The Science of Better Acoustics

Modern interior spaces often feature large open areas and many hard surfaces such as glass, tile, wood or concrete. Visual appeal, air quality, appropriate lighting, comfortable room temperature and optimal acoustics all contribute to the experience occupants have when they're in a space. Noise and echo or reverberation can make the most attractive and comfortable rooms unpleasant. There are many creative and appealing solutions to avoid or resolve acoustical problems. To optimize the acoustics of a room, it's important to understand a little about the science behind acoustics to determine the best solution for your application.

Creating Sound

When a gong is struck with a mallet or striker, it creates vibrations. Strummed or plucked strings on a guitar create vibrations. Vocal cords vibrate, resulting in speech. These vibrations create a sound wave that travels through the air in the form of small changes in atmospheric pressure, alternating above and below the static pressure. Loudness is the physical response to sound pressure and intensity. Our ears vibrate in a similar way to the original sources of the vibration, allowing us to hear different sounds.

Measurement

Sound is measured using a compact scale incorporating decibels (dB). Decibels are units of measure of sound pressure. Zero decibels is not audible and 130 decibels is a painful threshold.

Two sounds with the same apparent loudness at different frequencies may have different sound pressure levels. Therefore, sound level measurements only give part of the information needed to analyze noise issues. Noise spectra are also used in acoustical analysis. Below are examples of sound levels as they relate to decibels.

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Jet takeoff, artillery, elevated train	120 to 100 dB
Subway, printing press, police whistle	100 to 80 dB
Vacuum cleaner, street noise, noisy office	80 to 60 dB
Large store conversation, average office noise	60 to 40 dB
Private office, quiet conversation	40 to 20 dB
Rustle of leaves, whispering, soundproof room	20 to 0 dB

Sound Quality

The quality of sound is determined by frequency. Measured in units of hertz (Hz), frequency is the number of complete cycles of vibration above and below the static pressure in a unit of time. The human ear detects pressure changes at a rate of 16 times per second or more. The most sensitive frequency is approximately 1,000 hertz. Low-frequency sounds are harder to hear. The table below shows the frequency of various sound sources as they relate to the frequency range of human hearing.

Human hearing	16 to 20,000 Hz
Speech intelligibility	600 to 4,800 Hz
Speech privacy	250 to 2,500 Hz
Home sound speaker system	200 to 5,000 Hz
Male voice (energy output peak)	350 Hz
Female voice (energy output peak)	700 Hz

Types of Sound and Reflection

Direct sound travels from the source directly to the ear. Indirect sound is reflected from a surrounding surface. Portions of sound energy are absorbed when the sound is reflected off a surface.

Reflection of sound signals can enhance the quality and strength of speech and music. Delayed reflections or multiple sounds reflected simultaneously can cause echoes, which reduces speech intelligibility.

Direct
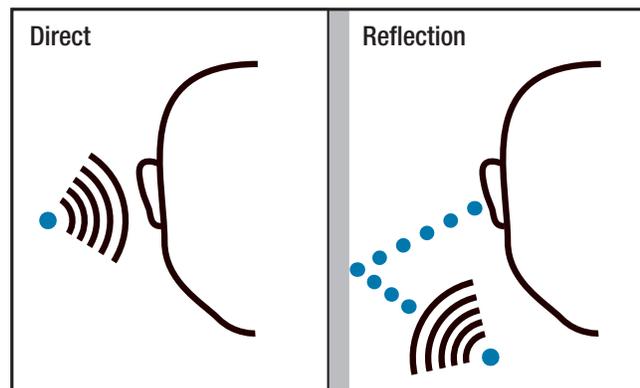
Reflection

Absorption

Sound loses part of its energy when it is reflected from a surface. The portion of energy that is not reflected, is sound absorption coefficient. If a surface reflects 80 percent of the sound energy, its sound absorption coefficient is 0.20.

Reverberation Time

If you clap your hands once in a room, the sound will continue to reflect from surfaces until it loses enough energy from absorption and dies out. This is described as reverberation time, which is identified as the number of seconds required for a sound to die out to one millionth of its original energy (60 dB).

A room's reverberation time is influenced by the dimensions and absorptive properties of the surfaces and other content in the room. Reverberation impacts speech intelligibility, enjoyment of music and overall noisiness of a room. Optimum reverberation time is based on the size and use of a room. Below are the optimum reverberation times for various uses based on a space of 300,000 or 1,000,000 cubic feet.

Room Uses	Ideal Reverberation Time (300,000 cu. ft.)	Ideal Reverberation Time (1,000,000 cu. ft.)
Worship facility (music)	1.6 seconds	1.9 seconds
School auditorium	1.3 seconds	1.4 seconds
Movie theater	1.2 seconds	1.3 seconds
Speech	1.1 seconds	1.2 seconds

The Right Solution

Treat the Room

Many pinta acoustic products, including SONEX® Panels and Baffles, absorb a high percentage of sound energy and dissipate it as kinetic heat energy. Maximum noise reduction potential when treating a room with SONEX is from 4 to 6 decibels, resulting in a noise level reduction of 20 to 30 percent.

How much do you use? Less than you may think. Typically, some SONEX Panels on the ceiling and a strip of SONEX Panels on the walls will reduce the noise level by 20 to 30 percent.

Acoustic Material

Noise Source
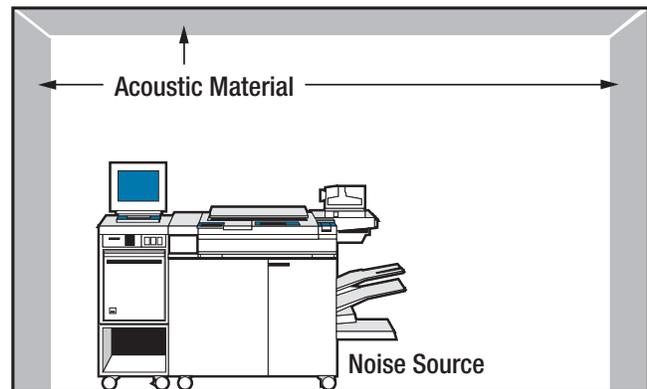
More is better, right? Actually, the more sound absorbing material added to a room, the less it does. Some simple calculations can help you determine when to stop adding acoustical panels, tiles or baffles.
- Multiply the width and height of the walls.
- Multiply that number by the absorption coefficient of the surface material at 500 Hz (see next page).
- Example: 10 ft. x 10 ft. x .05 in. (gypsum board) = 5 sabins of absorption.
- Complete the above calculation for the floor, ceiling and all walls.
- Add the sabins for each together for the total absorption of the room.

Absorption Coefficients

Carpet on concrete	0.09
Concrete block, painted	0.06
Concrete block, unpainted	0.31
Poured concrete	0.02
Tile or linoleum	0.03
Wood flooring	0.10
Plate glass	0.04
Gypsum board	0.05
Plaster on lath	0.03
Metal ceiling	0.03
Suspended acoustical ceiling	0.60
Unpainted plywood	0.17
Openings (doors, large gaps or partial walls)	1.00

A more complete list is available from the Acoustical Society of America.

If you double the amount of noise-reducing material, such as SONEX, there will be a 3 dB reduction. For a 3 dB noise reduction of a room with 100 sabins of absorption, add another 100 sabins. A 2 ft. x 2 ft. x 2 in. SONEX tile contains 0.85 sabins. You would need approximately 118 square feet to add 100 sabins.
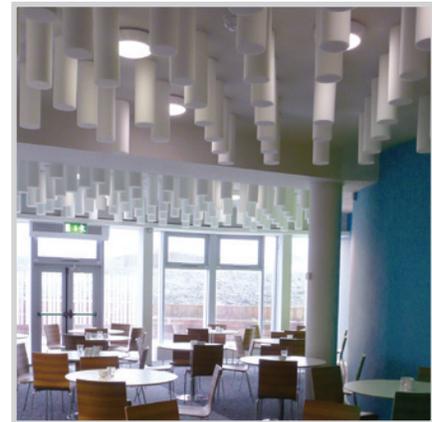
Some situations call for a more lively or active uses of a room. This calculation is different.
- Use the total absorption of a room from the previous calculation.
- Multiply the cubic volume of the room by the total absorption in the room. This is the reverberation time (in seconds).
- Example: a 100,000 cu. ft. room x 0.049 total absorption ÷ 750 sabins of absorption = 6.5 seconds of reverberation time.
- Identify the recommended reverberation of a room as described previously.
- If the desired reverberation time is 1.45 seconds, you'll need to know how many sabins are needed to meet the optimum reverberation time level.
- Example: 100,000 cu. ft. room x 0.049 ÷ 1.45 seconds = 3,379 sabins
- Subtract the sabins that the room already has.
- Example: 3,379 sabins – 750 sabins = 2,629 additional sabins are required.
- 2-inch-thick SONEX contains 0.81 sabins per sq. ft. at 512 Hz.
- 2,629 additional sabins ÷ 0.81 per sq. ft. = 3,245 sq. ft. of SONEX.

These examples are estimated for an empty room. To obtain a more accurate measurement with machinery and other materials in a room, a reverberation time test is needed.

Practical Methods to Reduce Noise from a Sound Source

Treat the Wall Nearest to the Noise Source (Fig. 1)

Another option is to cover the wall closest to the noise source with SONEX® Acoustic Foam Panels. Maximum sound reduction will vary from 2 to 6 decibels. This solution reduces noise levels from 10 to 30 percent at a low cost.

Build a Barrier or Shield (Fig. 2)

PROSPEC® Barriers can be used to create instant walls that isolate noisy machinery, such as a copy machine. PROSPEC Composite combines the sound absorption of foam and the containment of barrier material to isolate noise effectively.

Build an Enclosure (Fig. 3)

An acoustic enclosure around the machine also quiets noise at the source. This is the ideal solution for mechanical rooms.
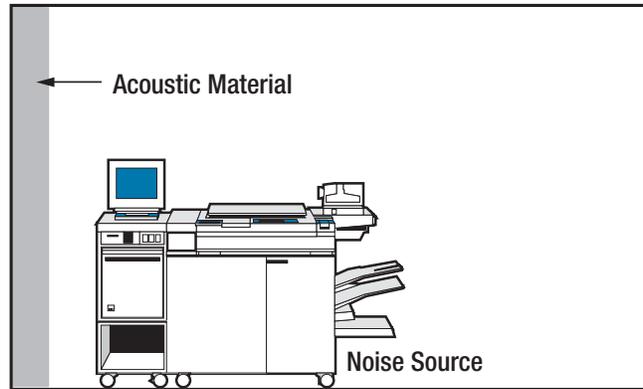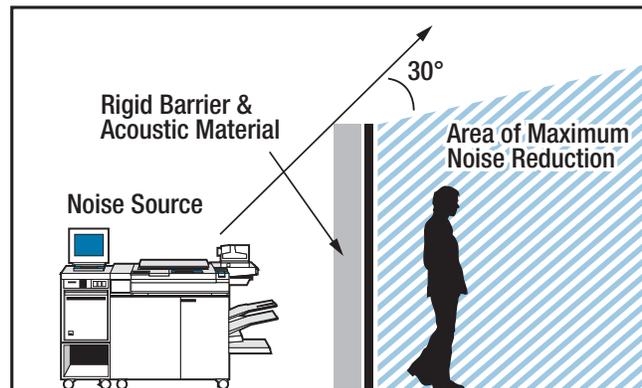
Acoustic Material

Noise Source

Fig. 1

Rigid Barrier & Acoustic Material

Noise Source

30°

Area of Maximum Noise Reduction

Fig. 2

Rigid Enclosure
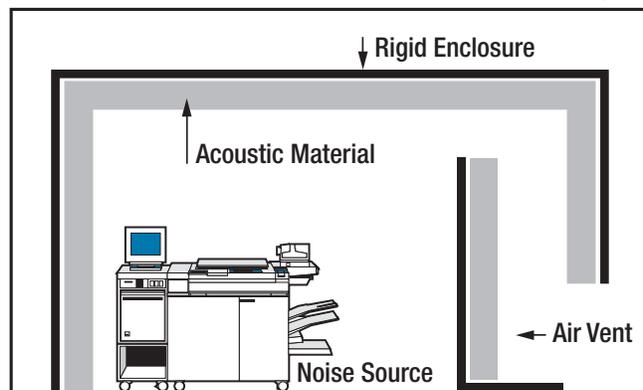
Acoustic Material

Air Vent

Noise Source

Fig.3

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