Using Acoustic Plenum Barriers above Interior Partitions to Comply with Sound Isolation Requirements in Standards

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Sound isolation between rooms can be important for speech privacy. For example, in patient exam rooms in a medical building, conversations between patients and their doctors are meant to be private; or in an enclosed office between an HR director and an employee. Even when speech privacy is not a concern, sound transmitting from one room into another can be annoying or distracting and can inhibit productivity, concentration or relaxation.

The Center for the Built Environment (CBE) at the University of California Berkeley maintains one of the largest post-occupancy building satisfaction survey databases with 53,000 surveys from the occupants of over 350 buildings spanning more than 10 years. It reports that the highest level of dissatisfaction is observed for sound privacy.[1] Clearly, it is hard to conclude that designers should continue the same sound isolation design approaches in future buildings.

Learning Objectives

1. Learn how requirements for sound isolation between rooms have become more stringent in the acoustic standards
2. Understand the advantages and disadvantages of the three main sound isolation design approaches for commercial interiors
3. Recognize which materials are best for acoustic plenum barriers
4. Gain familiarity in specifying, detailing and installing acoustic plenum barriers

Sound Isolation Requirements in Standards

Achieving sound isolation between rooms relates to the construction of the overall envelopes of the rooms including the walls, floors, windows, doors, and sometimes, the ceilings. The overall level of sound isolation often depends on the weakest link in the construction.

Acoustics requirements in building standards, guidelines and building rating systems list Sound Transmission Class (STC) most frequently as the sound isolation performance metric. Noise Isolation Class (NIC) is starting to appear in more standards instead of STC because it is a measurement made in the finished building and accounts for all possible paths sound can travel. STC is a laboratory measurement of a particular material or assembly and does not account for how all the materials or assemblies perform together as a room enclosure in a real building.

STC requirements generally range from 40 to 50 points, with STC 45 being the most commonly occurring requirement for interior construction when sound isolation is required.(2) Higher STC ratings mean that more sound is blocked by the assembly. STC-rated partitions are required to be full height from structural floor slab to structural floor slab or roof, with any penetrations sealed airtight.

- **Healthcare facility design** Guidelines by the Facility Guidelines Institute (FGI) and the Canadian Standards Association (CSA) Z-8000 *Canadian Healthcare Facilities* standard require STC 45 partitions between patient rooms. The CSA Z-8000 also requires STC 45 partitions between exam and treatment rooms while FGI requires STC 50 partitions.
- **Education facility design** ANSI/ASA S12.60 *Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools: Part 1 Permanent Schools* requires STC 45 partitions between classrooms and corridors and STC 50 partitions between adjacent classrooms. The Collaborative for High Performance Schools (CHPS) requires STC 43 partitions between classrooms.
- **Commercial workplaces** U.S. Green Building Council’s LEED® v4 and the Government of Canada’s *Workplace 2.0 – Fitup Standards* require STC 45 partitions between standard private offices. Workplace 2.0 also requires STC 45 partitions between meeting rooms, while LEED v4 upgrades the partitions to STC 50 for executive offices and conference rooms. The WELL Building Standard™ uses NIC instead of STC as a sound isolation metric. That standard requires NIC 40 between offices. At a minimum, an STC 40 partition would be required if constructed exactly as it had been during the laboratory test. The partition may need to be STC 42-45 to achieve NIC 40 in the actual building. Acoustic standards for workplaces have become more stringent. Five years ago, LEED did not have acoustic criteria for offices and the WELL Building Standard did not yet exist.

Several overarching commonalities can be observed. Whether it is STC or NIC, more building types now have to comply with sound isolation requirements in a standard, guideline or building rating system. Those sound isolation requirements have become more stringent over the past five years. General rooms that are normally occupied by people require STC 45 levels of sound isolation. More critical rooms require STC 50 levels of isolation or higher. An STC 40 level is minimal, and not many standards permit this low of sound isolation. Speech privacy and sound isolation should not be expected when the sound blocking performance is less than STC 40.

Design Approach Options

Acoustics standards require STC-rated partitions between most normally occupied rooms, especially when speech privacy or confidentiality is important. Even when they are not, STC-rated partitions are still typically required when occupants of the room will be listening, concentrating, sleeping, working or relaxing. STC-rated partitions, by definition, must be constructed full height from structural floor slab to structural floor slab or roof. The perimeters and any penetrations through them must be sealed airtight with acoustical caulk. Care must be taken to avoid penetrations that align on both sides of the partition, creating a noise flanking path or “leak” through the partition.

While STC-rated partitions are the surest design approach to comply with standards and to result in occupant satisfaction, some designers and building owners decide to terminate the interior partitions at the height of a suspended, modular, acoustic ceiling. In some cases, standards fall short of being sufficiently descriptive. They state the required STC rating, but fail to explain that the STC-rated construction must extend full height. Designers mistakenly think that using the appropriate STC-rated partition up to the suspended ceiling, leaving an open plenum above, complies with the standard. Acoustic professionals are diligently revising standards to clarify this issue, but since some of these standards have multi-year revision cycles, it will require more time.

Other designers and building owners opt to stop the interior partitions at the height of the ceiling for different reasons. Some projects require suspended ceiling systems that run continuously over the tops of interior partitions. This configuration is far less disruptive and costly when, in the future, the partitions need to be reconfigured due to changing spatial needs. The ceiling suspension systems and all of the lighting and air distribution devices in it can remain intact, independent of the moving partitions.

Figure 1: Architectural and operational trends in commercial interiors of combining demountable partition systems with continuous acoustic ceilings can lead to poor sound isolation because noise travels over the partition through the space above the ceiling.

Premanufactured, demountable partition systems, whether they are glass or opaque, have become popular in many different types of buildings. Some manufacturers are now providing STC-rated partition systems that reach the values required in the acoustic standards. However, these systems typically stop in height at the underside of the ceiling. If the ceiling is a suspended, acoustic panel ceiling with an open plenum above, the noise simply passes through the ceiling, over the high STC-rated partition and back down through the ceiling in the adjacent room.

Perhaps the most common reason some designers and building owners decide to terminate the height of the interior partitions at the ceiling is to save initial construction cost. Not only are they saving the cost of the partitions that no one will see above the ceilings, but also the cost of a return-air duct system. If there is a common plenum above the ceiling, then return air can be pulled from rooms through open return air grilles in the ceilings and back to the mechanical equipment room without the cost of rigid, return-air ductwork.

Regardless of the reason, when designers and building owners decide to stop interior partitions at the height of the ceiling, they are relying on the ceiling alone to block sound between rooms. If the ceiling is a suspended, modular, acoustic ceiling, then compliance with the standards is not possible and meeting occupant expectations is highly unlikely. Acoustic ceiling panels are made of lightweight, porous, fibrous materials. Their surfaces are specifically engineered to allow sound to pass through into the core of the panel to get absorbed. They typically weigh 1 pound per square foot (psf) or less. These attributes make them great sound absorbers. That is what acoustic ceilings are engineered to do.

Limitations of Acoustic Panel Ceilings

To block sound and provide inter-room sound isolation, nonporous, massive surfaces are required. Compare an acoustic ceiling panel to a sheet of gypsum wall board. It is made of dense gypsum. A 5/8-inch-thick sheet of gypsum board, common in commercial interiors, weighs approximately 2.3 psf. Partitions are constructed of at least two and up to four layers. Additionally, the gypsum board is primed and painted to seal the pores of the surface. Sound cannot easily pass through the surface into the core. If the interior partition must stop at ceiling height, then the ceiling should also be made of gypsum board of the same weight. If the partition is STC 50 with two layers of gypsum board on each side of the studs, then the ceilings in both rooms should also be double-layer gypsum board. This matches the sound-blocking capacity of the partition with the sound-blocking capacity of the ceiling.

The sound blocking capacity of an acoustic ceiling panel is quantified by Ceiling Attenuation Class (CAC). Similar to STC, the higher the CAC value, the higher the sound-blocking performance. CAC accounts for a double-pass through the ceiling – up through the first ceiling, a short distance through the plenum and then down again through the ceiling in the adjacent room. Values of most ceiling panels fall in the range of 20-35, but there are a limited number of panels that can achieve CAC 40 or slightly more. As CAC increases, Noise Reduction Coefficient (NRC), the sound-absorbing performance of the ceiling panel, typically decreases. There are some specialty panels that have both high sound-absorbing and moderate sound-blocking performance, but these panels are typically composite panels that are more expensive.

The CAC rating of acoustic ceiling panels does not account for the fact that the ceiling system is penetrated by numerous elements such as recessed light fixtures, open return-air grilles, supply-air diffusers, loudspeakers, etc. that allow sound to leak through. During CAC laboratory tests, ceiling panel manufacturers fill the suspension system with *only* their ceiling panels. Recent research has demonstrated that once the ceiling system is tested again with lights and air devices, the CAC rating of the ceiling decreases about 10 points.[(3)] For example, a ceiling system that contains panels rated at CAC 37 actually tests at CAC 27 once lights and air devices are installed. Designers must differentiate CAC_{panel} versus CAC_{system} and not mistakenly think that the panel rating applies to the whole ceiling system with penetrations for building services. A suspended acoustic panel ceiling system can provide about 20-30 decibels (dB) of sound blocking capacity considering a double pass. That is insufficient on its own to comply with the STC 40, 45 and 50 levels of sound isolation required in acoustic standards, guidelines and building rating systems.

Acoustic Plenum Barriers

Historically, designers and building owners in the U.S. have limited themselves to just two design approaches when it comes to sound isolation in commercial interiors – full-height partitions, which perform acoustically, but cost more; and relying on an acoustic panel ceiling to block sound, which saves money initially during construction, but does not work acoustically for occupants over the lifetime of the building. Designers and building owners in other countries have a third option in their design toolboxes that they use quite frequently – acoustic plenum barriers.

Figure 2: A private office inside a commercial interior fitout. View from below the acoustical ceiling with some ceiling panels removed to show the plenum barriers above partitions that terminate at ceiling height. The plenum barriers block noise that would otherwise transmit through the ceiling and over the top of partition.

Lightweight materials – such as stone wool insulation with a foil facing, mass-loaded vinyl (MLV) and gypsum board – are placed vertically over partitions that stop at the ceiling height. The plenum barrier extends from the top of the partition to the underside of the floor or roof above, blocking the plenum acoustically. The suspended acoustic ceiling and lightweight plenum barrier work together effectively as a system to provide the same amount of sound isolation as the STC-rated wall construction below the ceiling level.

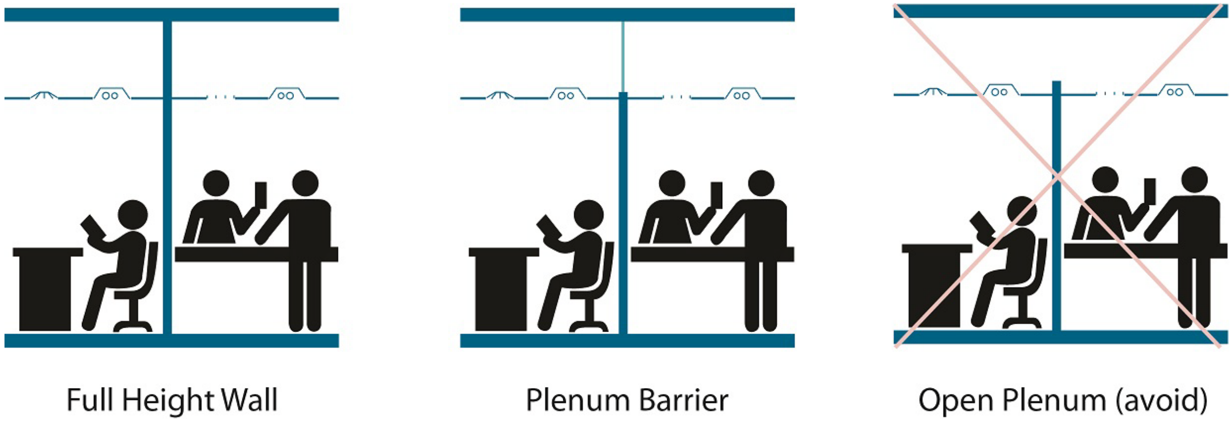


Figure 3: Three design approaches for sound isolation in commercial interiors: full-height walls that comply with standards and user expectations, but cost more during construction (left); lightweight plenum barriers above partial height partitions, which meet sound isolation requirements at lower cost (center); and partitions that stop at ceiling height leaving an open plenum, which does not work acoustically (right).

Canada's Workplace 2.0 Fitup Standards for federal office buildings requires the use of acoustic plenum barriers above all interior partitions to achieve enhanced speech privacy between private offices, meeting rooms, training rooms, telecommunications rooms and quiet rooms (refer to table A3-3 on page A-28). It is not until secure speech privacy (approximating STC 52) that full-height walls are required between rooms such as Assistant Deputy Minster offices. Conversely, the same standard only permits partitions that stop at the ceiling with open plenums above (approximating STC 35) for rooms not normally occupied by people such as storage rooms, equipment areas, kitchenettes and similar support spaces.

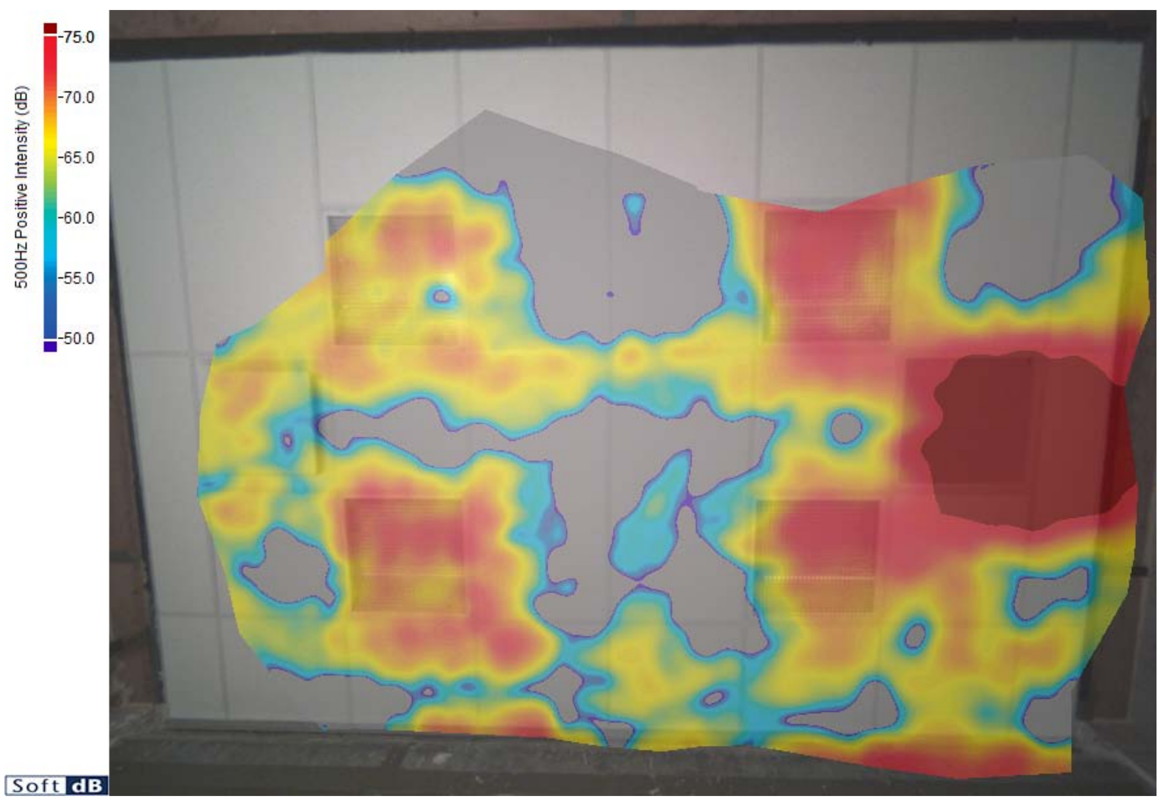
The Government of Alberta's Department of Infrastructure (previously known as the Department of Public Works, Supply and Services) has conducted extensive research on the sound isolation between offices with suspended ceilings.(4) It states that attempting to match the isolation performance of a ceiling to that of an interior partition can lead to disappointing results. It is important to know the combined effect of the wall, ceiling system, and any flanking that might be introduced through the ceiling. The final conclusion is that the most effective method of reducing sound transmission through the ceiling is to introduce a barrier into the plenum.

The value of acoustic plenum barriers is only recently becoming recognized in the U.S., and their use is starting to appear in U.S. standards, guidelines and building rating systems. The National Institutes of Health (NIH) *Design Requirements Manual* (revision 0.2: 09/05/2017) states that “acoustic plenum barriers shall be constructed above partitions if they terminate at the height of acoustic tile ceilings.”

Seeing the Difference

Architects and interior designers are often visual people by nature. When acousticians and standards use acronyms such as STC, CAC, NIC and quantitative values such as 40, 45 and 50 points, some designers, specifiers and building owners find it hard to see the difference between the various design approaches. Figure 4 uses colors to visually show how noise transmits through suspended acoustic ceilings when a plenum barrier is not implemented and when one is. An acoustic camera, much like a thermal-imaging camera, is used to show loud noise in red and yellow colors, and faint to inaudible noise in light blue and purple colors. Only part of the ceiling system is scanned; the white areas along the tops and left sides of the images do not contain noise level data. The color noise contours in Figure 4 are for the 1,000 Hertz (Hz) octave band and are characteristic of what occurs at other frequencies.

(4a) Image of a ceiling system, representative of a typical office ceiling, installed in a laboratory test chamber; a plaque-style, ducted, supply-air diffuser (left), four recessed light fixtures (center) and an unducted, return-air grille (right). The partition along the bottom of the image is common with an identical room with the same ceiling system and white noise playing at 94 dB through loudspeakers.



(4b) ***Without Plenum Barrier*** **– This ceiling system is comprised of 5/8-inch thick, mineral-fiber, ceiling panels with a CAC 35 and NRC 0.60. It is suspended using a 15/16-inch- wide, metal, tee-bar, grid. The partition along the bottom of the image stops at the underside of the ceiling system, leaving the plenum above the ceiling open to the adjacent room (*i.e.*, no plenum barrier is used). Red and yellow colors along the bottom edge show noise leaking through the gap that can occur between the top of the partition and the underside of the ceiling system. Dark red color on the right side of the image shows very loud noise leaking through the return-air grille. Lighter red and yellow colors, elsewhere in the image, show noise leaking through the recessed light fixtures (center) and supply-air diffuser (left).**

(4c) ***With Plenum Barrier*** **- This ceiling system is comprised of 1-inch-thick, stone wool, ceiling panels with a CAC 22 and NRC 0.95. It is suspended using the same grid. A double-layer, stone wool, plenum barrier is installed above the partition along the bottom of the image. Overall, noise levels have been decreased an additional 20-25 decibels (dB) compared to using the mineral fiber ceiling panels alone.**

The noise being played through loudspeakers in the adjacent room was 94 dB, which is much louder than would be present in an office. A man speaking loudly is typically 70-75 dBA. The level of the noise played through the loudspeaker is irrelevant in this example because the absolute value shown on the color scale adjacent to the images is not important. The relative decrease in noise level between the design approaches is the important aspect on which to focus. Without the plenum barrier, the CAC 35, mineral fiber, ceiling system decreases noise approximately 28 dB in the 1,000 Hz octave band. This is far from the 40, 45 and 50 levels of noise reduction required in acoustic standards, guidelines and building rating systems. If the noise in the next room were a man talking at 70 dB, the resulting noise level heard would be 42 dB (70-28 dB). Assuming a background sound level of 35 dB, the talking would be 7 dB louder, clearly audible and intelligible.

The CAC 22, stone wool, ceiling system combined with a double-layer plenum barrier decreases noise 51 dB in the 1,000 Hz octave band. This complies with the STC/NIC 40, 45 and 50 levels of noise reduction typically required in the standards. In this case, the man talking in the next room at 70 dB would be reduced to only 19 dB (70-51 dB). The same background sound at 35 dB would be 16 dB louder than the talking, masking it, and making it inaudible.

Materials

Plenum barriers can be constructed of a variety of different lightweight materials including MLV; stone wool insulation with a foil facing; standard gypsum wall board; or some combination of these materials. There are also other commercially available products that have various materials already laminated or sewn together.

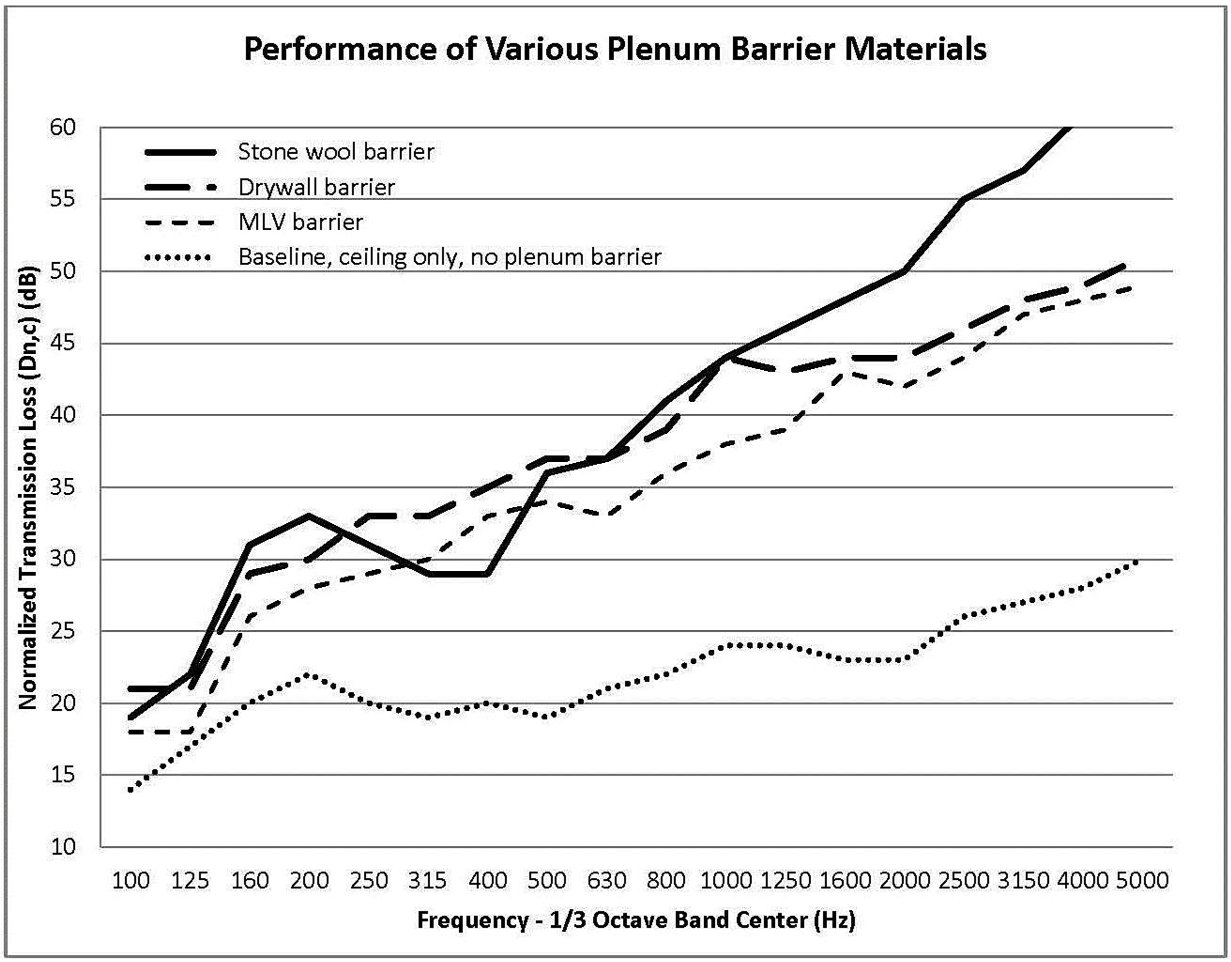


Figure 5: Laboratory tests show that a single layer of MLV (1/8 inch thick, 1 psf) has lower transmission loss performance than a single layer of GWB (5/8 inch thick, 2.3 psf) and a single layer of stone wool with a foil facing (1.5 inch thick, 1 psf). During these tests, all plenum barriers were penetrated by a supply-air duct, three metal conduits and three PVC pipes that were suspended in the plenum to better represent conditions in actual buildings.

Figure 5 shows that MLV plenum barriers generally do not perform as well as stone wool insulation and gypsum board plenum barriers. Fire-rated MLV for use in ceiling plenums is much more expensive than stone wool insulation and gypsum board. Some manufacturers laminate a foil facing onto standard MLV to decrease cost and improve fire performance, but this option is still more expensive than gypsum board and stone wool insulation. The installation of MLV plenum barriers is more time-consuming because it is limp and not self-supporting. Since it typically is available in rolls and has a memory, MLV curls while being installed, requiring more fastening. It is difficult to prevent openings around the perimeter and between adjacent pieces as the material curls.

Figure 6: A MLV plenum barrier is installed above an interior partition. The memory of the material causes it to curl, pulling the material away from the taped seams and resulting in openings in the barrier. Because the material is thin and smooth, caulking gaps around penetrating elements is not possible.

While gypsum board plenum barriers are just as cost-effective as stone wool plenum barriers and can work just as well acoustically in some frequencies, the rigidity of the material can be a disadvantage in some buildings where there is floor or roof deflection, seismic joints or expansion/contraction joints. Gypsum board is not as forgiving as MLV or stone wool insulation during installation. It is rigid, and one little undulation in the edge can hold the rest of the panel away from the abutting surface, resulting in a large gap.

Figure 7: Part of a gypsum board plenum barrier is installed around a supply air duct. The rigidity of the material combined with the imprecise score-and-snap method of cutting the material result in many small gaps and openings.

Figure 8: Plenum barrier board made of 1.5-inch-thick stone wool insulation is shown with a fiber-reinforced, foil, facing adhered to one side.

Stone wool insulation with a fiber-reinforced, foil facing on one side has been found to be the best material for acoustic plenum barriers. Combined with a stone wool, acoustic, ceiling system, the stone wool plenum barriers can achieve up to a STC 52 level of sound isolation. While the stone wool plenum barrier material is more costly than gypsum board, the easier and quicker installation makes it the better overall value. Stone wool is self-supporting and comes in flat, straight, semi-rigid boards that can span from the top of the partition to the underside of the floor or roof above. Adjacent pieces abut nicely, leaving no openings or gaps. Stone wool is dense enough to block sound transmission, but is still pliable enough to conform to imperfect surfaces. This pliability leads to higher transmission loss performance in the important speech privacy frequencies (1,000-4,000 Hz) because unlike MLV and GWB, the stone wool conforms and seals around penetrating elements (refer to high frequency performance in Figure 5). For these reasons, this education course focuses on stone wool plenum barriers. Other material options should be considered on a project-by-project basis.

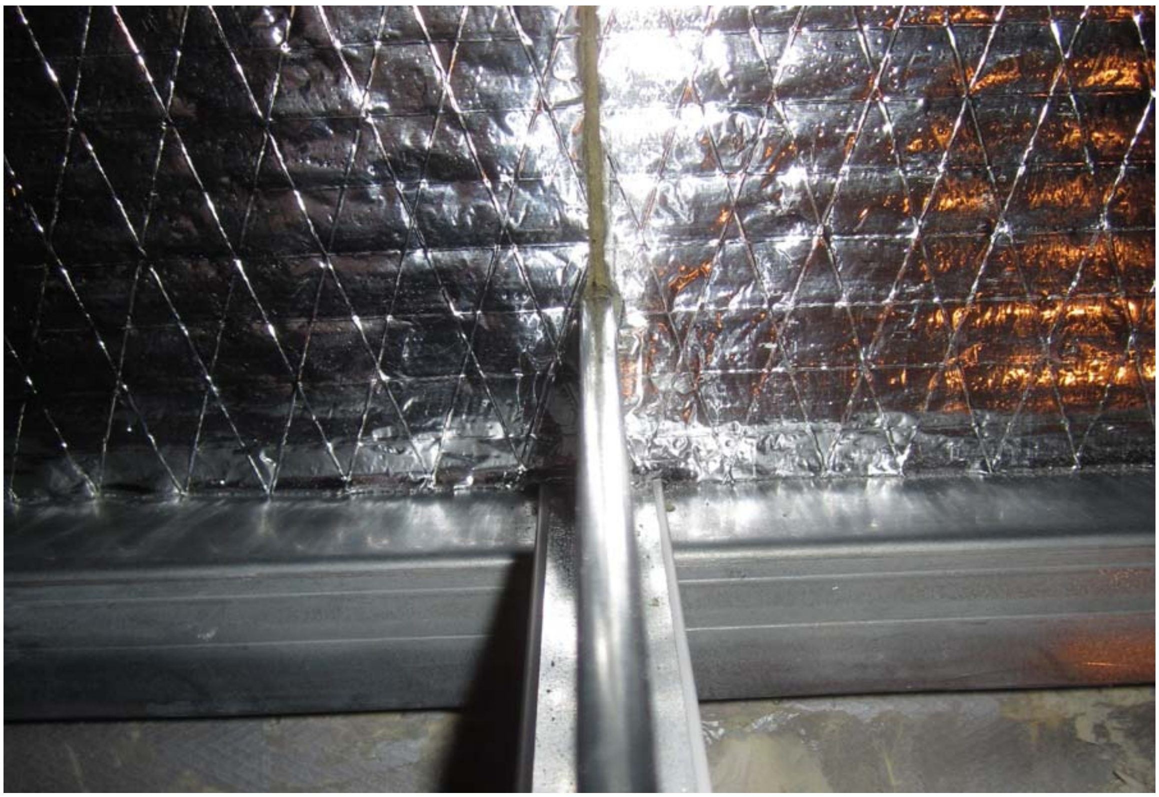


Figure 9: A close-up of a stone wool plenum barrier installed over an interior partition. The pliability of the material lets it conform around elements, such as the ceiling suspension system's main runner, and along uneven adjacent surfaces, such as the top track of the partition, without leaving gaps and openings. Typically, no caulking is required.

Designing with Plenum Barriers

The first step in designing with acoustic plenum barriers is to determine where they should be located throughout the project. This can be accomplished in a number of ways. If there is an acoustics consultant on the design team, he or she will work with you to determine which rooms should have full-height partitions and which should have plenum barriers above the partitions. If the design must comply with a specific standard, guideline or building rating system, begin by looking at the sound isolation requirements in the acoustics section. They usually will be listed in a STC (or NIC) table that provides the minimum STC ratings by room type. If the required rating is STC 35 to 50, those rooms are perfect candidates for acoustic plenum barriers above partitions that terminate at ceiling level. Because stone wool plenum barrier performance peaks at approximately STC 52, any requirements above STC 50 should be met by using a full-height wall. If the requirement is STC 35 or lower, it is probably not a normally occupied room and speech privacy and sound isolation are not expected or required. Plenum barriers are not required in these cases, because the partition is not providing adequate sound isolation.

If the required performance is STC 35-40, a single-layer, stone wool plenum barrier should be used in combination with a suspended, stone wool, acoustic ceiling system or a ceiling of equal performance (refer to Figure 10). The stone wool plenum barrier is 1.5-inches thick and has a fiber-reinforced foil facing adhered to one side. It extends from the top plate of the partition below up to the underside of the structural floor slab or roof above. The plenum barrier is held in place using a combination of mechanical fastening at the top, taping along the sides and a friction fit along the bottom. The ceiling panel does not run under the plenum barrier. Instead the ceiling panel is cut to abut tightly against the bottom edge of the plenum barrier, locking it in place.

A single-layer plenum barrier is often used over the partition with the door into the room or a substantial amount of standard glass. Because doors and windows are usually the weakest link in sound blocking, more robust plenum barriers are not typically required over these partitions unless the doors and windows are also rated at STC 35-40.

Figure 10: Lightweight, stone wool, plenum barriers installed above the central demising wall of the laboratory's chamber during testing. Top-left: Single-layer. Top-right: Double-layer with a 1-5/8 inches airspace in between. Bottom-left: Double-layer with seams staggered and small cuts at the bottom so the panels slide down over the grid bulb. Bottom-right: Installation complete with tops screwed, seams taped and ceiling panels installed.

If the required performance is STC 45-50, a double-layer stone wool plenum barrier should be used in combination with a suspended, stone wool, acoustic ceiling system. A double-layer plenum barrier is typically used over partitions between two enclosed rooms having no doors or glass. The first layer is installed exactly the same as the single-layer plenum barrier. Then, the same process is repeated on the other side of the top, metal channel, creating a 1-5/8 inch wide airspace between the layers. Over narrower partitions, the airspace can be decreased to as little as 1 inch. Over wider partitions, the airspace should be increased to improve acoustical performance further. As the second layer is installed, the boards are staggered so that the vertical seams between boards do not align with the first layer. This may require a small slit with an insulation knife in the bottom of the plenum barrier board so it can slip down over a ceiling grid if it runs continuously over the top of the partition.

The drawings for new construction should indicate that ducts, conduits and pipes associated with the building's mechanical, electrical, plumbing and fire suppression systems should not run over rooms with plenum barriers. There is usually plenty of room to run these utilities down corridors or over open areas. The only penetrations through the plenum barrier should be for the utilities serving that particular room: the supply duct, the return air opening or duct, and perhaps a pipe associated with the fire suppression system. These penetrations should be located over the door into the room. Unless the door is STC-rated with a heavy panel and full perimeter gaskets, it will be the weak link in the room envelop. Locating the plenum barrier penetrations over the door results in no further degradation in sound isolation than is already present from the door.

Installation

As the contractor prepares a piece of plenum barrier board for installation, he or she should measure and cut the boards slightly larger (approximately 1/8 inch) than the space it will be filling. As the boards are installed, the contractor compresses the material vertically and laterally. The friction along the top of the partition and underside of the deck above should hold the barrier in place. If the board tilts in easily and falls out unless held, it was cut too short and should be used elsewhere. It should take effort to press the board in place. Each board is mechanically fastened by using two, self-tapping, metal screws and insulation washers along the top edge into a standard 1-5/8-inch metal channel. As the contractor installs boards along the top of the partition, he or she abuts each panel with no overlap or open gap.

The installation should be inspected as the boards are being installed by using bright work lights behind the plenum barrier. The light shines through any openings, making the need for adjustments easy to recognize. If gaps large enough to let light through exist, the contractor has the option of either replacing or adjusting that particular board or, if the gaps are small and few, filling them with nonhardening, acoustic caulk. Caulking all joints and around penetrations is not required or recommended; only where light shines through.

The vertical seams between adjacent panels are then covered with metal, butt-joint tape. While laboratory testing shows that the tape does not necessarily improve acoustic performance, taping the seams ties all the boards together into a system that is more durable over the years as maintenance personnel access and work inside the plenum.

Summary

Acoustic ceilings are for sound absorption. Select and specify them based on the minimum NRC value or maximum reverberation time required in the standard, guideline or rating system applicable to the project. Typically having CAC values between 20 and 35, and decreased performance when penetrated by building utilities, acoustic ceilings are too lightweight and porous to provide the required STC/NIC 40, 45 and 50 levels of sound isolation. Combining acoustic ceilings with stone wool plenum barriers above partitions is a valuable third design option that achieves the required sound isolation between rooms, at lower cost than full-height walls or bulkheads, while allowing the ceiling suspension system to run continuously over partitions for easy relocation of partitions in the future.

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