Noise Control Basics & Acoustical Product Directory 2018

a Practical Guide for:

- Room Acoustics
- Sound Isolation
- Environmental Noise
- Mechanical Noise

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NoiseEngineers.com

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Acoustical Consulting

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Disclaimer

This text is intended to give general information about noise control and acoustical products. It is not intended to be a substitute for acoustical consulting services from a member of the National Council of Acoustical Consultants (NCAC). The author makes his best effort to keep the information current and accurate; however, because of continual changes no guarantee can be made as to the accuracy of the information contained within.

Your Feedback is Greatly Appreciated

I am very interested in hearing your thoughts. Please let me know if this book has been helpful or if you have any suggestions to make it better. I welcome any comments or questions.

You can email me bill@noiseengineers.com or leave a message on Twitter (twitter.com/noiseengineers) or Facebook (facebook.com/noiseengineers).

Thank you for your interest in this topic and I hope you find this helpful.

TABLE OF CONTENTS

1.0 Introduction

"The sound of a kiss is not so loud as that of a cannon, but its echo lasts a great deal longer." - Oliver Wendell Holmes, Sr.

The purpose of this book is to help people address acoustical issues. I am providing basic acoustic information and a list of product suppliers for each application.

Acoustics is a critical part of many types of projects - architectural and environmental. Applications can include hearing conservation, speech intelligibility and privacy, sound quality, mechanical noise, and environmental noise regulations. Types of projects can include: schools, churches, condominiums, theaters, hospitals, libraries, manufacturing facilities, roads, rail, airports, shooting ranges, mines, power plants, industrial facilities, cell towers and many more.

With tools and resources, many projects you can handle by yourself. If you need assistance, feel free to contact Noise Engineers: bill@noiseengineers.com, 520-979-2213.

Bill Holliday, P.E., M.S. is an Acoustical Consultant who has been working in the field of acoustics since 1992. He has extensive experience working on both environmental and architectural acoustics projects. He is a registered Profession Engineer in Acoustics in Oregon and Environmental Engineering in Arizona. Bill received his master's in mechanical engineering with a focus and thesis in acoustics from Purdue University. He has worked for Digisonix (an active noise control company), Daly-Standlee Associates (acoustical consulting in Portland, OR), David L Adams Associates (acoustical consulting in Denver, CO), and Entranco (engineering firm). Entraco was later bought by DMJM Harris and later by AECOM. In 2004, he started Noise Engineers acoustical consulting.

Noise Engineers provides complete acoustical engineering services from noise measurements, analysis, and design to providing acoustical materials and installing them. They provide:

- Noise Measurements
- Analysis
- Reporting and Expert Testimony
- Noise Mitigation Design
- Provide Sound Absorption and Soundproofing Materials
- Install Acoustical Solutions

Bill works throughout the US and Mexico on a wide variety of acoustical projects. Noise Engineers has offices in:

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2.0 Acoustics Basics and Terms

Sound Pressure Level

Sound, or noise, is the term given to variations in air pressure that are capable of being detected by the human ear. Small fluctuations in atmospheric pressure (sound pressure) constitute the physical property measured with a sound pressure level meter. Because the human ear can detect variations in atmospheric pressure over such a large range of magnitudes, sound pressure is expressed on a logarithmic scale in units called decibels (dB). Noise is defined as "unwanted" sound.

Technically, sound pressure level (SPL) is defined as:

$$SPL = 20 \log (P/P_{ref}) \text{ dB}$$

where P is the sound pressure fluctuation (above or below atmospheric pressure) and P_{ref} is the reference pressure, 20 µPa, which is approximately the lowest sound pressure that can be detected by the human ear.

The sound pressure level that results from a combination of noise sources is not the arithmetic sum of the individual sound sources, but rather the logarithmic sum. For example, two sound levels of 50 dB produce a combined sound level of 53 dB, not 100 dB. Two sound levels of 40 and 50 dB produce a combined level of 50.4 dB.

Sensitivity to Changes in Sound Level

The following table shows an approximation of human sensitivity to changes in sound level. Noise is measured in decibels (dBA). Because people respond differently to sound at different frequencies, a weighted scale (dBA) is used to approximate the sensitivity of the human ear. Note that a 6 dBA change is required for the sound level change to be clearly noticeable.

Table 1
Human Sensitivity to Changes in Sound Level

Change in Sound Levels (dBA)	Change in Apparent Loudness
1	Imperceptible
3	Just barely perceptible
6	Clearly noticeable
10	About twice (or half) as loud
20	About four times (or quarter as loud)

A-Weighted Sound Level

Studies have shown conclusively that at equal sound pressure levels, people are generally more sensitive to certain higher frequency sounds (such as made by speech, horns, and whistles) than most lower frequency sounds (such as made by motors and engines) at the same level. To address this preferential response to frequency, the A-weighted scale was developed. The A-weighted scale adjusts the sound level in each frequency band in much the same manner that the human auditory system does. Thus the A-weighted sound level (read as "dBA") becomes a single number that defines the level of a sound and has some correlation with the sensitivity of the human ear to that sound. Different sounds with the same A-weighted sound level are perceived as being equally loud. The A-weighted noise level is commonly used today in environmental noise analysis and in noise regulations. Typical values of the A-weighted sound level of various noise sources are shown in Table 2.

Table 2
Common Sound Levels in dBA

Common Outdoor Sounds	Sound Pressure Level (dBA)	Common Indoor Sounds	Subjective Evaluation
Auto horn at 10’ Jackhammer at 50’	**100**	Printing plant	Deafening
Gas lawn mower at 4’ Pneumatic drill at 50’	**90**	Auditorium during applause Food blender at 3’	Very Loud
Concrete mixer at 50’ Jet flyover at 5000’	**80**	Telephone ringing at 8’ Vacuum cleaner at 5’	
Large dog barking at 50’ Large transformer at 50’	**70**	Electric shaver at 1’	Loud
Automobile at 55 mph at 150’ Urban residential	**60**	Normal conversation at 3’	
	50	Office noise	
Small town residence			Moderate
	40	Soft stereo music in residence Library	
	30	Average bedroom at night	Faint
Rustling leaves		Soft whisper at 3’	
Quiet rural nighttime	**20**	Broadcast and recording studio	
	10	Human breathing	Very Faint
	0	Threshold of hearing (audibility)	

Equivalent Sound Level

The Equivalent Sound Level (L_{eq}) is a type of average which represents the steady level that, integrated over a time period, would produce the same energy as the actual signal. The actual *instantaneous* noise levels typically fluctuate above and below the measured L_{eq} during the measurement period. The A-weighted L_{eq} is a common index for measuring environmental noise.

Statistical Sound Level
The statistical sound level is given as "L_{xx}," which corresponds to the level exceeded "xx" percent of the specified measurement time. For example, the L_{50} would be that level exceeded 50% of the time during a specified time period. Typically, in noise regulations and standards, the specified time period is one hour.

NC curves
The noise criterion (NC) curves are a series of octave-band sound spectra for rating the noisiness of indoor spaces; a measured octave-band spectrum is compared with this set of curves to determine the NC level in the space.

Day-Night Average Sound Level
The day-night average sound level (DNL) descriptor is a 24-hour descriptor computed by averaging (on an energy basis) the hourly equivalent sound level (L_{eq}) measured in each hour during a 24-hour period after 10 dB is added to the levels measured between 10 PM and 7 AM.

Noise Reduction Coefficient (NRC)
The NRC rating is an average of the absorption coefficient at 250, 500, 1000, and 2000 Hz. In general terms, the NRC represents the average percentage of sound that is absorbed by the material. An NRC of 0.85 generally states that the material absorbs, on average 85% of the sound for mid and high-frequency sound.

Hearing Impairment
A degree of hearing loss, temporary or permanent due to many causes. Hearing loss can be caused by illness, disease, or by exposure to excessively high noise levels. Affects 25-50 million people in USA of all ages. Hearing impairment as generally used means a hearing loss of a mild, moderate, or severe degree as apposed to "Deafness" which is generally described as little or no residual hearing with or without the aid of an assistive listening device. Hearing Impaired persons are particularly victimized by long reverberation times.

Hearing Range
16-20,000 Hz (Speech Intelligibility)
600-4,800 Hz (Speech Privacy)

Hertz (Hz)
Frequency of sound expressed by cycles per second.

Sound Propagation
Sound levels at different distances from a noise source can be calculated using the Inverse Square Law. As a sound wave propagates spherically, the sound energy is distributed over the increasing surface area of the wave front surface. The Inverse Square Law states that for every doubling of the distance from the sound source in a free field situation (no walls), the sound intensity will diminish by 6 dB.

There are limitations to this calculation because it does not include any contribution from reflected noise paths (walls, ground, ceiling).

That is for a point source. If you have a line source (like a road) than the noise level reduces by 3 dB every doubling of distance.

3.0 Acoustical Absorption

3.1 Background - Reverberation Time & Noise Reduction

When evaluating a space that has too much echo or the sound level is too high, reverberation time is generally used. Reverberation time is a measure of how long sound stays present within a space after it is made. More specifically, reverberation time is defined as the time required for the level of sound in a room to drop 60 dB after the signal is turned off.

The preferred reverberation time for a space is dependent upon its physical volume, as well as its intended use. For instance, for speech, we normally want a relatively short reverberation time within a space. If the reverberation time is too long and if the speaker does not speak slowly, a listener will actually hear sound from more than one word simultaneously. The result is a garbled sound that is not easily understood. On the other hand, if music is played within a space with a long reverberation time, the musical notes tend to blend together which is more pleasing than a dry dead sound. So the use of a space has a lot of bearing on what reverberation time is most desirable.

Mid-frequency sound (500 to 2,000 Hz) is generally the most critical because it is where the human ear is most sensitive and in the range where speech is produced. The reverberation time within a space can be controlled by the ratio of sound-absorptive surface area to sound-reflective surface area.

Reverberation time can be measured and can be predicted. It is a good tool for evaluating spaces before they are built. There are tables that show recommended reverberation times given the use and volume of the space. Here are a few examples:

- Conference Room, 30k ft^3, recommended mid-frequency reverberation time 0.6 seconds
- Classroom, 40k ft^3, recommended reverberation time 0.6 seconds
- Theater, 100k ft^3, recommended reverberation time 0.8 seconds
- Multipurpose Auditorium, 200k ft^3, recommended reverberation time 1.4 seconds
- Catholic Church (organ music), 300k ft^3, recommended reverberation time 1.7 seconds

The design of music spaces requires attention to specific qualities such as reverberation, diffusion, absorption, shape, reflections, and volume to achieve optimum performance acoustically. It is desirable to have a space with a moderate reverberation time, good positive reflections relatively close to the source and diffusion. Sound diffusion is the random scattering of sound waves from a surface and is a beneficial characteristic of a music room, as it will give the musician and director the sensation that sound is coming from all directions.

The change in reverberation time is used to calculate the reverberant noise reduction. Table 3 shows an approximation of human sensitivity to changes in reverberation time and the corresponding reverberant sound level. Note that a 75% reduction in reverberation time results in a 6 dBA change which is required for the sound level change to be clearly noticeable.

Table 3
Human Sensitivity to Reverberation Time
and the Corresponding Sound Level Reduction

% Reduction in Reverberation Time	Reduction in Sound Level (dBA)	Change in Apparent Loudness
20	1	Imperceptible
50	3	Just barely perceptible
75	6	Clearly noticeable reduction
90	10	About half as loud
99	20	About quarter as loud

If you are working with a space where the primary concern is understanding someone talk (speech intelligibility), the more acoustical absorption the better. The same is true if your goal is just to reduce noise build up, such as in a gymnasium or pool. The benefit of doing an analysis is so you know what to expect and so that you do not spend more than needed to treat the space. You will not go wrong by adding as much absorption as possible but there do become diminishing returns.

For example, say that 2k ft^2 of acoustical absorption reduces the reflected noise level by 3 dBA. It would take another 4k ft^2 of acoustical absorption to get 3 dBA more reduction and another 8k ft^2 to get an additional 3 dBA reduction.

When predicting the reverberation time in a space you need to know the area and NRC of each surface type. There are tables of NRC ratings for a large variety of materials. There is information for each 1/3 octave band. Here are a few examples:

- Gypsum Board, NRC 0.07
- Empty Wood Pew (per ft^2), NRC 0.30
- Carpeted Floor, NRC 0.35
- Occupied Upholstered Seat (per ft^2), NRC 0.88
- Acoustic Ceiling Tiles, NRC 0.50 to 0.90
- Fiberglass Wall Panels, NRC 0.90
- Ordinary Glass Window NRC 0.04
- Concrete Block NRC 0.07 (painted, dense), NRC 0.36 (light, porous)

3.2 Product Suppliers

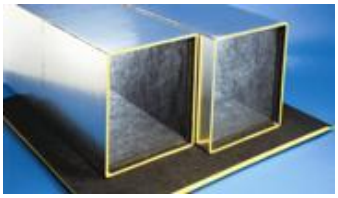
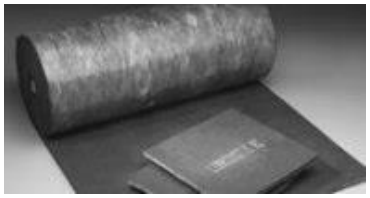
3.2.1 Fiberglass Wall Panels



Fiberglass acoustical panels are generally made with a 6 pound per cubic foot density fiberglass core wrapped with a fire retardant fabric or perforated vinyl. Panels are typically 1" or 2" thick and come in 2-foot increment sizes. Custom size and shaped panels would increase the cost. The products are very similar from each manufacturer. Generally, it is cheapest to buy panels from the closest supplier to minimize shipping costs.

Company	Website	Location	Products - Comments
Noise Expert	noiseexpert.com	Phoenix, AZ	Fiberglass, cotton, faced
Kinetics	kineticsnoise.com	Dublin, Ohio	
Gretch-Ken Industries	gretchken.com	Lakeview, OR	Sound isolation booths and noise control products
Ownes Corning - Conwed	conweddesignscape.com /products/wall-panels	Ladysmith, WI	Eurospan stretch system
Armstrong	armstrong.com	Lancaster PA	design and manufacture of floors and ceilings
Pinta Elements	pinta-elements.com	Minneapolis, MN	
Abell Acoustics	abellacoustics.com	Aurora, IL	Panel, curtains, barriers
ArtUSA	noisecontrolproducts.com	Norcross, GA	Noise control products
MBI Products	mbiproducts.com	Elyria, OH	
Gordon Inc	gordon-inc.com/acoustics	Bossier City, LA	
Ruido Industrial	ruidoindustrial.com	Mexico	Acoustic panels

3.2.2 Fiberglass Duct Liner

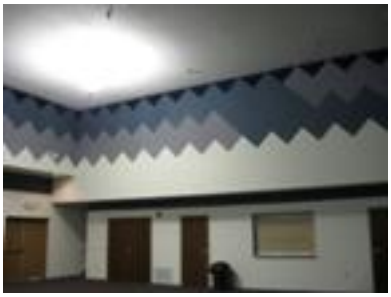




This can be applied to the ceiling and walls. It can be mounted behind perforated metal or PVC or open slat wood. If a mylar facing is used, the seams can be taped to allow them to be washed. This can be purchased through a local mechanical contractor - companies that sell mechanical ducts. Owens Corning sells duct liner (QuietR Duct Liner Board) and fiberglass board (SelectSound Acoustic Board). Johns Manville sells Linacoustic R-300 ductliner (about $\$2.55/ft^2$ plus another $\$0.20/ft^2$ for perforated hanger mounts, washers and adhesive). CertainTeed provides CertaPro acoustic fiberglass board. Rock Wool Manufacturing Company

sells an army green mineral board. The 8 pound density is often used and the price is about $1.25/ft^2 plus the cost for mounts.

Company	Website	Location	Products - Comments
Ownes Corning	owenscorning.com	Toledo, OH	Duct liner, fiberglass board
Johns Manville	jm.com	Denver, CO	Duct liner, fiberglass board
Rock Wool Manufacturing Company	deltaInsulation.com	Leeds, AL	Rock wool board
Noise Expert	noiseexpert.com	Phoenix, AZ	Faced fiberglass
Certainteed	certainteed.com	Valley Forge, PA	Fiberglass board
GLT Products	gltproducts.com	Solon, OH	Fiberglass, foam, tapes, wraps
Ruido Industrial	ruidoindustrial.com	Mexico	Duct liner – for industrial applications

3.2.3 Cotton Acoustic Panels


Cotton insulation can be purchased as batt insulation or in compressed 1" thick 6 pound/ft^3 panels. Cotton panels are generally more expensive then fiberglass but the panels can be mounted without any covering, making them less expensive.

Company	Website	Location	Products - Comments
Acoustical Surfaces	acousticalsurfaces.com	Chaska, MN	Cotton panels are fabricated in Chandler, AZ (Bonded Logic)

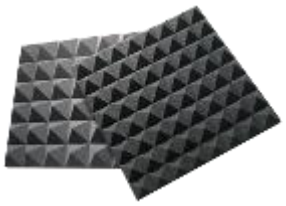
3.2.4 Acoustic Fabric Track Systems



Fabric track systems can be applied in any shape. Fiberglass is placed in the track and material is stretched between the tracks to cover the insulation. They generally install 1 inch thick fiberglass.

Company	Website	Location	Products - Comments
Whisper Walls	whisperwalls.com	Aurora, CO	fabric covered interior finishes
Snap-Tex	snaptex.com	Montgomeryville, PA	
Archi Textures	fabricpanels.com	Mukilteo, WA	
Ownes Corning – Conwed	conweddesignscape.com	Ladysmith, WI	Eurospan stretch system

3.2.5 Foam Acoustic Panels



Although these are seen in many studios and laboratories, they are not more effective then fiberglass or cotton at absorbing. The cones or waves are purely decorative. The effectiveness is limited to the thickness of the panel. As with cotton panels, there can be cost savings by not needing to wrap them.

Company	Website	Location	Products - Comments
ATS Acoustics	atsacoustics.com	Piper City, IL	
Gretch-Ken Industries	gretchken.com	Lakeview, OR	
Acoustical Surfaces	acousticalsurfaces.com	Chaska, MN	
Sound Seal	soundseal.com	Agawam, MA	Panels, curtains
ArtUSA	noisecontrolproducts.com	Norcross, GA	Noise Control Products
GLT Products	gltproducts.com	Solon, OH	Fiberglass, foam, tapes, wraps

3.2.6 Spray-on Acoustical Absorption


Spray-on treatment is one of the more cost effective ways to add absorption to a room. The spray-on treatment is available typically as a relatively soft cellulose fiber-material or as a cement-based plaster. Some treatments are sprayed on and some trawled on. Some are not very resistant to abuse resistant and others can be applied inside and outside.

Sprayed acoustic material is applied by many local insulation contracting companies. The sprayed material should be applied directly to the walls to provide the recommended surface area.

Company	Website	Location	Products - Comments
International Cellulose Corp	spray-on.com	Houston, TX	K13 - up to 3" thick
Pyrok	pyrok.com	Mamoroneck, NY	Acoustement plaster, inside and outside
Monoglass	monoglass.com	Vancouver, BC	
Ruido Industrial	ruidoindustrial.com	Mexico	Spray on acoustical treatment

3.2.7 Acoustic Ceiling Tiles



Acoustic ceiling tiles can used if they are hung or mounted with a minimum of 2 inches from the structure. Mounting the tiles directly to the structure will not provide sufficient absorption at low frequencies. The ceiling tiles should have an NRC no less than 0.90 when hung in a suspended ceiling.

Company	Website	Location	Products - Comments
Armstrong	armstrong.com	Lancaster PA	design and manufacture of floors and ceilings
USG Interiors	usg.com	Chicago, IL	
Pinta Elements	pinta-elements.com	Minneapolis, MN	

3.2.8 Acoustic Baffles or Lapendaries



Acoustic baffles typically come in 4' by 8' panels which are 1 or 2 inches thick. Acoustic baffles consist of fiberglass wrapped in sail cloth or other fabrics.

Company	Website	Location	Products - Comments
Noise Expert	noiseexpert.com	Phoenix, AZ	baffles
MBI Products	mbiproducts.com	Elyria, OH	baffles, lapendaries
Kinetics	kineticsnoise.com	Dublin, Ohio	
Pinta Elements	pinta-elements.com	Minneapolis, MN	
ArtUSA	noisecontrolproducts.com	Norcross, GA	
Gordon Inc	gordon-inc.com/acoustics	Bossier City, LA	
Ruido Industrial	ruidoindustrial.com	Mexico	baffles

3.2.9 Metal, Wood, PVC, Other Acoustical Absorption



Metal acoustic ceiling systems consist of a sheet of perforated metal (usually in a wavy pattern) with fiberglass resting on the metal. The fiberglass can be bagged in mylar.

Company	Website	Location	Products - Comments
Noise Expert	noiseexpert.com	Phoenix, AZ	Perforated metal, fiberglass or mineral wool absorption
Eckel	eckelacoustic.com	Cambridge, MA	Test chambers, facilities, panels
Sound Seal	Soundseal.com	Agawam, MA	Wood absorption
Gordon Inc	gordon-inc.com/acoustics	Bossier City, LA	Alpro Acoustical Systems
Armstrong	armstrong.com	Lancaster PA	design and manufacture of floors and ceilings
Ruido Industrial	ruidoindustrial.com	Mexico	Perforated metal, fiberglass or rock wool absorption

4.0 Sound Isolation

4.1 Background - Sound Transmission Class

Airborne noise isolation addresses noise sources such as televisions, stereos, human speech, etc. The Sound Transmission Class (STC) is a single-number rating of the sound transmission performance for a partition tested over a standard frequency range. The higher the STC, the more efficient the partition is for reducing sound transmission between spaces. The following is a list of STC descriptions which corresponds the single-number STC rating to a subjective evaluation of a typical listener. The STC descriptions are based on the audibility and intelligibility of speech between two spaces, and assume relatively low background noise. Keep in mind that the subjective descriptions below are based on typical human speech. Low frequency noise, such as from music, will be more easily audible than speech.

STC 30	Normal speech can be heard and easily understood
STC 35	Loud speech can be heard and easily understood
STC 40	Loud speech can be heard and moderately understood
STC 45	Loud speech is audible, but will sound “muffled.”
STC 50	Loud speech is difficult to detect. An occasional word may be understood.
STC 55	Loud speech is not audible.

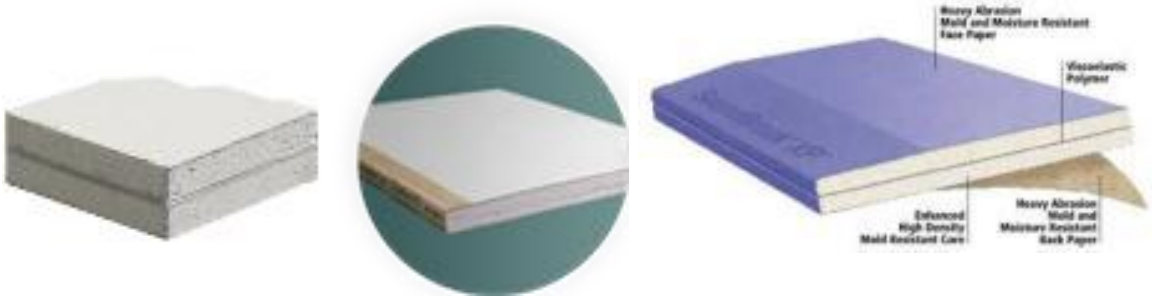
Here are a few guidelines for improving sound transmission:

- Extend the wall to the structure. In office spaces, as a minimum extend the all above the acoustic tile ceiling. The path through the ceiling tiles (CAC) may be the week path.
- Seal the wall at the perimeters and all penetrations with non-hardening caulk. Do not allow any gaps in the wall. All drywall seams should be taped and mudded (on each layer).
- Receptacle boxes should not be located back-to-back on opposite sides of a wall.
- Adding acoustical absorption in the air cavity +5 STC
- Double layers of dry wall on one side of a wall +3 STC
- Double layers of dry wall on both sides of a wall +5 STC
- Double air cavity of the wall +5 STC
- Change from single studs to staggered studs +10 STC
- Add resilient channels to one side of wood studs +5 STC
- Add resilient channels to both sides of wood studs +10 STC

As with the ceiling, doors and windows can become a week path. All of the improvements done to a wall may have very little effect on the overall sound transmission is there is a weak path.

4.2 Product Suppliers

4.2.1 Composite Gypsum Board



Sound damped panel delivering high STC performance that outperforms multiple layers of gypsum and is dramatically more reliable - replacing traditional noise reducing methods like resilient channel, mass loaded vinyl, and soundboard.

Company	Website	Location	Products - Comments
Quiet Rock	quietrock.com	Newark, CA	Noise control drywall, sealants, glues
National Gypsum	nationalgypsum.com	Charlotte, NC	Soundbreak XP

4.2.2 Loaded Vinyl

Mass loaded vinyl (MVL) is a heavy, dense and flexible material. One pound per square foot vinyl can provide an STC of about 25. It can have acoustical absorption attached in the form of quilted fiberglass or 2” thick fiberglass panels.

Company	Website	Location	Products - Comments
Noise Expert	noiseexpert.com	Phoenix, AZ	MLV & absorptive MLV
Kinetics	kineticsnoise.com	Dublin, Ohio	MLV & absorptive MLV
Gretch-Ken Industries	gretchken.com	Lakeview, OR	Sound isolation booths and noise control products
Abell Acoustics	abellacoustics.com	Aurora, IL	Panel, curtains, barriers
Sound Seal	Soundseal.com	Agawam, MA	Panels, curtains
Goff's Enterprises	goffscurtainwalls.com	Pewaukee, WI	
Ruido Industrial	ruidoindustrial.com	Mexico	MLV & absorptive MLV

4.2.3 Resilient Clips

Resilient clips are used to mount gypsum board walls or ceilings. They provide a disconnect from the studs and other wall. This greatly improves the STC (and IIC for ceilings). There are many different types that provide varying improvement. They can be applied to one or both sides of a wall.

Company	Website	Location	Products - Comments
Kinetics	kineticsnoise.com	Dublin, Ohio	
PAC International	pac-intl.com	Las Vegas, NV	Resilient (Rubber) Sound Isolation Clip (RSIC)
Mason Industries	mason-industries.com	Hauppauge, NY	
Phillips	phillipsmfg.com	Omaha, NE	

5.0 Sound Barriers

5.1 Background - Barriers

- A barrier needs to block the line-of-sight between the noise source and the receiver to have any impact. A barrier provides approximately 5 dBA noise reduction if it just blocks the path.
- The higher the barrier is, the more noise attenuation is achieved. For every foot that the barrier breaks the line-of-sight between the source and receiver, about 0.5 dBA additional noise reduction is achieved. The actual amount of attenuation depends on the spectrum of the noise source (low vs high frequency, high frequencies are more easily attenuated by barriers) and the distance from the barrier to the noise source and receiver.
- A barrier is more effective close to the noise source or noise receiver. A barrier is least effective half way between the two.
- They should be constructed airtight with no leaks along the bottom or between individual pieces of the barrier.
- In many cases, the barriers should have an acoustically absorptive treatment on the side facing the noise sources. This prevents noise from reflecting off of the barrier, back to the source, and over the wall.
- Barriers should be solid (at least 2 pounds per square foot) and airtight. However, the transmission loss of the barrier does not need reduce the noise by more than 10 dBA below the level attenuated by diffraction effects over and around the barrier. Vegetation alone is not an effective barrier, unless it is dense and more than 50 feet thick.
- To select a material for your barrier consider: cost, durability, wash ability, weight, wind load, and space available.
- An earthen berm alone or in conjunction with a wall can be used.

5.2 Product Suppliers

5.2.1 Metal

Install prefabricated metal panels consisting of a solid metal barrier on one side and perforated metal on the side of the noise source with fiberglass in the air space. An independent structure is required.

You can use a local metal fabricator to construct metal barriers.

Company	Website	Location	Products - Comments
Noise Expert	noiseexpert.com	Phoenix, AZ	Panels, custom enclosures
Empire	empireacoustical.com	Princeton, IL	
Abell Acoustics	abellacoustics.com	Aurora, IL	Panel, curtains, barriers
Phoenix-E	catalog.phoenix-e.com	Camarillo, CA	Acoustical panels
Ruido Industrial	ruidoindustrial.com	Mexico	Metal panels, barriers, enclosures

5.2.2 PVC

PVC barriers are similar to metal but lighter weight.

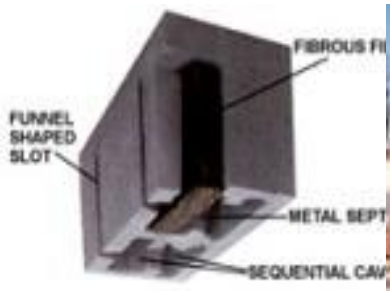
Company	Website	Location	Products - Comments
Ail Sound Walls	ailsoundwalls.com		
ArtUSA	noisecontrolproducts.com	Norcross, GA	Noise Control Products

5.2.3 Loaded Vinyl

Loaded vinyl can be used as an exterior or interior barrier. It is flexible and can be hung on a cable so that it can easily move.

Company	Website	Location	Products - Comments
Noise Expert	noiseexpert.com	Phoenix, AZ	Barriers + custom enclosures
Kinetics	kineticsnoise.com	Dublin, Ohio	
AmCraft	amcraftindustrialcurtainwall.com	Elk Grove Village, IL	Industrial curtain walls
Abell Acoustics	abellacoustics.com	Aurora, IL	Panel, curtains, barriers
ArtUSA	noisecontrolproducts.com	Norcross, GA	Noise Control Products
Sound Seal	soundseal.com	Agawam, MA	Panels, curtains
Firwin	firwin.com	Champlain, NY	Insulation solutions
Ruido Industrial	ruidoindustrial.com	Mexico	MLV & absorptive MLV

5.2.4 Block




Acoustic cement blocks have absorption inside and openings on the noise source side of the wall. Acoustical absorption can be applied to a block wall to prevent noise from reflecting back to the noise source and back over the wall.

Company	Website	Location	Products - Comments
Proudfoot	theproudfootcompany.com	Monroe, CT	Soudblox
Pyrok	pyrok.com	Mamaroneck, NY	
Kinetics	kineticsnoise.com	Dublin, Ohio	Panel Absorbers
Empire	empireacoustical.com	Princeton, IL	M-90 Absorptive Panel
Noise Expert	Noiseexpert.com	Phoenix, AZ	Fiberglass with perforated metal cover
Ruido Industrial	ruidoindustrial.com	Mexico	Fiberglass with perforated metal cover

6.0 Impact Insulation

6.1 Background - Impact Insulation Class

The methods to measure the degree of impact noise isolation provided by a floor/ceiling assembly. The impacts for these measurements are produced by the "Standard Tapping Machine", an electrically operated mechanism consisting of five 0.5 kg hammers which fall regularly and freely onto floor surface from 40 mm height at a rate of 10 impacts/second. The sound pressure levels generated in the room directly below the floor/ceiling assembly undergoing testing are then measured, for each of the 16 third-octave-bands between 100 Hz and 3150 Hz, and they are normalized and plotted on a standard graph.

6.2 Product Suppliers

6.2.1 Floating Floors



A resilient surface is generally installed under a hard floor. A floated floor will improve the IIC and usually to some extent the STC.

Company	Website	Location	Products - Comments
Kinetics	kineticsnoise.com	Dublin, Ohio	Variety of floating floor options
ArtUSA	noisecontrolproducts.com	Norcross, GA	Noise Control Products
Sound Seal	Soundseal.com	Agawam, MA	Floor underlayments
USG	USG.com	Chicago, IL	Floor underlayments
US Rubber	usrubber.com	Colton, CA	QuietSound underlayment

6.2.2 Rubber Floors



Rubber floors are often used in gymnasiums and cross-fit gyms.

Company	Website	Location	Products - Comments
Regupol	regupol.com	Lebanon, PA	Recycled rubber
US Rubber	usrubber.com	Colton, CA	
Rubber Flooring	rubberflooringinc.com	Chandler, AZ	
sofSURFACES	sofsurfaces.com	Petrolia, Ontario	Rubber floors inside & outside
Infinity Flooring	infinityperformance.com	Indianapolis, IN	

6.2.3 Ceiling Hangers


To improve the sound and vibration transmission properties of a floor-ceiling assembly, the floor and/or ceiling can be treated. Resiliently suspending a ceiling will improve the IIC and STC.

Company	Website	Location	Products - Comments
Kinetics	kineticsnoise.com	Dublin, Ohio	
PAC International	pac-intl.com	Las Vegas, NV	Resilient (Rubber) Sound Isolation Clip (RSIC) Products
Mason Industries	mason-industries.com	Hauppauge, NY	

7.0 Mechanical Noise

7.1 Background - HVAC

Typical mechanical system noise is comprised of a variety of noise components. In an effort to familiarize the reader with these noise components and establish some common terminology, the basic components of mechanical system noise are discussed below. The source of the noise in each of these cases could, for example, be the noise generated by a fan unit ventilating the spaces, as illustrated in Figure 2.1. The sound generated by the fan will travel along the ductwork both upstream and downstream of the fan. The velocity of sound is much greater than the velocity of air in ducts, therefore, fan noise can travel equally well upstream and downstream.

Ductborne noise propagates along the ductwork, follows all transitions and takeoffs, and ultimately exits at the diffuser or grille, thus, impacting the space being served.

Break-out noise also propagates along the ductwork, however, at some point transmits through the wall of the duct, thus impacting the adjacent space.

Break-in noise is essentially the reverse of break-out noise. Noise from an adjacent space transmits through the duct wall and becomes additional ductborne noise or possibly break-out noise, ultimately impacting an adjacent space.

Crosstalk occurs when noise from a space, e.g. talking, music, radiated noise, etc., enters the ductwork, propagates along the duct work, and ultimately impacts an adjacent space. A common example occurs in residential homes when on the third floor, you can hear the television on the first floor by listening at the supply diffuser or return grille. Crosstalk is typically composed of ductborne noise, break-in noise, and break-out noise.

Radiated noise is the free-field noise radiated in any direction from powered equipment such as fans, pumps, chillers, generators, compressors, etc.

Many rating systems have been developed to help establish acceptable noise exposure levels in occupied buildings. The rating systems most commonly used to describe mechanical system noise are the Noise Criteria (NC) and Room Criteria (RC) rating systems. The RC rating system has become the preferred rating system by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE), and is based on the level of the mechanical system background noise in octave band frequencies. The RC rating system employs two descriptors; a number descriptor which represents the speech interference level of the spectrum, and a letter descriptor which represents the subjective quality of the sound to a typical listener (N=Neutral, R=Rumbly, H=Hissy, T=Tonal, RV=Perceptible Noise-Induced Vibration). The RC rating system also considers the potential for low-frequency induced vibrations in the

building construction. The RC curves are widely used to evaluate existing mechanical systems and to establish design goals for new mechanical systems. The optimal RC rating design goal for mechanical system background noise depends on the intended uses of the occupied building space. Room Criteria design goals are typically stated in ranges, as shown in Table 4.

Table 4
Recommended RC ratings for acceptable mechanical system background noise within various spaces

Intended Use of Area	RC Rating	Equivalent dBA	Intended Use of Area	Equivalent dBA	RC Rating
Broadcast Studio	15-20(N)	26-30	Cafeteria	47-52	35-45(N)
Recording Studio	15-20(N)	26-30	Restaurant	42-47	35-40(N)
Concert or Recital Hall	15-20(N)	26-30	Open Plan Office Area	42-47	35-40(N)
Production Studio	20-25(N)	30-34	Courtroom	42-47	35-40(N)
Auditorium	20-25(N)	30-34	Library	42-47	35-40(N)
Theatre	20-25(N)	30-34	Hospital Corridor	42-47	35-40(N)
Bedroom	25-30(N)	34-38	Lobby	47-52	40-45(N)
Hotel/Motel Unit	25-30(N)	34-38	Open Plan Office Area	42-47	35-40(N)
Hospital Patient Room	25-30(N)	34-38	Reception Area	47-52	40-45(N)
Executive Office	25-30(N)	34-38	Gymnasium	47-52	40-45(N)
Large Conference Room	25-30(N)	34-38	Indoor Swimming Pool	47-52	40-45(N)
Sanctuary	25-30(N)	34-38	Computer Equipt Room	47-52	40-45(N)
Teleconferencing Room	25-30(N)	34-38	Large Dining Room	47-52	40-45(N)
Music Room	25-30(N)	34-38	Hospital Exam Room	47-52	40-45(N)
Meeting Room	25-30(N)	34-38	Corridor	47-56	40-50(N)
Private Office	30-35(N)	38-42	Restroom	47-56	40-50(N)
Classroom	30-35(N)	38-42	Kitchen	52-56	45-50(N)
Cinema	30-35(N)	38-42	Laundry Room	52-56	45-50(N)
Small Conference Room	30-35(N)	38-42	Industrial Shop	52-56	45-50(N)
Small Dining Room	35-40(N)	42-47	Reception Area	47-52	40-45(N)
Hospital Operating Room	35-40(N)	42-47			

7.2 Product Suppliers

7.2.1 Silencers



Duct silencers reduce the airborne noise in ductwork. There is some noise generated by the air in the silencers. The noise is higher if the silencer is located near and elbow or other transition.

Company	Website	Location	Products - Comments
ArtUSA	noisecontrolproducts.com	Norcross, GA	Noise Control Products
Alan Manuf	alanmfg.com	Wooster, OH	Rectangular and round duct silencers
Kinetics	kineticsnoise.com	Dublin, Ohio	

7.2.2 Duct Lagging



Circular ductwork is significantly more resistant to break-out noise than rectangular ductwork. Circular ductwork should be considered for noise sensitive spaces with exposed ductwork. In extreme break-out noise situations, double-wall circular duct can be considered.

Lagging (or wrapping) rectangular ductwork with fiberglass insulation of minimum 2-inch thickness and a limp-mass facing, such as sheet-lead or lead-loaded vinyl, of minimum 1.0 psf surface density is often effective in controlling break-out noise. If there is space, a drywall enclosure can be constructed to contain breakout noise. Gypsum board can be screwed directly to the duct to add stiffness and improve low frequency sound transmission or an enclosure can be constructed around the ductwork (with no rigid connections and fiberglass in the cavity).

Company	Website	Location	Products - Comments
Firwin	firwin.com	Champlain, NY	Insulation solutions
Kinetics	kineticsnoise.com	Dublin, Ohio	
ArtUSA	noisecontrolproducts.com	Norcross, GA	Noise Control Products
GLT Products	gltproducts.com	Solon, OH	Fiberglass, foam, tapes, wraps
Ruido Industrial	ruidoindustrial.com	Mexico	Fiberglass with perforated metal cover

7.2.3 Vibration Isolators

All fans, chillers, pumps, generators, compressors, and other rotating equipment should be vibration isolated from the structure with isolation mounts selected for the individual equipment's operating characteristics and the design of the structural system supporting the equipment.

Company	Website	Location	Products - Comments
Mason Industries	mason-industries.com	Hauppauge, NY	
Kinetics	kineticsnoise.com	Dublin, Ohio	

7.2.4 Plumbing Isolation

Plumbing noise is a common source of annoyance in private residences. The single most important thing that you can do is to isolate the piping from the building structure wherever possible. We recommend that all domestic hot and cold water and waste piping be isolated from the building structure by wrapping the pipe with ½" thick closed cell foam insulation and fastening the pipe to structure with a standard pipe clamp or strap (sized to fit over the insulation). The fastening method described above can reduce plumbing noise in an adjacent space by as much as 15 to 20 dBA, which is a very significant reduction. Closed cell foam may also be used as a sleeve through stud, joist, and floor penetrations to eliminate rigid contact between piping and the structure.

Prefabricated resilient supports are also available. These systems work fairly well, but generally provide slightly less noise reduction than the methods described above, and are more expensive. However, they may have ease of installation benefits that warrant their consideration.

Cast iron waste piping reduces water flow noise by 5 to 10 dBA when compared to plastic piping such as PVC. However, plastic supply pipes (hot and cold water) can reduce water flow noise by approximately 5 to 10 dBA when compared to copper. While we recommend that cast iron be used for waste piping, we feel that your choice of domestic water piping materials should be determined by factors other than noise.

In addition to isolating piping from the structure, we recommend installing either double-bellows neoprene flexible pipe connectors or at least three grooved-flexible couplings on the intake and discharge of pumps. The connectors, in particular the double-bellows neoprene connectors, should be installed as close to the pump as is practical. The connectors should be reviewed by the mechanical engineer or contractor for their suitability at the heating system operating temperatures.

Company	Website	Location	Products - Comments
PAC International	pac-intl.com	Las Vegas, NV	Resilient (Rubber) Sound Isolation Clip (RSIC) Products
Specialty Products Company	lspproducts.com	Irving, TX	Acousto-Plumb
Victaulic	victaulic.com	Easton, PA	
Mason Industries	mason-industries.com	Hauppauge, NY	
Armstrong	armacell.us	Mebane, NC	armacell

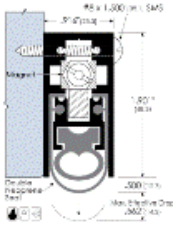
8.0 Doors and Windows

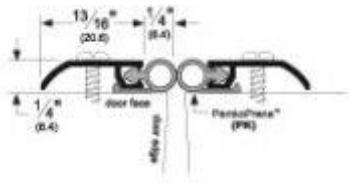
8.1 Background - Sound Transmission

In general, where sound transmission through a door is an issue, we recommend using solid-core wood or insulated metal doors. In many cases a kerf-in weatherstrip is effective. The seal is applied directly to the jamb and replaces the jamb stop. For double doors, we recommend installing astragals. We recommend sealing the bottom of the doors with an automatic drop bottom. Where the door is located over carpet, the best seal will be achieved by installing a metal or wood threshold for the door bottom to seal against. The carpet should be cut back to allow the threshold to be sealed directly to the concrete floor slab. If an automatic door bottom is not desired, a neoprene sweep can be used together with a threshold.

8.2 Product Suppliers

8.2.1 Door Seals





Door seals are a critical part of improving the sound transmission of a door. If you can see light through the door, from the perimeter, the seals are most likely not performing well.

Company	Website	Location	Products - Comments
Zero International	zerointernational.com	Bronx, NY	
Pemko	pemko.com	Ventura, CA	
National Guard Products	ngpinc.com	Memphis, TN	

8.2.2 Acoustical Doors

Solid core metal or wood doors with good perimeter seals can provide a high Sound Transmission Class (STC). In many cases, that may be all that is needed. However, in special conditions an acoustically rated door is required.

Company	Website	Location	Products - Comments
Overly	door.overly.com	Greensburg, PA	
Krieger	kriegerproducts.com	Pico Rivera, CA	
Noise Barriers	noisebarriers.com	Libertyville, IL	
ArtUSA	noisecontrolproducts.com	Norcross, GA	Noise Control Products
Phoenix-E	catalog.phoenix-e.com	Camarillo, CA	Acoustical panels

8.2.3 Acoustical Windows



As with acoustical doors, in many situations a window with a known construction (dual pane, laminated, ...) is adequate. It is important to be aware of the mullion construction, so that that is not a weak path. Sometimes an acoustical window system is needed.

Company	Website	Location	Products - Comments
Krieger	kriegerproducts.com	Pico Rivera, CA	
Climate Seal	climateseal.com	Chaska, MN	

9.0 Acoustical Enclosures

Noise Expert and Ruido Industrial designs and installs custom enclosures that can have absorptive, transparent and operable components. They both custom make and install enclosures.

Noise Expert and Ruido Industrial use an acoustic cameras for noise source and noise path identification.

Company	Website	Location	Products - Comments
Noise Expert	noiseexpert.com	Phoenix, AZ	Custom industrial enclosures
Ruido Industrial	ruidoindustrial.com	Mexico	Custom industrial enclosures

10.0 Sound Measuring Equipment & Software

10.1 Background - Acoustical Equipment

There is a great range in prices for acoustical equipment and software. How much you need to pay depends on the uses you have. If you are doing noise measurements and need to have accurate readings for compliance with a regulation, you will need calibrated, more expensive, equipment. However, you can estimate the noise levels with simple apps or inexpensive sound level meters.

10.2 Product Suppliers

10.2.1 Sound Level Meters

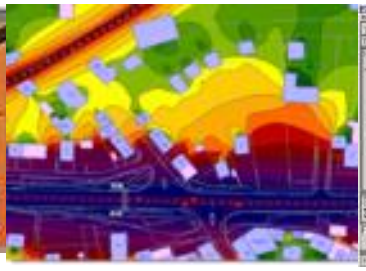
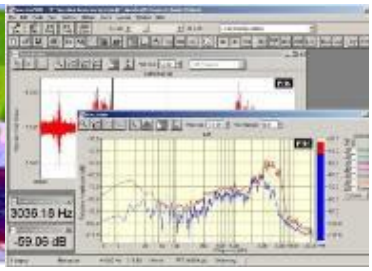


Sound level meters come in a large range of prices. The advantage of the more expensive meters is that they perform well at a larger range of frequencies and levels.

It is important to get a calibrator as well as a sound level meter, so that you can be sure the meter is accurate.

Company	Website	Location	Products - Comments
Larson Davis	larsondavis.com	Provo, UT	
Bruel Kjaer	bksv.com	Norcross, GA	
3M	3m.com		
Norsonic	norsonic.com	Norway	
Rion	scantekinc.com	Columbia, MD	
Extech	extech.com	Nashua, NH	

10.2.2 Noise Prediction Software

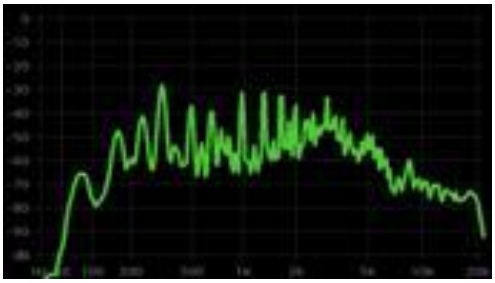




Many acoustical calculations can be made with a calculator or spreadsheet. If you are doing very complex calculations, require certain graphics or will be needing to

perform calculations regularly, buying a software package may make sense. There are some free programs (AIM for HVAC) but most are expensive. Spectra Plus turns your laptop into a signal processing FFT analyzer. It allows you to view the time history and frequency spectrum of a signal. It is much less expensive than buying a

Company	Website	Products - Comments
Cadna	datakustik.com	Environmental and room acoustics
Sound Plan	soundplan.com	Environmental acoustics
Spectra Plus	spectraplus.com	FFT, reverb time software
Acoustic Information Model (AIM)	pottorff.com	Free mechanical system prediction software
GNU Octave	gnu.org/software/octave	free Matlab alternative
Free Mat	freemat.sourceforge.net	free Matlab alternative
Sci Lab	scilab.org	free Matlab alternative

10.2.3 Apps



We have found that smart phone sound level meter apps work well for mid frequency noise in moderate amplitude ranges. High or low amplitudes (above 80 dBA and below 40 dBA) are not accurately measured using the small smartphone microphone. High and low frequencies also very from a high quality sound level meter. The apps are useful in getting an estimate of the noise levels but not much more.

Company	Products - Comments
Sound Meter Lite	Android - free
FrequenSee	Android - free
DB	iPhone - free

10.2.4 Sound Masking

Sound masking is used to improve speech privacy generally in an office environment. Increasing the background noise level makes conversations more difficult to understand providing more privacy. Masking systems generally cost about $1-$2 per square foot. The controls can be done from a computer.

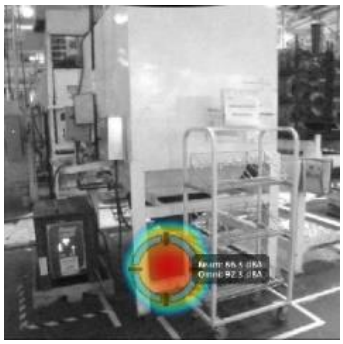
Company	Website	Location	Products - Comments
Logison Systems	logison.com	Rocklin, CA	
Speech Privacy Systems	speechprivacysystems.com	Plano, TX	

11.0 Acoustic Cameras

An acoustic camera is an imaging device used to locate sound sources and to characterize them. It is constructed of an array of microphones that gather information and project that on an image. The array is on a portable disk that is connected to a laptop. Videos and still photos can be generated.

There is a feature to block the noise from a particular spot, so that you can see the noise contribution from other areas. The output shows the spectrum of the noise (octave, third octave, narrow band) and the level. The acoustic camera can be aimed at the ceiling, walls and floor to measure the amount of noise coming from these reflected paths.

Company	Website	Location	Products - Comments
Noise Expert	noiseexpert.com	Phoenix, AZ	Acoustic camera sale, rental and measurement services
Ruido Industrial	ruidoindustrial.com	Mexico	Acoustic camera sale, rental and measurement services



12.0 Price List

I have included two price lists to give you an idea of product costs. One company is located in the US the other in Mexico. Both companies can install products as well.

The following Price List is subject to change without notice. Does not include taxes and shipping. Please contact Noise Expert for installation and acoustical consulting services

Noise Expert acoustical solutions - http://noiseexpert.com/acoustical-products/

Item Code	Description	Size	Cost (US$)	Unit (per)
NE Acoustic Panel	1 inch thick, cloth wrapped, fiberglass board core	multiples of 2 feet	$ 7	ft2
	2 inch thick, cloth wrapped, fiberglass board core	multiples of 2 feet	$ 9	ft2
	mounting hardware	approximately	$ 1	ft2
	installation	approximately	$ 1	ft2
	http://noiseexpert.com/acoustical-products/acoustic-panels/			
NE Metal Barriers-Panel	Solid barrier, perforated metal, mineral wood fill (custom sizes available)	2" or 4" thick	$ 29	ft2
	http://noiseexpert.com/acoustical-products/metal-barrier-panel/			
NE MLV Shield	1 pound per ft2	4.5´ x 30´ roll	$ 238	roll
	2 pounds per ft2	4.5´ x 15´ roll	$ 238	roll
	Grommets	various hole sizes	$ 1	ft2
	http://noiseexpert.com/acoustical-products/mlv-vinyl-barrier/			
NE Quilted MLV Shield	1 inch compressed fiberglass on one side	4´ x 50´ roll	$ 588	roll
	2 inches compressed fiberglass on one side	4´ x 25´ roll	$ 552	roll
	2 inches compressed fiberglass on both sides	4´ x 25´ roll	$ 570	roll
	http://noiseexpert.com/acoustical-products/quilted-vinyl-barrier/			
NE Acoustic Baffles	2 inch thick, sail cloth wrapped, fiberglass core, grommet hung, baffles	multiples of 2 feet	$ 5	ft2
	2 inch thick, sail cloth wrapped, fiberglass core, wall mounted, panels	multiples of 2 feet	$ 4	ft2
	http://noiseexpert.com/acoustical-products/acoustical-baffles/			
NE Mineral Wool	1 inch thick, 8 pounds per ft3, board	4´ x 8´ panel	$ 26	panel
	2 inches thick, 8 pounds per ft3, board	4´ x 8´ panel	$ 43	panel
	2 inches thick, 2 pounds per ft3, batt	12 sheets - 2' x 4'	$ 53	12 sheets
	http://noiseexpert.com/acoustical-products/acoustic-mineral-roll/			
NE Acoustic Spray	1 inch thick - price varies based on ease of installation	approximate installed	$ 6	ft2
	2 inch thickes - price varies based on ease of installation	approximate installed	$ 6	ft2
	http://noiseexpert.com/acoustical-products/ne-acoustic-spray/			
NE Custom Enclosures	MLV flexible enclosures	custom	contact us for quote	
	Metal rigid enclosures	custom	contact us for quote	
	http://noiseexpert.com/acoustical-products/ne-custom-enclosure/			

Ruido Industrial soluciones acústicas - http://ruidoindustrial.com/productos/

Codigo del producto	Descripcion	Tamaño	Precio (pesos)	Unidad
RI Recintos a la Medida	Flexibles de MLV	a la medida	llamanos para precio	
	Rigidos de metal	a la medida	llamanos para precio	
	http://ruidoindustrial.com/productos/ri-recintos-a-la-medida/			
RI Barrera-Panel Metal	Barrera solido, metal perforado, lana mineral adentro (fabricamos a la medida)	2 o 4 pulgadas de grueso	$ 420	pie2
	http://ruidoindustrial.com/productos/barrera-panel-metal/			
RI MLV Shield	no reforsado - para adentro, pegado a una maquina o pared	1.37 x 18.29 metros	$ 9,720	rollo
	reforsado - puede usar afuera, colgado	1.37 x 18.29 metros	$ 21,362	rollo
	transparente	1.37 x 18.29 metros	$ 29,160	rollo
	ojales	variado	$ -	pie2
	http://ruidoindustrial.com/productos/ri-mlv-shield/			
RI Quilted MLV Shield	1 pulgada de grueso fibra de vidrio compresada en un lado de MLV no reforsado	1.21 x 15.24 metros	$ 7,560	rollo
	1 pulgada de grueso fibra de vidrio compresada en un lado de MLV reforsado	1.21 x 15.24 metros	$ 10,584	rollo
	2 pulgadas de grueso fibra de vidrio compresada en un lado de MLV reforsado	1.21 x 7.62 metros	$ 9,936	rollo
	2 pulgadas de grueso fibra de vidrio compresada en dos lados de MLV reforsado	1.21 x 7.62 metros	$ 10,260	rollo
	http://ruidoindustrial.com/productos/ri-quilted-shield/			
RI Spray Acústico	1 pulgada de grueso	instalado	$ 86	pie2
	2 pulgadas de grueso	instalado	$ 108	pie2
	http://ruidoindustrial.com/productos/ri-spray-acustico/			
RI Bafles Acústicos	2 pulgadas de grueso, envuelto en tela de vela, fibra de vidrio adentro, ojales, bafles	multiples de 2 pies	$ 120	pie2
	2 pulgadas de grueso, envuelto en tela de vela, fibra de vidrio adentro, para pared	multiples de 2 pies	$ 110	pie2
	http://ruidoindustrial.com/productos/ri-bafles-acusticos/			

RI Lana Mineral	1 pulgada de grueso, 8 libras por pie3, placa	0.61 x 1.22 metros	$ 82	placa
	2 pulgadas de grueso, 8 libras por pie3, placa	0.61 x 1.22 metros	$ 164	placa
	2 pulgadas de grueso, 2 libras por pie3, batt	12 hojas: 0.61 x 1.22 metros	$ 958	12 hojas
	http://ruidoindustrial.com/productos/ri-lana-mineral/			
RI Panel Acustica	1 pulgada de grueso, envuelto en tela, place de fibra de vidrio adentro	multiples de 2 pies	$ 116	pie2
	2 pulgadas de grueso, envuelto en tela, place de fibra de vidrio adentro	multiples de 2 pies	$ 175	pie2
	conectores para montar	variados	$ 21	pie2
	http://ruidoindustrial.com/productos/ri-paneles-acusticos/			

Lista de Precios: Pueden cambiar sin aviso. Precios no incluyen impuestos ni transporte. Comuníquense con Ruido Industrial para servicios de instalación y asesoría acústica.

13.0 Thank You

Thank you very much for your interest in Acoustics and our 2018 directory. If you would like more information about acoustics and noise control, please sign up for our newsletter and follow our blog at www.noiseengineers.com.

Please share your thoughts and comments with me (bill@noiseengineers.com). I would like to make the next version even better and more useful.

Thank you,
Bill Holliday, PE