



DESIGN CONSIDERATIONS FOR THE ACOUSTICS OF PIPING SYSTEMS IN MULTI-TENANT BUILDINGS



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ABSTRACT

Offices and multi-tenant residential buildings, such as high-rises, condos and duplexes present distinct acoustical challenges. Unwanted noise can come from external sources, such as passing cars or nearby bus and train lines, as well as internal sources, such as washing machines in neighboring units or businesses in adjacent offices.

Noises associated with the building's pipe systems, including plumbing noises, also need to be minimized in a multi-tenant setting. Sounds of toilets flushing, "water hammer," and rainwater draining off the roof can all lead to occupant frustration. Not surprisingly, water traveling 30 stories from the roof to the ground can generate quite a bit of noise. And mechanical noises from sources such as pumps delivering chilled and heated water or air handlers on the roof can create unwanted noise that disturbs tenants.



STANDARDS FOR ACOUSTIC PERFORMANCE

ASTM International has developed two standard test methods that can be helpful for engineers specifying pipe systems for multi-tenant buildings. ASTM International is one of the world's largest international standards developing organizations, creating and publishing standards for materials, products, systems and services.

Mechanical engineers use primarily two test methods to determine the performance of different acoustic systems and to help design insulation or lagging for specific jobs. Those two test methods are ASTM E1222 and ASTM E90, each discussed in detail below. For pipe systems, ASTM E1222 is more relevant because the insulation is tested in a pipe configuration that is more consistent with installation in the field.

ASTM E1222

ASTM E1222: Standard Test Method for Laboratory Measurement of the Insertion Loss of Pipe Lagging Systems determines how effective insulation or lagging is at reducing breakout noise from a pipe. The term insertion loss refers to reducing sound by adding insulation and/or jacketing (lagging) to a pipe or duct system to prevent sound from traveling outward, away from the source of the noise.

During the E1222 test, noise is produced inside a pipe (commonly made of steel) in a reverberation room, which is a room designed to reflect noise equally in all directions. Average sound pressure levels are measured first with sound radiating from the bare pipe and then with sound radiating from the same pipe covered with a lagging system. The insertion loss of the lagging system is the difference in the sound pressure levels measured with sound radiating from the bare and lagged pipe, with an adjustment for changes in room absorption due to the addition of the lagging system.

Figure 1 shows an example of raw data collected when testing bare pipe and pipe lagged with 2 inches of JM [Micro-Lok® HP Ultra](#) fiberglass insulation. The higher the pressure level, the higher the noise perceived by our ears. The graph shows that the noise from the bare pipe was between 40 and 65 decibels (dB). When we added the 2 inches of Micro-Lok® HP Ultra, the pressure level/noise decreased substantially, especially for frequencies over 1000 Hz. As a rule of thumb, a difference of 10 dB is perceived as half as loud or quiet. From the raw data presented in Figure 1, insertion loss can be calculated, and the resulting graph is shown in Figure 2. This graph shows that 2 inches of fiberglass insulation is effective in reducing noise at frequencies above 1000 Hz. The fiberglass did not significantly contribute to noise reduction at lower frequencies because fiberglass is relatively light and greater mass is needed to reduce lower frequencies.

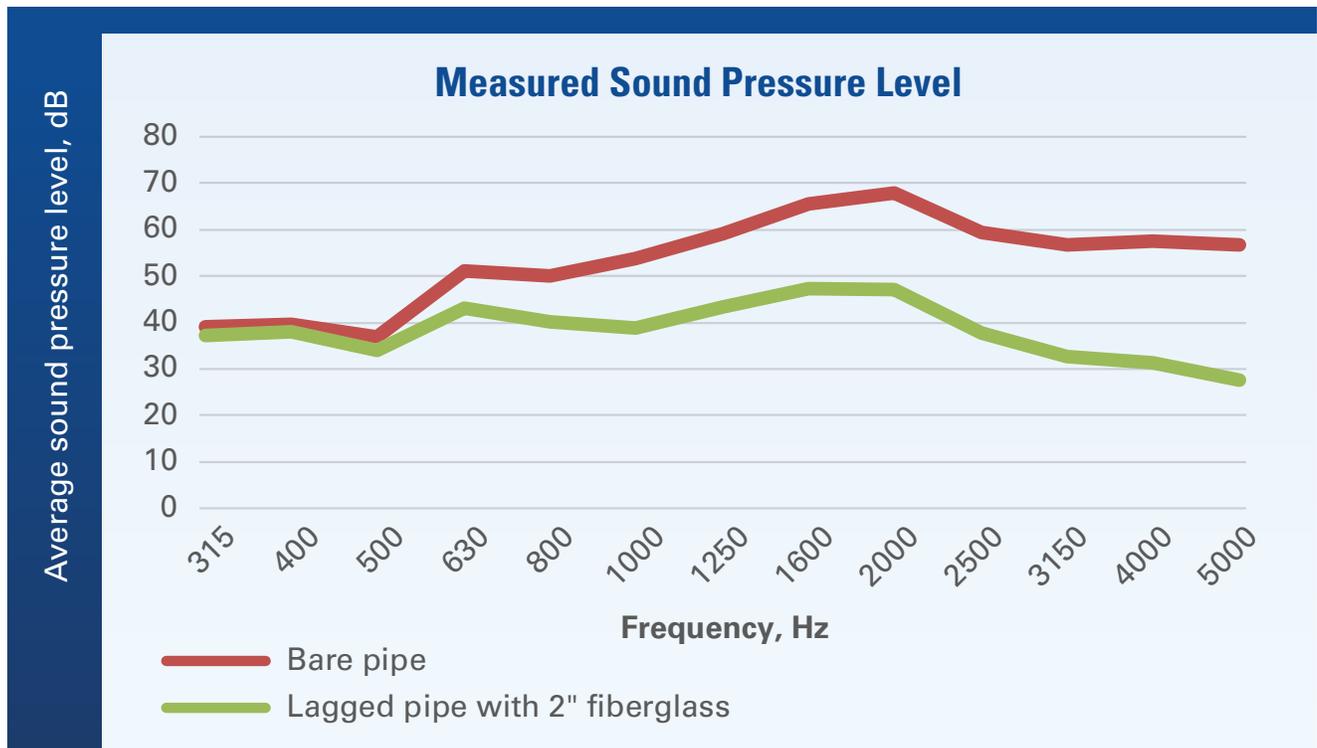


Figure 1: Measured sound pressure level for bare and lagged pipe.

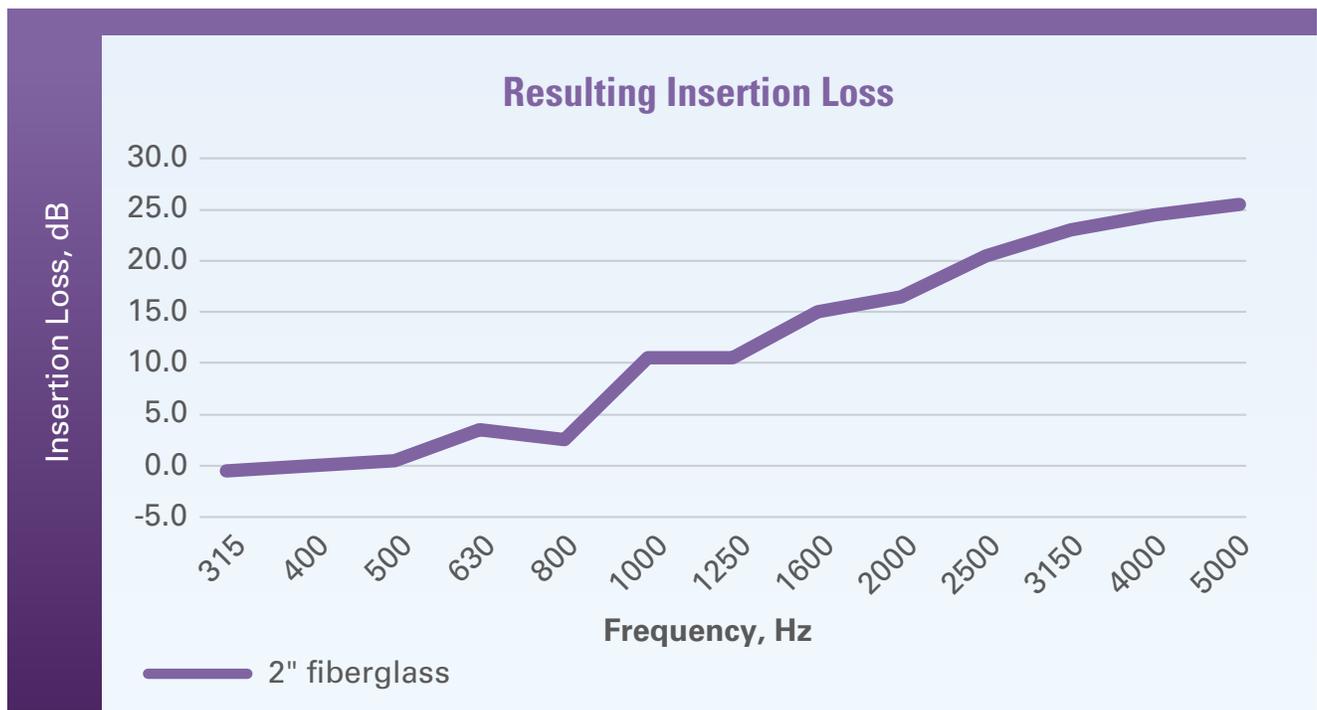


Figure 2: Resulting insertion loss for pipe lagged with 2 inches of fiberglass insulation.

ASTM E90

Another test that can help engineers specify the right acoustic treatment for pipe scenarios is ASTM E90. This test measures the airborne sound transmission loss of interior and exterior building partitions and elements, such as windows, doors, and roof assemblies. The test results are used to calculate the sound transmission class (STC) and outdoor-indoor transmission class (OITC) ratings of the item tested.

According to a sound control guide developed by the North American Insulation Manufacturers Association (NAIMA), STC is a numerical rating for the ability for a wall or floor/ceiling assembly to minimize sound transmission. The higher the STC rating, the better the wall or floor/ceiling assembly can minimize sound transmission. The OITC is a number rating of the sound transmission loss of a constructed assembly, and helps designers determine how effectively their design will protect occupants from sounds generated outside of the building or unit.

ASTM E90 testing is done in a flat configuration, where the assembly under test is installed in an opening of a wall, so it's not as relevant or applicable for pipe systems. Accordingly, some caution is needed in interpreting E90 results for pipe insulation. In addition, poor installation can reduce acoustic performance by approximately 15-20 points from the laboratory values, according to NAIMA. By definition, pipe system installation will not be flat and results are expected to deviate from those obtained in the lab when running ASTM E90. ASTM E1222 is therefore a more relevant test when it comes to the pipe geometry.

For the ASTM E90 test, two reverberation rooms are set up adjacent to one another with an opening between them. The item to be tested is installed in the opening between the rooms. Noise is generated in one room and received in the second room. The test measures the sound transmission loss between the sending and receiving rooms. An example layout of this testing is shown in Figure 3.

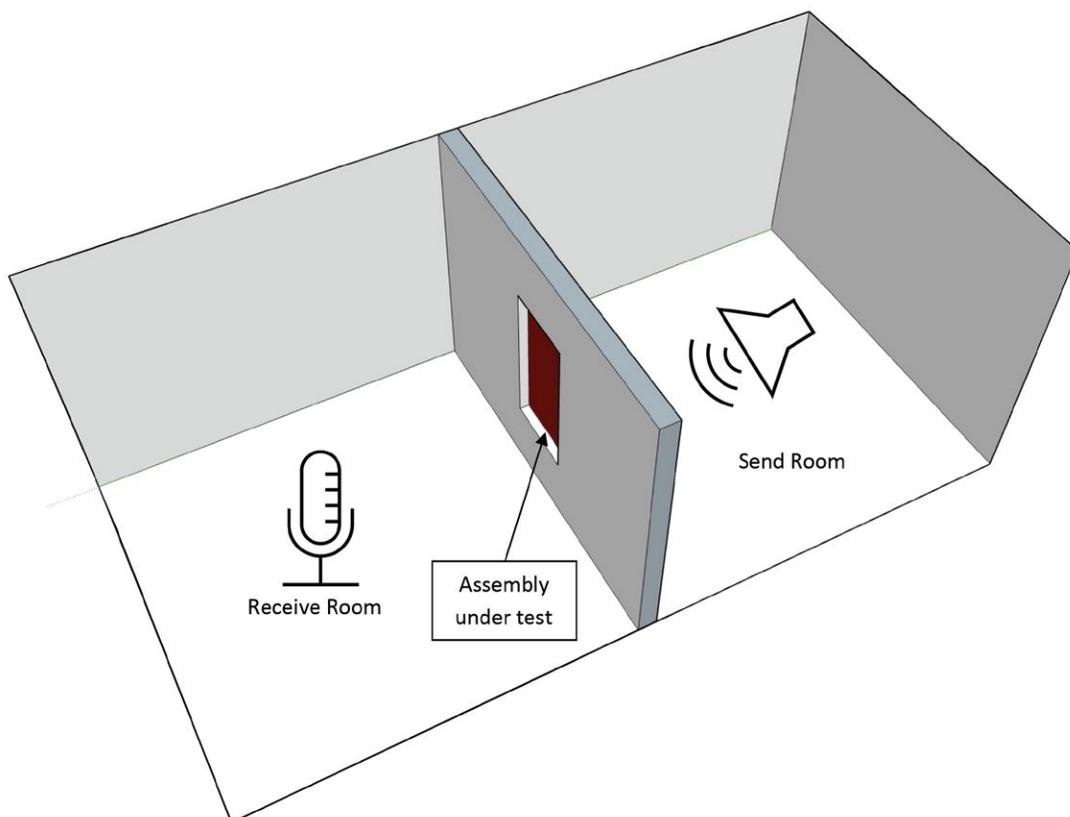
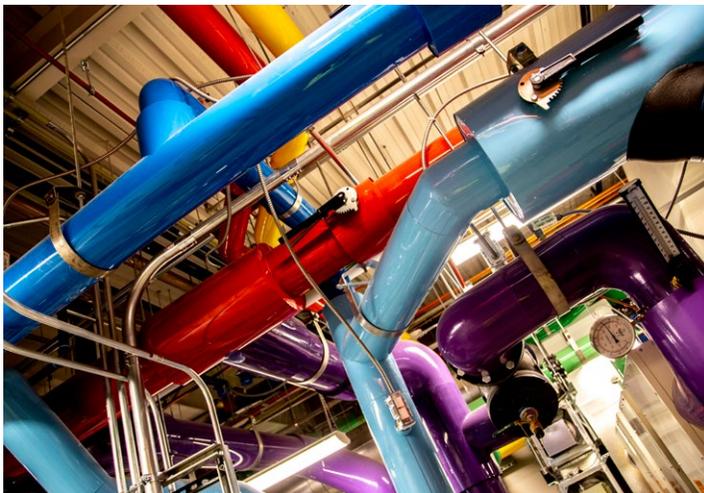


Figure 3: Schematic of the room set up for ASTM E90 testing.

ACOUSTIC SOLUTIONS ON THE MARKET

Now that we have gone over the test method, we can discuss insulation system solutions. Figure 4, Figure 5 and Figure 6 show the performance of lagging assemblies using 1-inch and 2-inch Micro-Lok® HP or Micro-Lok® HP Ultra fiberglass insulation as a base on 12-inch pipe. Zeston® PVC and JM Mass-Loaded Vinyl jacketing are also shown. Fiberglass insulation is highly effective in mitigating higher frequency noise. The addition of the [Zeston® PVC](#) jacketing further improves performance. When considering the performance of fiberglass and system with PVC jacket, it can be observed that 1 inch of fiberglass insulation with PVC jacketing will perform better than 2 inches of unjacketed fiberglass insulation, and a practical advantage will be a thinner profile. If the space is limited, adding PVC jacketing can provide an effective solution to noise control. The disadvantage is the additional labor cost of installation; however, PVC jacketing installation is relatively fast especially for straight runs.



To achieve top performance, a combination of a heavy jacket and fiberglass will be required. Typically, mass-loaded vinyl like JM [Mass-Loaded Vinyl](#) is the choice product for heavy jacketing, given its ease of cutting and installing. Mass-loaded vinyl can be found as a system with quilted fiberglass blankets or as rolls only. It can come in 1 pound per square foot (psf) or different weights. Mass-loaded vinyl at 1 psf is most common and is generally easier to work with than the heavier options. Despite the weight, the material is pliable and is installed on top of the fiberglass insulation, if it is purchased as rolls. As a side note, while mass-loaded vinyl may not be

commonly used for residential applications, acoustic systems with mass-loaded vinyl are used extensively in the industrial insulation sector for liquefied natural gas (LNG) and other facilities to mitigate noise from compressors and other equipment.

Figure 4 and Figure 5 show that the addition of JM Mass-Loaded Vinyl further improves the performance of the lagging systems. Please note the performance below 1000 Hz. Lower frequency noises in pipes may originate from pumps, compressors, flow noise, various bending modes of the pipes, or vibrations transferred structurally. As can be seen in Figure 4, lagging systems with mass-loaded vinyl can provide noise reduction between 10 and 40 dB depending on the frequency, which can provide substantial mitigation of noise. You'll notice that the y-axis shows numbers below zero. This is because some lagging systems can actually add to the noise. This may happen for a variety of reasons and it is usually only an issue at lower frequencies. Similar performance is seen in the ASTM E90 data shown in Figure 5.

Considering all of the data on various lagging systems, you can see that there are options with varying degrees of complexity and performance. Depending on the situation, budget, space constraints, you can design a system to help mitigate noise and keep residents happy (and quiet).

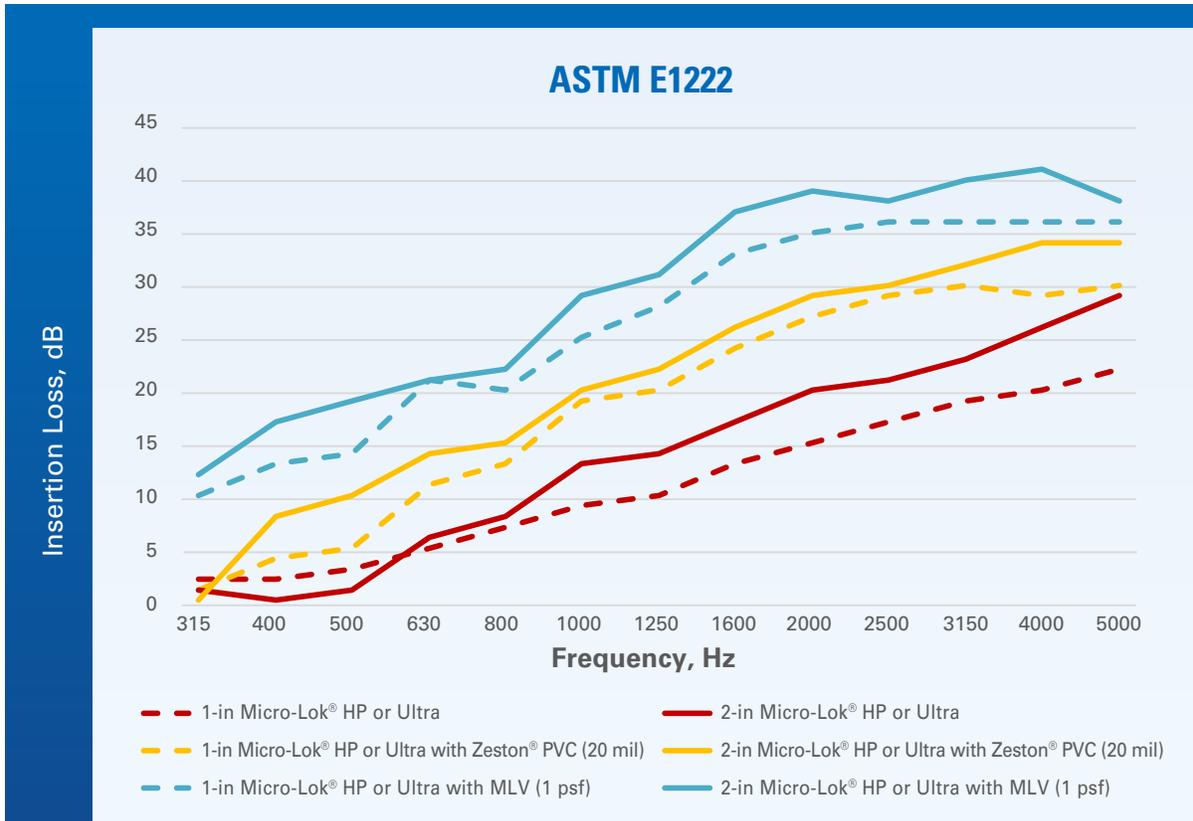


Figure 4: Typical results for ASTM E1222 using Micro-Lok HP or Micro-Lok HP Ultra fiberglass, JM Zeston PVC and JM Mass-Loaded Vinyl as lagging options.

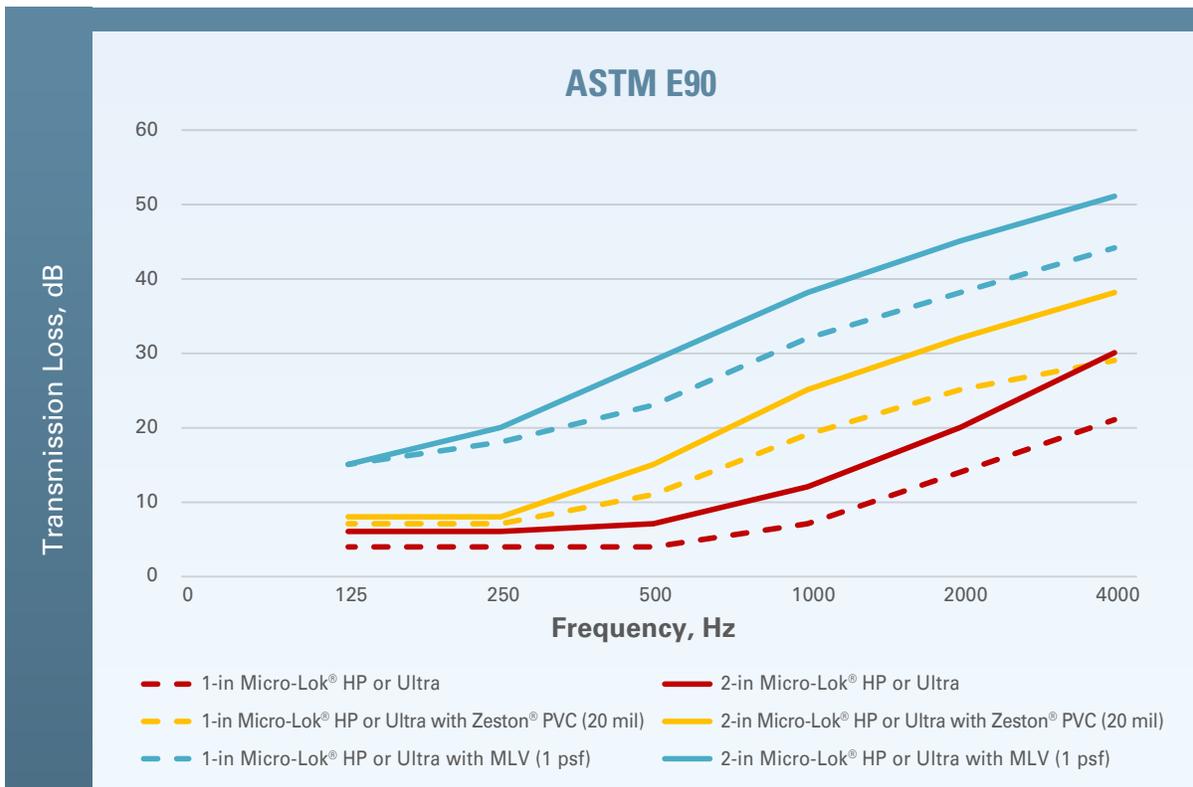


Figure 5: Typical results for ASTM E90 testing using Micro-Lok HP or Micro-Lok HP Ultra fiberglass, JM Zeston PVC and JM Mass-Loaded Vinyl as lagging options as lagging options. Caution is needed in interpreting E90 results for pipe insulation.

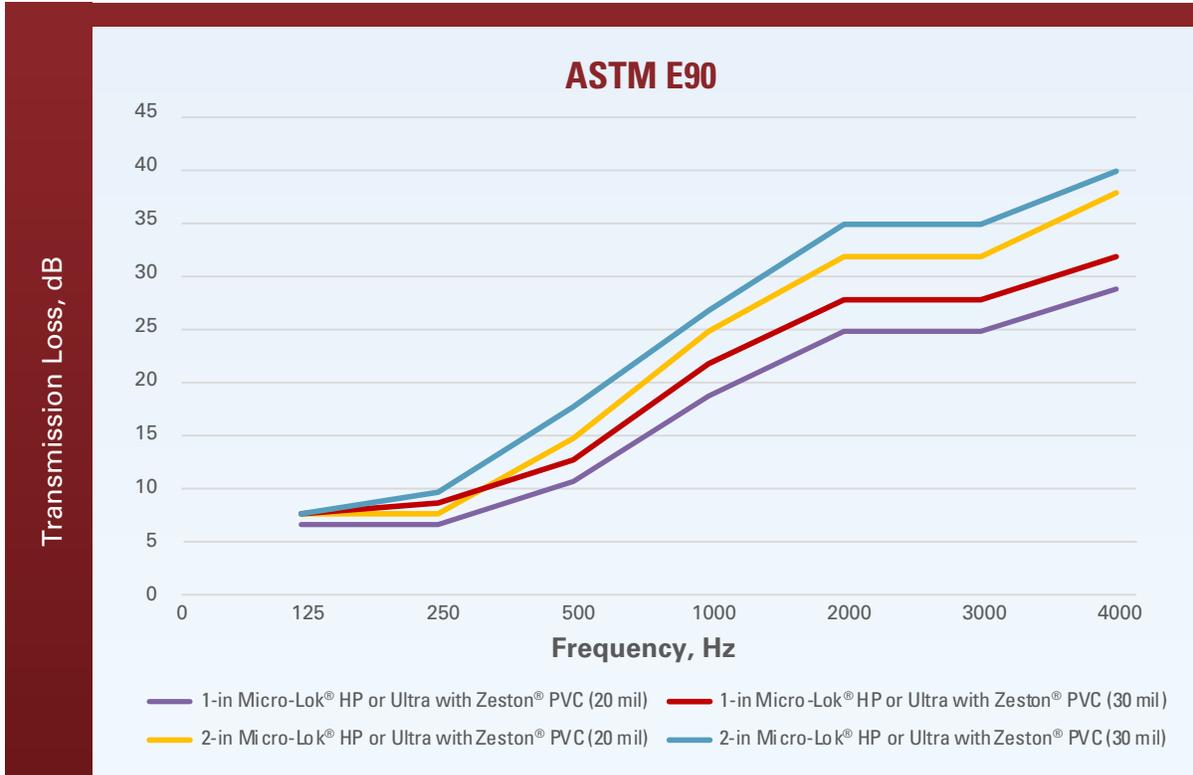


Figure 6: 30 mil Zeston PVC Jacketing provides increased performance with regards to transmission loss regards to transmission loss. Caution is needed in interpreting E90 results for pipe insulation.

A PROACTIVE APPROACH TO ACOUSTICS IS ESSENTIAL

When designing a multi-unit residential, engineers need to take a proactive approach to the acoustics issues surrounding the piping systems. As more people shift to remote or hybrid work environments, residents are spending more time at home, and a separate work environment may be needed. Failing to properly design for acoustical control of the piping systems can result in frustrated residents in the short term. And in the long term, bad building acoustics can result in a lack of interest in multi-tenant residential and office buildings, less vibrant downtowns, and lower economic benefits to builders, commercial tenants and communities through lower economic activity. No one wants to live in a noisy building, but this is especially true of residents in higher-end buildings. Those tenants expect an even greater degree of privacy and noise control.

Here are some considerations when designing the piping systems for multi-unit residential buildings:

Isolate plumbing pipes. It's important to mechanically isolate the plumbing system pipes and drains from your walls or ceiling assemblies. If the pipes are not properly isolated from these components, you risk turning the entire wall into a speaker that transmits noises from unit to unit. Ideally, where plumbing is installed in double-stud assemblies, it should be installed only on the stud row of the unit that it serves.

Specify the right products. Using a heavy pipe for wastewater, such as cast iron, will help minimize noise. Ideally, the pipe would be enclosed in the wall assembly, located in a space where this noise would be more acceptable, such as a hallway. Situating it next to a bedroom would not be ideal. For rain draining off a roof, using bends in the pipeline will help slow the flow of the water down and minimize noise. When you have a pipe in a wall assembly, specify gypsum panels around the pipe. Gypsum board panels can help reduce background noise. Where PVC is used, fibrous pipe lagging with a jacket can reduce breakout flow noise. The heavier the jacket, the greater the performance will generally be. Using mass-loaded vinyl would be best, and a PVC jacket would provide better performance than just an all-service jacket.

Ensure that insulation is correctly installed. Design teams must work together with installers to make sure that insulation around the piping systems is installed correctly. When insulation is not installed properly, acoustic performance can be much lower than what was expected.

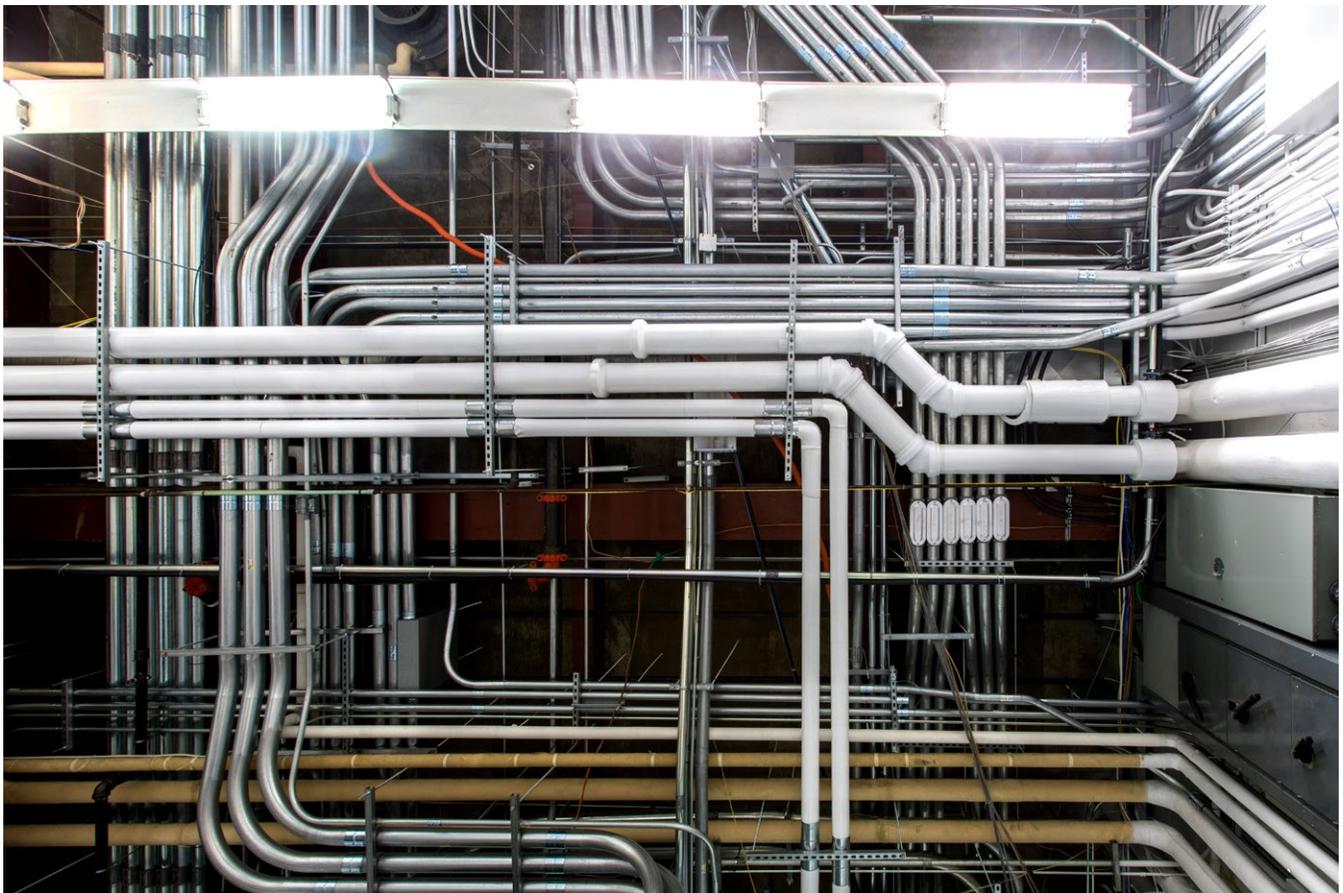
Insulate walls properly. Insulation isn't just about thermal performance, it's also about acoustical control. As more designs incorporate single-stud assemblies, walls are becoming thinner, which results in more noise traveling among units. So it's a good idea to fill the cavity in a wall assembly with a fibrous insulation product. An empty wall cavity can turn into a drum chamber, transmitting and amplifying noise. Plus, most wall assemblies without fibrous insulation will not meet International Building Code (IBC) minimum performance requirements and may result in noise complaints.

Do it right the first time. The cost of retrofitting an existing piping system to reduce unwanted noise would be extremely high and involve either replacing existing pipes with cast iron or installing mass-loaded vinyl jacketing over the existing pipes. Installing jacketing will be less invasive than a complete pipe replacement. However, both of these approaches would involve opening walls and having to redo finishes. Further, it is extremely unlikely that any retrofit would be able to incorporate all of the elements that can be included when taking a proactive approach to the project.

CONCLUSION

When designing piping and utility systems for multi-tenant buildings, it's essential that engineers take acoustics into consideration. Proper acoustic design can help with sound control and increase the comfort of residents and tenants, which improves their ability to enjoy the space.

To learn more about JM solutions that can help you address acoustics issues, visit:
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03/10/22

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