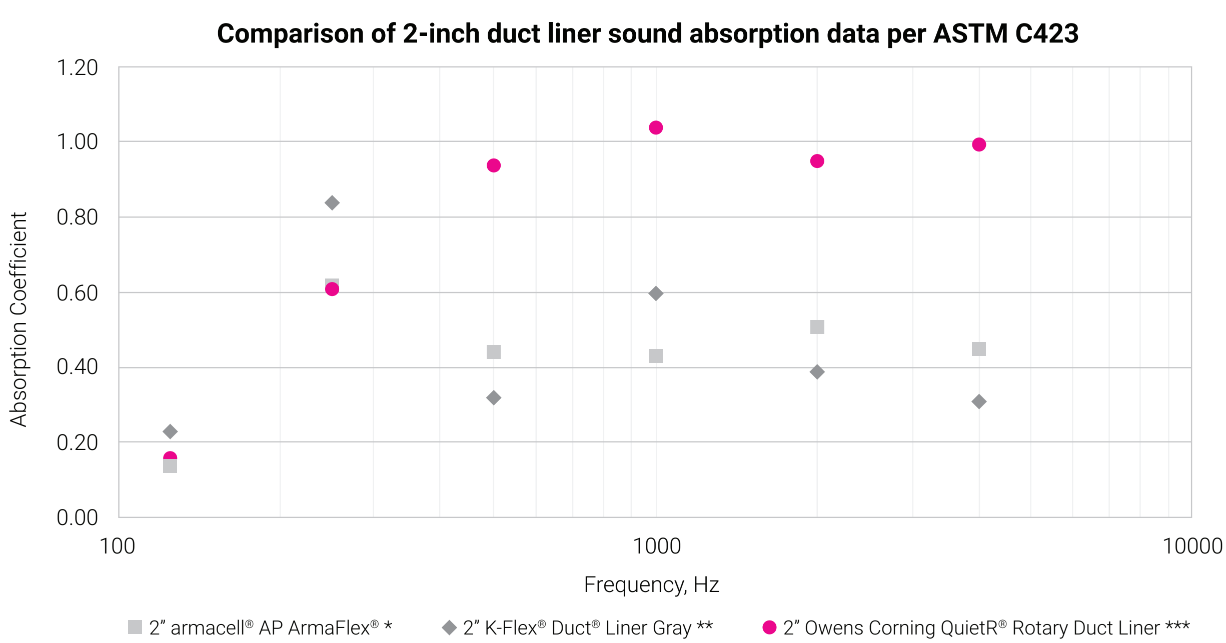
A plot of the average absorption coefficients taken from Table 1 for each material at one-and-a-half-inch thickness is shown in Figure 2b. K-Flex® did not show data for one-and-a-half-inch product. The foam and fiberglass material performance again are similar at frequencies below 1000 Hz except for 500 Hz. However, for frequencies at 1000 Hz and greater, the fiberglass duct liner shows to have superior performance.

*Figure 2b*




The average absorption coefficients taken from Table 1 for each material at two-inch thickness are shown in Figure 2c. The foam and fiberglass material performance are again similar except for 250 Hz. However, the fiberglass duct liner shows to have superior performance beginning at 500 Hz and above.

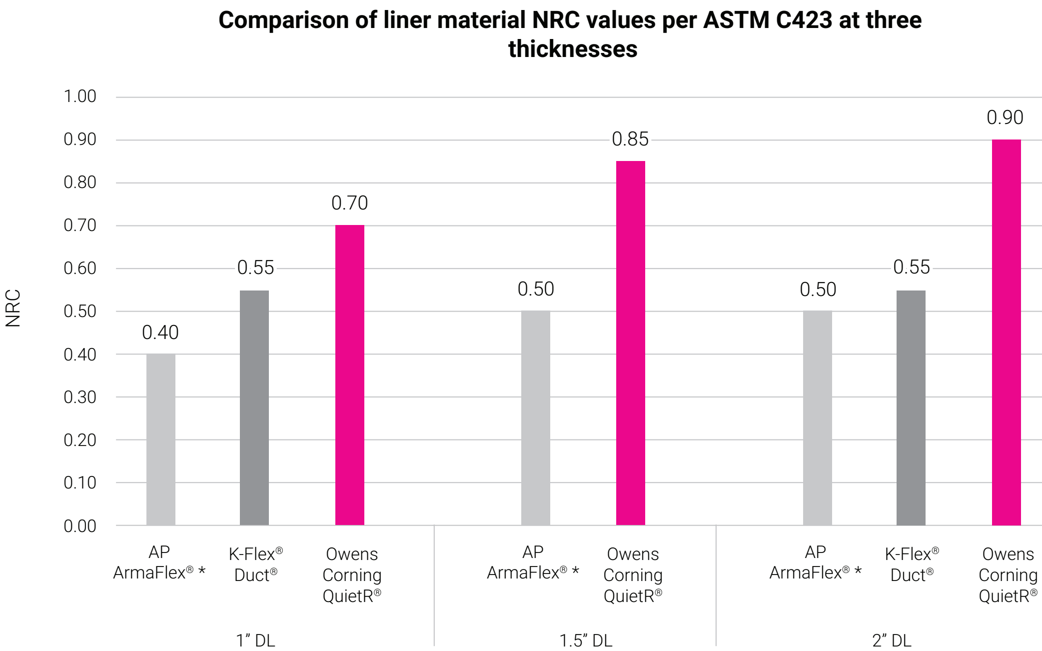
*Figure 2c*



**Testing ASTM E477: Fiberglass Duct Liner vs. Elastomeric Rubber**

Comparing the Noise Reduction Coefficient (NRC) values for each material is shown in Figure 3. Fiberglass liner materials have a higher NRC value than the foam material. However, at the one-inch thickness, the difference is smaller, but the foam performance is still lower than the fiberglass materials.

*Figure 3*




Measuring the actual performance of the duct liner products would appear to provide the most practical solution to comparing the effectiveness of different duct lining materials to reduce sound within a duct. A standard for this type of measurement exists. It is ASTM E477: *Standard Test Method for Laboratory Measurements of Acoustical and Airflow Performance of Duct Liner Materials and Prefabricated Silencers*. The ASTM E477 standard provides for laboratory testing of the acoustical properties of sound attenuation in ducts, including duct liner materials. This test for insertion loss is completed by determining the difference in sound pressure level in a reverberation chamber from an untreated duct system, connecting the chamber to a sound generation chamber with the sound pressure level when a test specimen is inserted into the duct system. Speakers in the sound generation chamber emit pink noise to create sound pressure levels that propagate toward the reverberation chamber through the duct system. Insertion loss between the untreated and treated duct is measured both with and without air flowing through the duct.

Owens Corning commissioned an acoustic study with a third-party laboratory in which a fiberglass duct liner along with a foam duct liner were submitted for testing by a third-party laboratory per the ASTM E477 standard. Two rectangular duct geometries were submitted. A 12-inch-by-24-inch duct and a 24-by-24-inch duct constructed from 24-gage sheet metal,

*Figure 4*
*Picture of ten-foot-long test ducts prepared for ASTM E477 testing.*

*Figure 5*
*Picture of duct liner test setup per ASTM E477.*

0.0250-inch thick (0.64 mm), were used for testing. One-inch duct liner was chosen for testing purposes. For a one-inch duct liner, actual duct size for testing is 26-by-26-inch square and 14-inch-by-26-inch rectangular to allow for the liner thickness. Samples of each duct geometry were prepared and shipped to the third-party testing laboratory. Figure 4 shows the lined sheet metal ducts and a crate protecting the fiberglass duct board for shipment. After testing the untreated duct, supplied by the testing lab, the specimens were mounted into the test system. Figure 5 shows the lined duct specimen mounted into the test system. The sound travels from the left to the right in the pictures to the Reverberation Chamber.

The average insertion loss of the liners for both duct sizes tested are shown in Table 2. The data indicates that the fiberglass duct liner provides better insertion loss compared to the foam duct liner. The foam duct liner demonstrated good performance in sound absorption per ASTM C423 at frequencies below 1000 Hz. However, that does not appear in the insertion loss data. For frequencies below 250 Hz, which is the HVAC system white noise domain in the 12-inch-by-24-inch duct and frequencies below 160 Hz for the 24-inch-by-24-inch duct, the fiberglass duct liner appears to be the only product with any insertion loss performance. The foam liner does not appear to have insertion loss greater than 0.3 dB/foot. below 630 Hz for the 12-inch-by-24-inch duct tested. To reduce the sound level by the same amount below 800 Hz with the foam duct liner, as much as three times the length of duct would need to be treated as with fiberglass duct liner. These frequencies are important because much of the HVAC sound generated by Variable Air Volume (VAV) units, reciprocating and centrifugal compressors, fan instability, and turbulent flow is below 800 Hz.

*Table 2*

**Measured average insertion loss data, in dB per foot, for evaluation of duct liner materials per the ASTM E477 Standard. Data represents average for all airflow conditions.***

| Duct Size (in) | 12x24 | 12x24 | | 24x24 | 24x24 |
|---|---|---|---|---|---|
| **Octave Band Center Frequency, Hz** | **1" Foam Duct Liner** | **1" Fiberglass Duct Liner** | | **1" Foam Duct Liner** | **1" Fiberglass Duct Liner** |
| 80 | -0.1 | -0.2 | | -0.1 | -0.1 |
| 100 | -0.5 | -0.5 | | -0.1 | 0.1 |
| 125 | -0.2 | 0.1 | | 0.0 | 0.1 |
| 160 | -0.2 | -0.1 | | 0.0 | 0.2 |
| 200 | -0.2 | 0.1 | | 0.1 | 0.3 |
| 250 | 0.0 | 0.5 | | 0.2 | 0.4 |
| 315 | 0.1 | 0.7 | | 0.2 | 0.6 |
| 400 | 0.1 | 1.1 | | 0.3 | 0.9 |
| 500 | 0.2 | 1.5 | | 0.5 | 1.3 |
| 630 | 0.3 | 2.2 | | 0.9 | 1.9 |
| 800 | 0.5 | 3.2 | | 2.3 | 2.8 |
| 1000 | 0.9 | 4.4 | | 1.7 | 3.9 |
| 1250 | 1.6 | 4.7 | | 1.0 | 3.2 |
| 1600 | 2.1 | 4.9 | | 0.9 | 2.3 |
| 2000 | 1.5 | 4.0 | | 1.0 | 1.9 |
| 2500 | 1.2 | 2.8 | | 1.3 | 1.7 |
| 3150 | 1.1 | 2.0 | | 1.1 | 1.6 |
| 4000 | 1.2 | 1.9 | | 0.9 | 1.6 |
| 5000 | 1.2 | 1.8 | | 0.8 | 1.6 |
| 6300 | 1.2 | 1.7 | | 0.7 | 1.5 |
| 8000 | 1.1 | 1.6 | | 0.7 | 1.4 |
| 10000 | 1.0 | 1.8 | | 0.7 | 1.6 |

*Testing commissioned by Owens Corning and executed by a third-party laboratory.

*Figure 6*

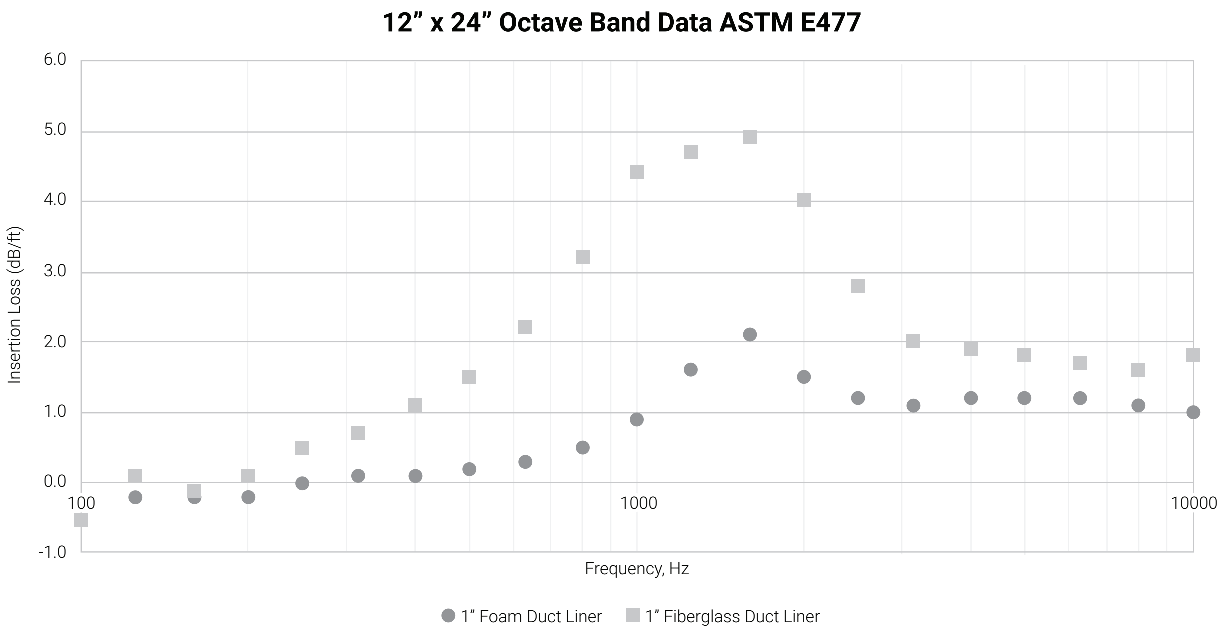
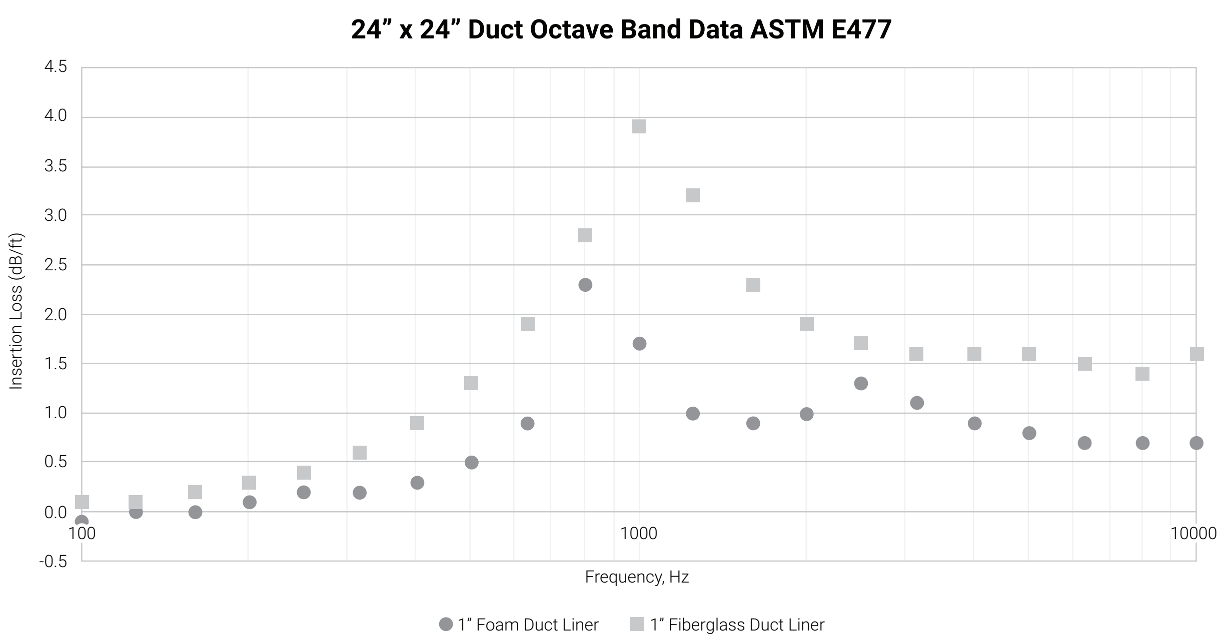



*Figure 7*



**Importance of Accurate Testing**

The setup for testing per the ASTM E477 standard is capital intensive and requires a large amount of space, including a reverberation room qualified to test per the requirements of ANSI Standard S12.51/ISO 3741: *Acoustics — Determination of Sound Power Levels and Sound Energy Levels of Noise Sources Using Sound Pressure — Precision Methods for Reverberation Test Rooms.* Only a small number of these test systems are available to perform testing as third-party laboratories, which impacts the cost of testing per this standard. This could very likely be one reason why the more readily available testing for sound absorption is chosen, even though it doesn't properly represent in application performance.

The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) developed tables showing insertion loss data based on laboratory tests using 10-foot lengths of duct in the 1980s. Chapter 49.22 of the ASHRAE® HANDBOOK (2019) includes Tables 17–18 for selected rectangular, and Tables 20–21 for selected circular, cross-section ducts showing the insertion loss values (dB/foot) for 1- and 2-inch fiberglass duct lining. Certainly, these tables can provide guidance, eliminating the cost of having the test performed. However, products evolve, and this data may not accurately represent more recently developed products available on the market.

**Using the Right Insulation for Install**

Although the sound absorption coefficients per ASTM C423 reported by manufacturers may provide a rank order of duct treatment products, the result is not consistent with level of performance when the products are installed and tested in a manner like the actual use environment. The sound absorption data showed that at lower frequencies the foam and fiberglass performance was comparable. However, the results from testing per the ASTM E477 standard showed that fiberglass provided three to four times the insertion loss of the foam. Fiberglass duct liner should be the preferred method to achieve the optimum result in reducing the sound traveling through the duct system given the significantly better performance of fiberglass duct liner compared to the foam material providing for lower costs as significantly smaller amounts of material is needed to meet noise reduction goals based on this study. This study also demonstrated that ASTM E477 provides much more useful data regarding how duct liner reduces heating, ventilation, and air conditioning system sound traveling in treated duct. Testing per the ASTM E477 standard should be the preferred performance measurement of duct liners.

If you're interested in the best possible acoustic solution over the frequency range that impacts your environment and the best overall performer the clear choice is fiberglass duct liner.

Be sure to check back for the next installment where we'll talk about life safety performance.

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