

**Twenty Years of Educational  
Acoustics**

*By: Jay Perdue*



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About the Author: Jay Perdue has been involved in educational acoustics for over twenty years and he holds several patents in architectural acoustics (more patents than anyone else in actual production of products). Jay's passion for learning and understanding in the educational environment, as well as clarity of the spoken word, has led to a strong conviction in the value of acoustics. Jay believes in the science of acoustics, and with several years of working in the field, he has analyzed some tried and true ways to create effective educational facility acoustics (and he explains WHY these methods are so effective). With this book, Jay hopes to give teachers, leaders, professors, and other decision-makers the knowledge on acoustics and the confidence to make successful acoustical choices.

### **Acknowledgments-**

I would like to acknowledge Angie Allen and Jayna Anglen. Jayna has been with me for 20 years in business and a lot longer than that in family life, as she is my younger sister. She has taken care of Perdue Acoustics clients with great ability and care for all these years. Thank YOU so much Jayna. Angie came to us as assistant manager and has helped us so much. She took over as manager in tough times and has handled it all with great skill and style, rising to the occasion at every turn. Thanks Angie. If I could I would list every single employee of Perdue Acoustics and give them accolades here. I tell them all the time, Perdue Acoustics is built on my many patents in architectural acoustics under girded by their infinite creative ideas as to how to tell the story of these superior products, manufacture these superior products, install and ship these superior products and everything in between. Thanks to EVERYONE!!!

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# Twenty Years of Educational Acoustics

The Truth About Educational Acoustics and how they relate to the Educational Environment.

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# Chapter I: The Importance of Acoustics

I have been in the acoustics industry for over 20 years. During this time, I have experienced firsthand the frustrations of professors, teachers, coaches, and band and choir leaders. I have also had the opportunity to be responsible for sound systems in large stadium venues, in new facilities, renovated facilities, and converted facilities. I saw, felt, and heard sound problems from many different perspectives.

Though speakers, microphones, and soundboards make sure that people can hear the information being given, the acoustics help to ensure people will *understand* it. The proper acoustics in a project help fine tune a room, create intelligibility and understanding, and make it possible to comfortably enjoy the effort put in by any sound equipment.

It's important to understand acoustics; without the application a room can feel too loud, full of echo, impossible to hear, or too dead for the overall purpose of the room. It is extremely important to include acoustics in the sound consideration of an educational facility. In fact, if a sound design company does not mention or address acoustics, but rather only talks about amplifiers, speakers, boards, etc., don't walk away...  
**RUN!**

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Sound waves have specific “wave lengths.” A 10,000 Hz frequency (the range of high sounding cymbals or the sound of an “S” or “T” in diction) has a wavelength of about an inch, a 1,000 Hz frequency (about the pitch of a police siren) has a wavelength of about a foot, and a 100 Hz frequency (just above the range of a kick drum) has a wavelength of about 10 feet. When these sound waves bounce off a reflective wall they can be in perfect harmony, or they can reflect off the wall and completely cancel the frequency (or one of many problems in between, depending on how reflective the surface is).

The problem with these sound reflections is amplifiers and speakers that were designed just fractions of a decibel from being perfectly flat from 50 Hz to 20,000 Hz are put into the room and become plus or minus **100 times** that because of the lack of acoustic treatment in the room.

I recently visited the Nashville showroom of one of the best-known home theater sound companies in the country. I noticed something that I’m not sure most people would notice; all of their demonstration listening rooms were FIVE-SIDED ROOMS. Will they ever sell a system that will go into a five-sided room? Probably not. They just know something that most people don’t know; parallel walls create echoes, and parallel walls don’t exist in five-sided rooms. The “flat” speakers stay sounding flat. The problem starts when you get the speakers home into your four-sided room and the automatic button to adjust the system to fit the room doesn’t work. You just cannot fix a room that has bad acoustics with equalization.

But that's not even the worst part; if the acoustics are bad enough, you may be able to *hear* the sound system, but you won't be able to *understand* it. It's not about hearing, it's about UNDERSTANDING. If the rooms where people are being taught, learning music, or playing basketball are excessive in echo and reverberation, the students will be able to hear something being spoken, but they will not be able to understand what is being said. Unfortunately, most of the time people use the two words hearing and understanding interchangeably, and they are not at all the same thing.

I remember when we were asked to take a look at the Lubbock Civic Auditorium in Lubbock, TX. The auditorium was a nice, large facility, but all the walls were reflective. The audience was able to *hear* the plays and musicals, but they were not able to *understand* what was being said. The facility had to offer headsets to guests to rent in order for the performances to be understood.

Because the facility was used by so many musical production teams, most performances came with their own sound system. Each sound system ran into the same problems of understanding. This facility provided the best proof that the sound systems were not the problem; the room acoustics needed to be addressed!

The design and installation of the acoustic treatment was to control echoes and excessive reverberation. The very first performance after the acoustic installation was a musical. People came early to get the headsets they normally needed in order to understand the performance. The Lubbock City Manager called to tell us about the "miracle" that occurred that night; every single one of the headsets was turned in at intermission! Every one!

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In this facility, where they had fought to understand what was being said on stage for years, the performance had become clear, and it has stayed that way performance after performance, different sound system after different sound system. That's good acoustics!

## Chapter 2: NRC and STC

Sound Transmission Class (STC) refers to acoustic energy transferring **between** spaces (how much sound gets out of the room to adjoining rooms) and Noise Reduction Coefficient (NRC) refers to acoustics **within** rooms (how much and how long the sound bounces around within a space). STC and NRC refer to two completely different worlds of acoustics, and they require two completely different lines of products to treat each one.

Most soft and fuzzy interior acoustical products are targeted at "Noise Reduction Coefficient" (NRC) problems. When a room is echoing or excessively reverberant, it is considered loud, boomy, indistinct, or distorted. In fact, most professional acousticians consider a reverberation time of more than two seconds to be excessive, and it is at this point that diction of the voice and overall clarity are lost. Therefore, even when maximum reverberation is desired it should not exceed two seconds. A simple test can be given to indicate the reverberation time of a room; shout or clap very loudly and see how long it takes for the sound to go away.

There are specific formulas that tell how much of a certain absorptive material is needed to reduce the reverberation in a room to a specified reverberation time. Clarity, intelligibility, and the ability to understand what's being said are lost proportionally as reverberation time rises above two seconds. There is no such thing as a highly reverberant room that retains clarity. Adding acoustical treatment is the best way to eliminate echo and negate reverberation in a room, restoring clarity and understanding.

Sound Transmission Class problems are altogether different. STC simply refers to how much sound is transmitted from one room or area to the next.

This problem is found throughout schools and universities, from classroom to classroom, office to office, auditorium to classroom, even bathroom to hall. These sound transmission problems cannot be treated using acoustical wall panels within a room. In an STC situation, cinder block walls filled with sand or double studded sheet rock walls with insulation woven in between become more important in initial construction than anything that can be done after the fact.

Sound takes the path of least resistance, so even the best built wall can have sound transmission problems if the door is not sealed correctly or the room has a drop ceiling and the wall does not go all the way to the roof deck (in this case, sound from one room goes up through the thin ceiling tiles over the wall and down into adjoining rooms). However, there are some helpful hints if the facility is already well past the construction phase.

The cheapest and best fix is to blow insulation into the ceiling as thickly as possible, or add blanket-type insulation tightly packed, eliminating voids. Another way to fix STC issues is to carry the walls up to the building's roof deck. After construction, this can be hard to do in some cases, but it may still be possible. It is also very important to address air vents and ducts. Special duct silencers are available, and board insulation can be used to line the last 2' to 3' inside of the ducts before the air enters or exits the room. Weather stripping around doors and windows also helps to seal the room and further eliminate STC problems.

Another issue in STC can be the HVAC system. Once I was called into a school to help with an STC problem. It seemed the school counselor was having problems with people in the reception area hearing everything that was said in her office. After they took me weaving down this hall and that we finally arrived at her door. I quickly realized that her office, even though a long way from the waiting room door where our journey had begun, was right next to the waiting room!

After further inspection, I discovered the return air vent of both rooms were just two feet apart and connected. Have you ever talked into a pipe to a friend at the other end when you were a child? Yep, it still works! Silencers for sections of HVAC pipe are available and planning them further apart with a few turns in them would be nice too!

## Chapter 3: Echo and Reverberation

Many people think echo and reverberation are the same, but once you learn the difference, you'll be amazed at how it will catch your ear. You'll not only know the difference, you'll hear the difference.

Reverberation is sound returning to you without definition or clarity, and echo is sound returning to you with definition or clarity. Echoes can be problematic in smaller rooms, but the larger the room, the longer sound travels, and the more negatively it can impact the listening experience. To successfully eliminate echo from a room, the large, smooth flat areas that allow echo must be dealt with.

Since speakers from the platform are aimed at the back of the room, when there is an echo that returns to the stage, these echoes are often referred to as “slap back echos.” Echoes from ceiling to floor or between side walls are often called “flutter echoes,” simply because the sound seems to “flutter” really fast between these surfaces due to the shorter distances. These echoes, when distinct and drastic enough, can make it impossible to *understand* the sound system, no matter how good the sound system is.

Any echo robs a room of clarity, no matter how distant or slow or close and fast the echo is. Slow echoes can double double everything everything you you say say, while fast echoes can double a certain consonant such as s, t, or d (D-D-D-DID-D-D-D I SAY THAT-T-T-T?).

Reverberation, however, is sound that comes back without distinction. That simply means that you clap your hands and the sound excites the room and it comes back to you seemingly from everywhere, but it doesn't sound like a handclap. In fact, it doesn't sound like anything, you're just aware that a sound has happened in the room of some kind, very indistinct.

Where echoes are categorized solely by their separation in time created by distance, reverberation is specifically quantified in length of time (or how long reverberation goes on). The longer the room allows the sound to reverberate, the harder it is to understand what's being said.

A reverberation time (RT-60) is the time it takes for a sound burst to decay 60 dB in a room. Since 40 dB of ambient room noise is common, I like to say, "The time it takes for a sound burst to decay from 100 dB to 40 dB." In some cases, 90 dB down to 30 dB is adequate.

For existing facilities, tests can be performed to see exactly what frequencies are reverberating and at what times. For an immediate close "guess," a loud hard clap, starter pistol, or snare drum whack and a stopwatch will tell you most of what you need to know (or just go with the loud hard clap and count slowly).

For facility planning, with a study of the proposed interior finishes, any acoustician can closely predict the RT-60, and look at the overall shape to predict areas of echo production. Because of their very unique intelligibility-robbing qualities and characteristics, we all strive to create rooms of various reverb times but without any echo whatsoever.

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Here's a hint to people who run sound boards...Because digital delay is equal to echo and robs the speaker/singer of clarity, it important to use controlled reverberation, NOT digital delay, to add life into the room without robbing it of clarity. Very slight amounts may be desirable for vocal performances, but never a good idea for a speaking voice because the echoes will rob the clarity and intelligibility of the message.

## Chapter 4: Classrooms and the Various Other Acoustical Environments

Every acoustical environment imaginable can be found in education facilities today; from the smallest rooms to the largest, from live acoustics of the classroom and gymnasium to dead acoustics for cafeteria and music rehearsal areas. Every room needs to be treated individually, but the acoustics serve the same purpose in all environments; to create intelligibility and understanding.

It is proven that unless rooms have less than two seconds of reverberation and little or no apparent echo, our minds cannot connect the dots of the sounds we hear to understand what is being said. We all experience listening fatigue or can't understand what's being said at various levels of echo and reverberation, but two seconds of reverberation maximum is a good, safe number to remember.

We lose our hearing, usually, from the highest frequencies first. Those frequencies are the diction frequencies of the sounds we make. I feel so sorry for older folks sometimes because they are missing these very important enunciations for them to be able to understand what's being said. They may be hearing sound come at them but they are not hearing enough of the high diction frequencies to be able to understand. This makes adult education an even bigger acoustical challenge. The older we get, the worse it gets, and the more important it becomes to teach in good acoustical environments.

If you are going to be LOUD you have to have shorter reverb times to keep it understandable. Volume is a factor of selecting the right RT-60 for a room. The louder the volume, the shorter the reverb time needs to be. The softer the volume, the longer the reverb time can be, but never more than two seconds.

Putting thinner acoustical products in an acoustical environment that has low frequency volume present may help have an RT-60 of two seconds from 500 Hz and above, but the low frequencies will still be booming around the room for three, four, maybe even five seconds. Remember the older folks? The frequencies they hear the best are the ones that are bouncing around the room. This is totally unacceptable.

Whatever is put into the room must be controlled. If sound is being put into the room down to 500 Hz, the room must be controlled down to 500 Hz. If sound is being put into the room down to 250 Hz, the room must be controlled down to 250 Hz, and if sound is being put into the room down to 125 Hz, the room must be controlled down to 125 Hz.

The fundamental of the male voice is about 125 Hz and the fundamental of the female voice is about 250 Hz. An NRC number used to test and compare acoustical products only **starts at 250 Hz!** The NRC numbers published for all acoustical products start where the female voice starts and goes up from there (the absorption values don't even include the frequencies where the male voice is!).

Carpet absorbs sound effectively from about 1000 Hz and above. One-inch thick acoustical absorbers made of mineral wool and fiberglass board absorb sound effectively from about 500 Hz and above. Two inch and three inch acoustical absorbers made of mineral wool and fiberglass board absorb sound effectively from about 250 Hz and above. The only thing effective at absorbing sound in the 125 Hz range are super thick manufactured and built-in acoustical absorbers of mineral wool and fiberglass board, including my own patents of the MegaWedge™ and 180° Diffusers.

This goes to show that we cannot put some carpet or half inch thick ceiling tiles on the wall and call it an acoustical treatment. It may appear to sound better to the untrained ear, but the truth is we've still left the room booming with low frequency energy. That's what the older listener is having the most trouble with. It garbles the sound for all of us, but for them it garbles their whole audible world!

It's important to note that it does cost more to do an acoustical treatment correctly when low frequencies are involved. It costs money to fill a room with low frequency, and it costs money to control it, so expect that it will.

## Chapter 5: Gymnasiums

Considering the loud noises of both kids and coaches, couple that with the excessive echo and reverberation gymnasiums have been notorious for, and you can see why most gyms are poor communication environments.

In small towns all over America, school gymnasiums are often the largest facility in town. They are the gathering place in the community for large functions, band concerts, plays, graduations, banquets, you name it, they all happen in the high school gymnasium.

Although some coaches may not be happy about not having the space all to themselves, something marvelous has come from sharing this space. It quickly became obvious that parents couldn't understand their child's name as he walked across the "stage" to get his diploma, the speech at the parent /teacher banquet was bouncing around so badly no one understood a thing the speaker was saying, and these examples led people to begin to realize that if they didn't know what was being said, the coach is not being understood in practices either. In other words no real coaching was going on!

The good news is that this can be fixed. With the introduction of the right acoustical products in the right places, the room can be used for various functions and serve all of them well, and it's a much better environment for coaching as well. The players can now actually understand what the coach is yelling at them from the sidelines.

If we could just get people to consider the truth of this in every area of our facilities, our educational facilities would be transformed into real teaching and communicating environments. That is what this book is all about; better education through better communication through better acoustics.

I was called out to a small town in New Mexico to look at a multi-purpose gymnasium. As I was introduced to the committee, the tension in the atmosphere could have been cut with a knife. As it turns out, they had been sold *four* sound systems in *three* years.

As I began to explain that the problem was not a sound system problem at all, but the way sound bounced around the room and garbled the enunciation, I could see lights come on and attitudes and faces change.

My heart broke for these people that had spent so much money and endured so much false hope and were left year after year with their problem. You can only imagine what it was like when they followed through with the acoustical recommendations and had a multipurpose room they could enjoy for all functions.

So how do we fix a room like this one? The problem in these big boxy rooms is primarily the hard reflective walls. Sound, either from the sound system or generated from the crowd, echoes between these hard, flat, parallel surfaces and makes intelligibility impossible.

I've seen people that didn't know what they were doing put in ceiling tile and grid systems to create an "acoustical" ceiling. When they were finished, the room was worse off than it was before they started. Adding this "acoustical" ceiling ignored several acoustical principals.

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First, the walls were the primary offender, not the ceiling. The ceiling had great clutter (beams, air conditioning ducts, lights, fire sprinkler systems, etc.) to break up the echoes and sound waves and now all that great clutter is covered.

Second, the flat ceiling just gave the walls a flat surface to skip across between the hard flat walls.

Third, even though the ceiling is made out of acoustical tiles, the absorbers only absorb by the percentage according to the angle of intercept. Simply put, they absorb 100% of their ability when the sound comes directly at them. Their ability goes down as the angle decreases until their ability to absorb is zero. So the sound echoing between walls is absorbed almost zero as it bounces back and forth between the walls at zero angle to the flat ceiling.

That's why shape is so important in absorption material. Absorption panels on the walls, and especially shaped absorption panels, will absorb the echoes between the walls at the right angle of sound wave intercept to be most effective. Because of the volume of these big, high ceiling, boxy rooms, additional absorption will sometimes need to be added to the ceiling, but it's best to use vertically hanging Baffles to catch even more of the overall reverberation of the room without unintentionally adding a sound mixing plain (like a flat ceiling tile grid or horizontal lapendary panels).

## Chapter 6: Cafeterias

Cafeteria acoustics can be a little different from all other spaces, especially if the cafeteria is a “cafetorium” (a space used as both a cafeteria and an auditorium). In this case both this chapter and the chapter on auditoriums would need to be considered.

As strictly a cafeteria environment, the acoustic challenge is to get the students hearing and understanding each other. The problem can actually become a health issue, as the students cannot understand one another and end up talking louder. The room ends up in an absolute roar with everyone shouting to be heard. It’s called volume competition, and we have fixed rooms like this where the students were actually getting physically sick from the noise with headaches that turned into stomachaches. Everyone is trying to get loud enough to be heard, thinking that through increased volume comes increased understanding, but it doesn’t.

The effects of acoustical science on the human body are real and the cures for these effects are real as well. Once the right acoustical products are put in the right places, the conversations quit bouncing around the room and the students can clearly understand each other at low volumes. The volume competition stops and the cafeteria remains relatively quiet with the students visiting during their lunchtime as should be expected.

Cafeterias are fixed similarly to gymnasiums, but cafeteria ceilings are usually not as high, providing less wall space to work with. The upper portion of the walls need to be treated, but in cafeterias the wall treatment is more ‘equal to’ the ceiling treatment instead of just being the primary focus of the treatment.

Using hanging Baffles rather than a flat acoustic tile ceiling as ceiling treatment in a cafeteria allows the “clutter” of the beams to be utilized as “free” diffusion and absorption-due-to-diffusion. Baffles act as “walls of isolation,” keeping sound relatively contained to the area of the room where it was created.

Another thing to consider in cafeteria acoustics is the panel finish. Micro-perforated vinyl allows sound to be absorbed while the surface remains easily cleanable with normal antiseptic methods. This type of absorber panel can be used in kitchens as well as cafeterias, if there is a need for easily cleanable surfaces or often-cleaned surfaces for the absorber panels.

## Chapter 7: Auditoriums

In auditoriums, special attention is given to the ceiling so that the sound from the stage can naturally be reinforced to the back seats, or those furthest from the stage. The use of reflection in a very specific way creates a ceiling where sound is focused to the back, and over midway to the back, to help keep the volume to all seats in the auditorium as equal as possible.

In the past, these curved ceiling areas were primarily done by rounded plaster sections of the ceiling. More recently this was achieved with gypsum board and metal framing. Curved plastic units are now available to create an almost instant reflective ceiling. The advantages are being able to “fine tune” the curved sections by changing the angle of the units by lengthening or shortening the hanging cables.

Just opposite from the cafeteria, the auditorium needs the ceiling to move the sound from the front to the back. This is one area of good room acoustics where the dual purpose of auditorium and cafeteria (“cafetorium”) are at polar opposites. If Baffles are used in a “cafetorium” to isolate the ceiling so the room will be quieter as a cafeteria, it will be hard for people to hear the actors of a play in the back of the room without a very good sound system when the room is being used as an auditorium. These choices have to be discussed and considered in multi-purpose rooms.

For large auditoriums, the fact is, we’re putting ten times more low frequency into our sound systems than we did when a half inch thick ceiling tile was considered an acoustical product. That is not an exaggeration! It might be an understatement when you consider both volume and the frequencies together that we’re dealing with here. We’re going louder and lower!

Low frequency is impressive, it is loud, it is thunderous, it is awesome, it is heart pounding, it does move us emotionally, and we do like it. But let's consider these heart pounding low frequencies for a few moments in relationship to what makes them exciting, and what destroys their ability to excite us.

First, that pounding kick drum. That super low frequency thump that gets the place rocking. It has to have power, it has to have depth, it has to be a force to be reckoned with, but more important than anything, it has to STOP!

It has to stop abruptly, quickly, suddenly, even powerfully...so it can come again, and again, and again. The power is in the punch, and without the punch it has no power. It gets its punch from going away as fast as it came so it can punch again. The power is in the speed of the punch.

The sound of a kick drum that is allowed to hang around in the room has no power. The last boom hasn't even gone yet before the next one comes in. Remember the RT-60 definition? The length of time it takes sound to come down 60 decibels? You can measure the impact, or punch of the sound, by how much it has come down before the next one strikes.

If the kick drum registers 110 decibels and only falls to 90 in the room before the next beat hits, it has an impact of 20 decibels. If the kick drum registers 110 decibels and falls to 20 in the room before the next beat hits, it has an impact of 90 decibels. What a huge difference!

It is common for a song to be at 120 beats per minute. That's a kick drumbeat twice per second or every one-half of a second apart. That's the "tick" and the "tock" of a clock. Tap that out in your mind. How powerful can the beat be when four other kick drum beats are still hanging around in the room at various volumes?

A kick drum at 100 decibels in a good, tight room, has a lot more power and punch than a kick drum at 110 decibels in a room that is allowed to echo and reverberate that “pop!” into a low rumble and roar...that roar, remember, that drives the older folks craziest. And it doesn’t matter if the room is tight in the upper frequencies. If it’s not tight in the low frequencies, the rumble and roar will be there!

The use of thinner acoustical products that are incapable and ineffective at absorbing low frequency energy might create a room as tight as one second of reverb time at 250 Hz and above, but it won’t mean a thing if 250 Hz and below are allowed to reverberate for two seconds. To that kick drum, it’s a two-second room!

Auditoriums are supposed to be designed for many different types of performances, so low frequency absorption in these spaces is very important. Most school auditoriums have carpeting and/or curtains. Carpeting and curtains are “high frequency only” absorbers. It takes both thickness and mass to absorb low frequency energy. Carpet and drapes have mass but no thickness. Carved foam products may have thickness, but no mass. These types of products are poor low frequency absorbers, so it’s important to check the low frequency absorption numbers.

When acoustically treating auditoriums, the thicker the acoustical absorber, the better. The MegaWedge™ System and the 180° system are superior products for this application because of the low frequency and overall absorption of these products. Using products with efficient low frequency absorption can “balance” the room if there is a lot of high frequency absorption from carpeting, curtains, or padded chairs by adding a vinyl finish that reflects high energy back into the room while the mid and low frequencies will pass through and be absorbed by the core.

Balancing high frequency, mid frequency, and low frequency absorption is the trick, and the best trick we’ve learned is to use absorbers that are efficient at absorbing low frequency energy (that would be the really super thick ones), and cover them in vinyl or micro-perforated vinyl. The plastic under the cloth or vinyl reflects the high frequency energy back into the room while the mid and low frequencies will pass right through and will be absorbed by the core of the product. This brings an out-of-balance room into perfect acoustical balance.

Another thing we need to talk about at this point is a thing called “diaphragmatic absorption.” At some point, depending on the thickness and the type of absorption material used, “soft and fuzzies,” no matter how thick and what type they are, will become more and more ineffective at absorbing sound in the extreme low frequency range. At this point, movable hard surfaces become better absorbers than do any of the “soft and fuzzy” products that are usually related to sound absorption.

For instance, a sheetrock wall will “shake” to the beat of a kick drum and thus absorb the energy of it, while a cinder block wall or tilt up concrete wall will throw it right back into the room fully!

When you consider the square foot area of the entire wall area, this can be the most substantial sub-low frequency absorption in the room, ever (a huge consideration when building). Of course, a wall inside a wall is always possible and a good idea for absorbing the sub-low frequency energy, but don't forget to fill the cavity between the cinder block wall and the inside sheetrock wall with insulation.

Speaking of insulation, let's talk about the difference in fiberglass and mineral wool insulation for a minute here. Most of my patents in acoustics are based on mineral wool insulation rather than the much more common fiberglass board insulation products. They issue patents based on improved results, so what are the improved results of my patented mineral wool products?

Overall better sound absorption; about 15% better. But the bigger picture is exactly what we're talking about here: twice the low frequency absorption of fiberglass board absorbers because the rockwool, stone wool, mineral wool fibers--it's called by all three names --are thicker and longer than fiberglass fibers. The same thing that makes sound takes out sound. Low frequency waves are longer and so it takes thicker products to affect them, and if that absorber product is made of longer, thicker fibers, that's even better.

Another product that has been misrepresented in the acoustic world for years are these things called "sound diffusers." The law for sound diffusion, simply stated, is this: "It takes a bump roughly the size of a wave form in order to diffuse that wave form."

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We'll talk more about that in the next chapter, but for our discussion here, consider this. A 10,000 Hz frequency is about an inch long, a 1,000 Hz frequency is about a foot long, and a 100 Hz frequency is about 10 feet long. So what is a 4' x 4' bump on the wall that sticks out about a foot going to "diffuse?" Not much!

However, if properly designed, manufactured, and tested, that bump on the wall can make a great diaphragmatic low frequency absorber. I created one that is manufactured in both size and thickness to absorb 100 Hz at 96% efficiency - a great low frequency absorber.

It is true that low frequency implodes and explodes out of corners, so corners are a great place for bass traps, but it is equally true that bass is omni-directional and needs to be absorbed everywhere, on all surfaces, for a really tight room in the low frequency range.

Remember, tightness in reverberation in the low frequency range equals punch and power in the music. You cannot have a mushy and boomy low frequency room and have power in this area. This is where rumble and noise become power and punch in today's music.

## Chapter 8: Music Rehearsal Facilities

The previous chapter covered a lot of information on the importance and need for low frequency energy absorption for live performance, so if you're an instrumental music teacher, and you just skipped over to the Music Rehearsal Facilities chapter, at least go back one chapter and catch up on all the information that was covered on the subject. It is vitally important to the instrumental music rehearsal room, because all the same rules apply.

Low frequency absorption is where most music rehearsal facilities miss it. Though mid and mid-high frequencies are the most annoying, low frequencies are the most damaging to hearing (and little has been known about this until recently). Band directors more specifically are losing their hearing prematurely all over America from rehearsing in poorly absorbed rehearsal spaces, and the only difference between them and what it's doing to the students in these spaces is simply a component of exposure, or duration of exposure.

The same thicker absorbers needed in auditoriums are also needed in music rehearsal facilities because the same frequencies needed to be absorbed in auditoriums are the same ones needing to be absorbed in music rehearsal facilities. The difference between the two spaces is the way the ceiling should be treated. Where the ceiling needs to be reflective in the auditorium to direct sound to the back of the room, the music rehearsal facility can use the ceiling surface to introduce more absorption into the room and isolate the sound just enough to reduce volume.

The damage to hearing is a function of volume [or amplitude] and duration. Isolating the ceiling with Baffles will not be so severe as to make it hard to hear the various parts of the group, it will just help to stop the compounding effect of sound to reduce the overall volume in the room and thus reduce hearing loss among both the instructor and the students.

There are several acoustical companies that recommend adding 4' x 4' "bubbles" in the ceiling they call diffusers. A 4' pyramid or bubble can only diffuse sound waves about the size of 4 feet, making the diffuser ineffective for the room needs. Baffles much more effectively emulate the curtains and bars of lights experienced during a performance on stage.

Another special consideration in music rehearsal facilities is carpeting. While we have already considered the effects of carpet as a "high frequency only" absorber in previous chapters, and how it causes the room to become out of balance with more high frequency absorption than low frequency absorption, here the carpeting has an entirely different ill effect; carpet on the floor of a music rehearsal facility has the ability to make certain instruments change their sound, timbre, or 'tone'.

The clarinet best describes this issue. On the performance stage the clarinet is pointed at a hardwood floor. The resonance of the hardwood floor not only does not dampen the tone of the clarinet but also projects it out into the audience. If the rehearsal is conducted in a carpeted space, the conductor could be asking for more and more from the clarinet section, only to be blown away by the clarinets during a performance on stage.

The end result is a rehearsal area that has one experience of balance and sound and a performance that has a completely different balance and sound. From an acoustical point of view, the room needs to provide the same sound in rehearsal that is going to be given on the performance stage. It's important to find ways to make the music rehearsal facility more like the performance stage. What the music rehearsal area lacks in cubic volume it can make up for by increased absorption.

A quick word on choral rehearsal facilities...The absence of low frequency (except when rehearsing a show choir), means the room can be acoustically treated using much less than instrumental facilities with thinner absorption products, but don't fall for the old lie that you don't need to deaden the room. Make the vocal rehearsal area as dead as the concert hall. Students do not get as confused going from a dead space to a more live one as they do going from a live space to one that's more dead. All of a sudden every flaw is apparent, and in the performance is NOT where you want your flaws pointed out!

## Chapter 9: Acoustics vs. Aesthetics

For twenty years I've seen aesthetic choices take precedence over acoustical choices in educational facilities based solely on "what looks good." This war has been waged for so long it demands a close look.

First of all, whether it looks best for the walls to be smooth and flat or to have angular or rounded shapes on them is an opinion. After years of treatment of flat, smooth walls in educational facilities with our chunky, angular MegaWedge™ or half round 180° System I can tell you as many people like the change as those that do not.

What is never opinion is whether or not people using the facility can understand better. Now, people can understand the professor, or the coach, or the instruments in a band hall, or the words to the songs that are sung, or the lecture, or the meeting speaker.

One choice creates an environment where people can understand what's being said and clear communication is obvious. The other choice creates confusion and confused communication so that clear communication is either hampered to various degrees or altogether impossible!

Flat walls echo. Hard walls reverberate. Echo ruins intelligibility. Excessive reverberation creates an environment where clear communication cannot exist. When did the color and shape of the walls become more important than allowing a professor or coach to be understood? When did contour of the structure get to be more important than clearly understanding so students can learn? The day we started putting aesthetic choice over acoustical fact; that was the day.

The aesthetic opinion has gotten into our choices, and when the wrong choice is made, the end result is continual confusion. Will aesthetic choices change the understanding of what is being taught? No. Will acoustical choices change the understanding of what is being taught? Absolutely! Every time!

Pictures of the inside of schools and universities go out into the public in many ways, but only those inside the facility have to deal with the “unseen” acoustical problems.

When we make choices that make the physical building right on the inside, the teaching gets inside the students through clear communication and understanding. Without these right choices, the pictures of our new building might look good, but on the inside it’s so acoustically rotten it’s practically unusable for its intended purpose!

## Chapter 10: Acoustical Choices and Testing

There are five ways to judge acoustical absorbers when deciding the best value.

1. Absorption - Not just the NRC rating number, but absorption at all frequencies including the low frequency 125 Hz number. (type “A” mounting)
2. Aesthetics - Not just how well the company puts the product together and the color and texture choices they have, but the aesthetic choices they have. Do they just have flat looking absorber panels or can you choose angular ones, round ones, etc., to complement and change the look of your room.
3. Durability - Impact resistance is just the beginning. Some so-called absorbers will fall completely apart if they ever get wet, and others can be easily vandalized. Consider all the possibilities of durability and make sure your choices are right for your room.
4. Fire Protection - This has become a huge factor in recent years. Don't just check the surface burning and smoke characteristics of the product based on the cloth they're covered in, but also find out what the product does in a fire 'as a unit'. You never want acoustical products that contribute to the fire!
5. Value - When you consider all the other four factors and then put a price tag on it, which choice is going to give you the best overall *value*, not which product is the

cheapest or cheapest per square foot? Cheapest per square foot can end up costing three times as much in the long run if the product doesn't meet your needs.

### **Absorption:**

To make wise acoustical choices takes knowledge, and just a little math. Sadly, there are those in acoustics who make a living selling “smoke and mirrors” acoustical products, and to make wise choices you have to know what the numbers mean. Beyond what you can see, it's all about absorption per dollars spent and absorption at what frequency! Low frequency absorption is more expensive than upper frequency absorption, and well worth it!

All acoustical products have an NRC rating. An NRC rating is simply a value per square foot of material of absorption. **For a room needing 1,400 sq. ft. Sabins reduction here's the simple math:**

It would take 1,000 sq. ft. of NRC 1.40  
It would take 1,400 sq. ft. of NRC 1.00  
It would take 2,000 sq. ft. of NRC .70  
It would take 2,800 sq. ft. of NRC .50  
It would take 4,000 sq. ft. of NRC .35

These are not slight differences! 1,000 sq. ft. of a product with an NRC of .35 is NOT equal to 1,000 sq. ft. of a product with an NRC of 1.4; only **one fourth** the desired absorption is being provided! Now that you know how to compare these products, you can't be fooled.

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It is important to note that the NRC rating averages only four frequencies, 250 Hz, 500 Hz, 1,000 Hz, and 2,000 Hz. Back years ago when this system was developed, tweeters and subwoofers were not even in common use. We are creating 10 times the low frequency energy we used to. For this reason, Perdue Acoustics always posts its low 125 Hz test frequency absorption. It is important to always check the 125 Hz absorption numbers and consider them when purchasing any acoustical product.

Always make sure the acoustical tests that are being compared are fair comparisons. Here are some tricks to watch out for.

- All tests should be Type “A” tests for comparison. A Type “A” test is done flat on the floor, which equals flat to the wall. Ceiling tiles are often tested 400 centimeters off the test chamber floor, which gives the illusion of a huge low frequency cavity boost that simply does not relate when fastened directly to a wall.
- All tests should be the product only, not tested with something else behind it that you don’t know about or intend to use. This would be like a test of wood fiber strand board or ceiling tiles over a frame with six inches of fiberglass underneath. Without the total composite construction, the result will be nowhere near the expected result. Read the fine print!
- Check the low frequency absorption numbers. It takes both thickness and mass to absorb low frequency energy. Carpet and drapes have mass but no thickness and carved foam products may have thickness but no mass. The numbers tell the story.

There is a product on the market that is called an acoustical absorber, and it is cheap. We were called in to treat a gymnasium that already had this product fully covering all four walls and the ceiling (and they still had a problem with both echo and reverberation). We were able to place our regular absorbers around the walls at one tenth the coverage and the problem was gone! That's because of the value of the absorbers we installed. One-third the square foot price with only one-fourth the absorption is NOT a good value!

### **Durability:**

For the most part, an acoustical absorbers durability is measured in “compressive resistance” (how the panel reacts to an impact) and “tensile strength” (tear strength).

Many fiberglass manufactures face their cores with a compressed  $\frac{1}{8}$ ” layer of fiberglass to make them more durable; when one of these “high impact” absorbers is struck, the  $\frac{1}{8}$ ” board can crack a hole in the panel, taking the cloth with it. Our company utilizes a stranded fiberglass mat that is the same type mat that is used in the production of boat bottoms. The reinforcing mat flexes and regains 90% compression immediately, and the other 10% over time. You can break through, but it's much harder to do so. Our panels also have a very high tensile strength of 2,631 pounds per square foot!

### **Fire Protection:**

In the standard fire tunnel test, two things are measured: “flame spread” and “smoke developed.” Numbers are then given to the product according to these standard testing procedures. For flame spread, Class A requires 25 or less, while the smoke developed rating is 150 or less for some and 450 for others.

The fact is that fiberglass board is rated barely Class A in most tests at flame spread 25. Every manufacturer I have ever researched uses a Class A cloth to cover their product and claims a Class A product, when the fact is the cloth, fiberglass board, and glue that holds it all together burn like crazy **as a unit**. I do not know how long it will be before the use of such products could be deemed downright negligent! Our products have a flame spread 10 and smoke developed 95 **as a whole unit**. Check local fire codes and make the best choice based on fire protection.

### **Quality Diffusion:**

All that can be done with sound is absorb it, diffuse it, and reflect it. Most people understand absorption and reflecting; it is diffusion that is a little harder to grasp. Simply put, diffusion turns echo into reverberation. It scatters echo's distinction into reverberation. This has the effect of giving sound fullness and life without the nuisance of the distinct repetition of echo.

So we take a box...all parallel surfaces...an echo nightmare. We take diffusers and diffuse the walls so the parallel walls cannot echo. Now we have a room of no apparent echo, but it reverberates for 4 seconds. This is precisely why we combine units. We need to add in some absorption to bring down the overall reverberation.

Then we might need ceiling reflection to deflect the sound to the back of the auditorium, Just the right blend of absorption and diffusion will create a room without echo but with exactly the desired amount of reverberation, and then reflection does it's job to get more sound to the back for more even coverage.

But what does a good job of diffusion and what is a good value when diffusers are needed? Since waveforms come in all sizes, a good diffuser needs to represent as many sizes as possible. I patented diffusers in this arena of acoustics because I used smaller chambers within an overall larger “bump.” The idea was to let the little chambers of various sizes diffuse the higher and mid frequencies while the overall larger “bump” of the entire unit diffuses the lower frequencies.

These types of diffuser units seem to work best at diffusing the most frequencies for the money. Beyond that, it just gets back to value and aesthetics because most are durable.

## Chapter 11: New Findings in Acoustics

Many things in acoustics are moving forward at a rapid rate, but so much of what we do and use in acoustics is fifty years old (old products, old formulas, old test methods, old education, etc.).

Some recent findings negated the much touted Binary Amplitude Diffusion. This product was designed as an absorber that is supposed to have diffusive characteristics as well. The latest studies have shown that the diffusion that this type of product exhibits is extreme near-field, if any at all. When just a few feet away from the panel, the diffusion goes away completely and acts only as a high-frequency partial reflector. The product was found to be not much better than the less expensive vinyl covered absorbers.

Another recent development in acoustics goes a long way to add additional credibility and supports the findings of one of my own patents, the Wedge™ and MegaWedge™ Diffusers. The Wedge™ / MegaWedge™ system was created to maximize absorption on the face of the panel while changing the angle of parallel walls and the way they react to one another. Thorough testing of thick flat absorbers (products most commonly used in rooms) explains that thickness works with some frequencies better, while other frequencies just pass through the uniform thickness of the panel much more easily, creating a non-uniform absorption rate in the low frequencies.

The great thing about the Wedge™ / MegaWedge™ system is the varying thickness of the Difforsorbers, creating a much smoother absorption in the lower frequencies. Uniform thickness creates non-uniform absorption, and non-uniform thickness creates uniform absorption, which is something we all want.

Over the past few years I have had the privilege of talking with some of the greatest minds in acoustics – sometimes arguing with them, and occasionally being right! Thinking outside the box has its advantages. I see things in acoustics that may seem years away, but we are right in the middle of it – and I still have a few acoustical patents up my sleeve!

One of my new patents is a system that I originally called the Wedge Riser System. Marketing people got a hold of it, and it is now known as "The Black Hole Acoustics Mounting System" sold by Acoustics in a Box ([acousticsinabox.com](http://acousticsinabox.com)). This new product utilizes the same sloping absorber technology as the Wedge™ and MegaWedge™ Difforsorbers, but in a "pseudo thickness" method, resulting in less cost and much smaller shipping volumes. "The Black Hole Acoustics Mounting System" is not nearly as durable as the Wedge™ and MegaWedge™ Difforsorbers, due to the fact that it is a one inch thick absorber with an angled space behind it, but in home theatres and church environments where durability is less of a factor, they can bring superior absorption at a smaller price.

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Variable Room Acoustics is my most recent patent. This acoustical product is designed to transform from a diffuser with an NRC of .25 into an absorber with an NRC of 1.15. These unit, when used as the primary source of room control, can make an auditorium perfectly right for a string quartet or vocal madrigal performance, and then transform in less than a second for a speech, only to change again to be perfect for an amplified rock concert! VERY exciting news for the acoustics world!

With this new information, acoustical decisions and designs should be easier, helping you to create an environment where the spoken word is clear. If I can help you further or help you to better understand any of these amazing choices we have to make in acoustics, please do not hesitate to call our offices. I will respond to and help you personally whenever possible. THANK YOU for your time in reading this. It's an honor to me that you would do so!

*Jay Perdue*





