# The Four-Fold Method of Noise and Vibration Control

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# MATERIALS SOLUTIONS TO NOISE AND VIBRATION PROBLEMS

Efforts to control noise and vibration in a wide range of mechanisms and devices inevitably require the use of passive acoustical materials. To achieve the greatest performance per dollar requires not only the correct choice of materials, but also an understanding of how they work, and of how and where to install them. All passive noise control systems use at least one of the following material types:

***Barriers***…enclosures, weighted materials, walls

***Absorption materials***…acoustical foams, fibrous batts or blankets, acoustical tiles

***Vibration isolators***…equipment mounts, plastic or rubber-based bushings and grommets, steel spring equipment supports

***Damping materials***…plastic sheets, mastic solutions, adhesive films

The first two categories above deal with *airborne* noise—noise already propogating in the air. The last two items deal with *structureborne* vibration, which will appear as airborne noise after being radiated by a structure, unless it is either isolated or damped. In general, effective noise control incorporates the use of *both* barriers and absorbers for airborne noise and *both* isolation and damping for structure-borne noise. It is important to remember that sound is mechanical energy, and that it will always find the path of least resistance from the noise source to the outside world. The process of noise control involves blocking these paths and eliminating the energy wherever possible.

## Barriers and Enclosures

A sound barrier is usually a solid material which, by virtue of its mass, acts as an acoustical reflector, interrupting the path of a sound wave. A barrier may be a rigid structure, such as a concrete wall, or a limp sheet material, such as a flexible noise curtain. For most installations, it is not the stiffness of the barrier that produces the noise reduction, but the mass. More specifically, the weight per unit area—usually stated in pounds per square foot— provides the best single indicator of the attenuation characteristic of a barrier. A common myth holds that lead sheet is the best choice for barrier applications. In truth, however, it does not matter what type of material is used to produce the weight if, all other factors being equal, the surface density (lbs/ft$^2$) is the same everywhere over the barrier's surface.

Obeying the laws of physics, a barrier will produce increasing attenuation at higher frequencies. This attenuation—*transmission loss (TL)*—is measured according to ASTM Standard E-90.

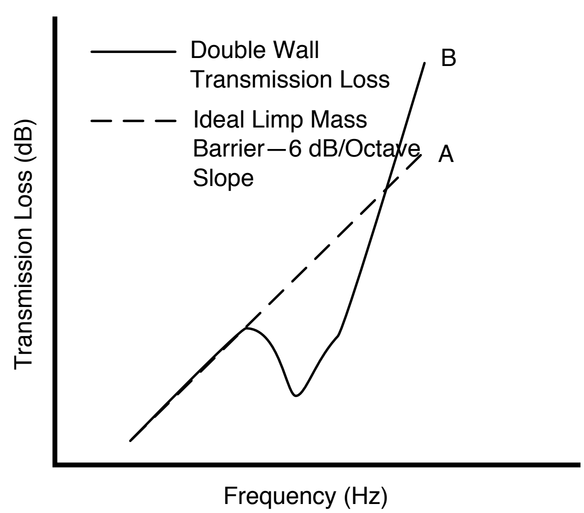



*Figure 1: Transmission Loss Behavior of Single and Double*

*Figure 1* shows a graph of TL for a simple limp barrier material (Curve A). The upward sloping curve indicates the increase in TL with increasing frequency. Experience shows that a simple limp barrier may be very useful in reducing noise in the range of 250 Hz and above depending, of course, on the surface mass utilized. Very low frequency noise, however, can be attenuated only by using very massive constructions, such as multiple layers of gypsum board or masonry.

Curve B depicts the performance of a *double-wall* barrier, sometimes referred to as a de-coupled barrier composite. This barrier system combines a simple limp barrier material with a soft decoupling foam. Performance at higher frequencies is enhanced using these systems, or equivalent performance can be attained at lower weight.

Flexible barriers can be used in composites to reduce noise in engine compartments and equipment cabs, as in boats, heavy duty trucks or portable generators, and can also be fabricated into curtains for enclosing noisy machinery. The key to effective utilization of a barrier material lies in reducing the number and size of holes, gaps and other penetrations in the assembly to an absolute minimum, consistent with accessibility and ventilation. Generally, the percentage of open area relative to the total enclosure area should never exceed 10 percent. Under ideal conditions, a 10 dB(A) reduction may be achieved with this amount of open area. If the open area can be decreased to 1 percent, the potential noise reduction improves to 20 dB(A) (refer to *Figure 2*).

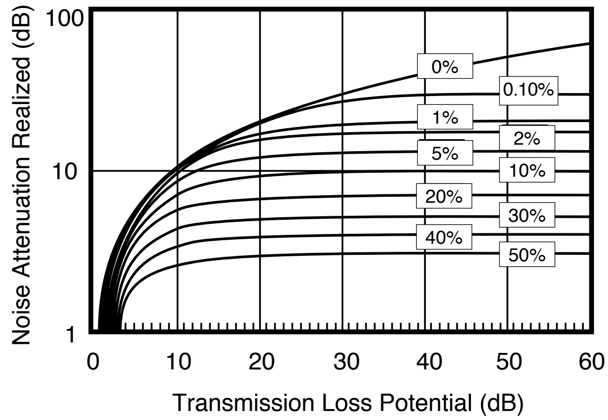



*Figure 2: Performance of an Enclosure Based upon Percentage of Open Surface Area*

Because barrier materials are usually installed close to the machinery being quieted, they often are subject to abuse. Choice of material or composite must therefore consider characteristics such as abrasion resistance, tensile strength, resistance to chemicals, flexibility at various temperatures and puncture resistance.

## Absorption Materials

Absorption materials are almost always used in conjunction with a barrier of some type, since their porous construction permits noise to pass through relatively unaffected. An absorber, when backed by a barrier, reduces the energy in a sound wave by converting the mechanical motion of the air particles into low-grade heat. This action prevents a build-up of sound in enclosed spaces and reduces the strength of reflected noise.

Typical absorption materials include urethane semi-reticulated foams or fiberglass batts or blankets. While most of these products provide some degree of absorption at nearly all frequencies, performance at low frequencies typically increases with increasing material thickness. Thin materials show the general characteristic of higher absorption at higher frequencies. In *Figure 3,* the values plotted are for the *absorption coefficient,* alpha (α), of a 1-inch-thick "skin-faced" foam (E-100SF). An alpha (α) of 0.5 indicates that the material under test reduces the strength of reflected sound waves by 50 percent.

The porous nature of absorption materials renders them susceptible to contamination, moisture retention and deterioration due to physical abuse. To avoid these problems, facings may be attached to at least one side of the absorber. As can be seen in *Figure 3*, the addition of a facing to an acoustical foam has the effect of increasing the lower frequency absorption at the expense of the higher frequencies. This fact is important when considering what type of absorber to use in a given application.

Combining absorption materials with barriers produces composite products that can be used to lag pipe or provide

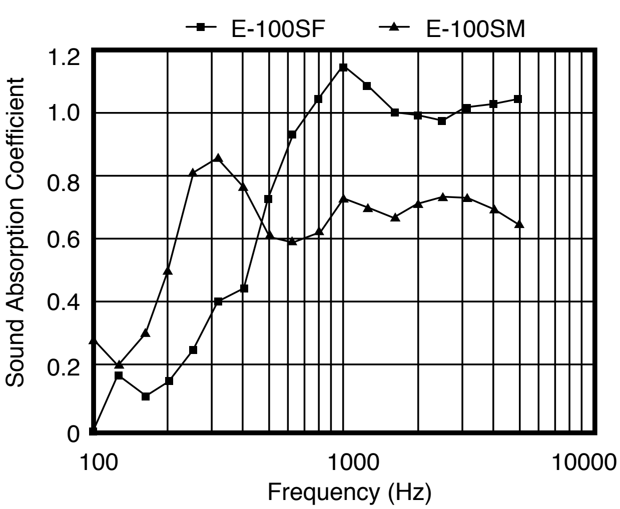
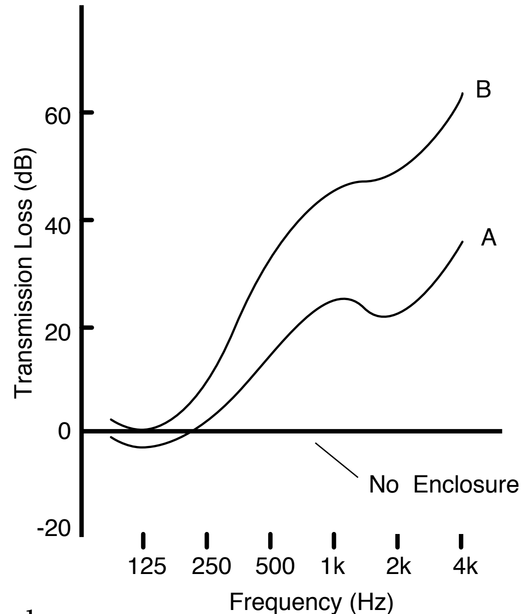



*Figure 3: Performance of Various 1-inch Acoustical Foams with Surface Treatments*




absorp-

*Figure 4: Insertion Loss of Sealed Enclosure without Absorption (A) and with Added Absorption (B)*

tive curtain assemblies. Another useful composite weds acoustical foam with sheet damping material to provide additional mass, panel damping and acoustical absorption in one product.

*Figure 4* suggests the importance of using absorption. This graph shows the *insertion loss,* or noise reduction in dB, for an *ideal* (0% opening) enclosure system. If a uniform noise pressure spectrum initially exists, an enclosure without added absorption has an amplifying effect at low frequencies and limited performance at high frequencies (Curve A). The same enclosure *with* added absorption (Curve B) shows considerably better attenuation in the higher frequency range and at lower frequencies as well. An enclosure works well only if it is free of holes and openings, however, and acoustical performance is severely compromised when the openings allow a direct line from the noise source to the outside.

Examples of enclosure/absorber systems include compressor wrap assemblies, a tabletop printer enclosure, an oxygen concentrator housing or a deburring machine enclosure.

## Vibration Isolation

Vibration, like sound, travels in all directions away from a source to surfaces where it can be radiated as noise. For example, it often is not the motor in a device that produces the most noise, but the panel or structure to which the motor is attached. Use of vibration isolators can stop the flow of vibration from one point to another and reduce noise.

While isolators are available in a very broad variety of designs, all have one characteristic in common: they provide a means of connecting two structures so as to provide relative motion between them under dynamic loads. The amount of motion required depends on many variables, the chief one being the range of frequencies over which the isolator must be effective. Isolation of noise in the A-weight frequency range—above 250 Hz—can be accomplished with a relatively stiff, low-deflection mount. Isolation of very low vibration frequencies, such as the fundamental rotation speed of an 1800 RPM (30 Hz) motor, requires considerably greater deflection capability from the mount. For example, an isolator designed to isolate vibration above 10 Hz requires 25 times more deflection under load than one operating at 50 Hz and above.

Most isolation materials are based on rubber or plastic technology, each of which has particular strengths and weaknesses. Rubber materials can exhibit very high bond strength and the ability to perform well in shear, but tend to fatigue if cycled between compression and tension. Plastic materials can exhibit very high damping, good resistance to compression set and a variety of molding characteristics, but typically do not achieve rubber's resilience and elasticity.

*Transmissibility, TR,* provides a common measure of isolator performance. Transmissibility can be expressed in linear units or logarithmically, for example, in decibels (dB). Briefly, transmissibility is a measure of the vibration response of a system divided by the magnitude of the vibration input to the system. Without exception, the lower the transmissibility, the better the isolation performance.

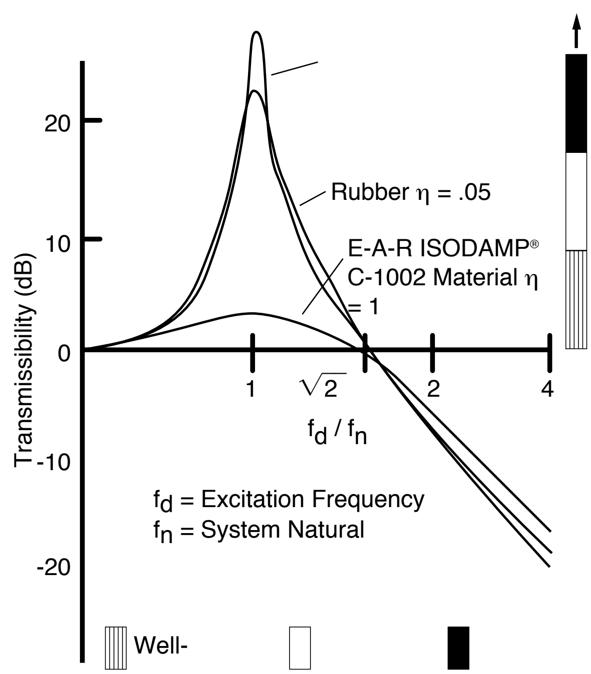



*Figure 5: Transmissibility of Isolation Materials with Different Loss Factors. Loss Factor (η) is a Measure of Damping*

*Figure 5* plots the transmissibility characteristics of several types of isolation materials. The shaded bands on the right-hand side of the figure indicate that transmissibility of less than about 6 dB at resonance can be considered well-controlled; between 7 and 15 dB is conditional and may cause malfunctions, and above 15 dB can be damaging, depending on the input force levels involved. For reference, 6 dB is a magnification factor (X) of 2X; 10 dB is 3X and 20 dB is 10X. So, for example, if an isolated system has an amplitude at resonance of 10 dB, the vibration output forces are 3 times the input forces.

The frequency of the resonance point of an isolated system can be controlled by pairing the correct type of isolator with the total weight of the machine to be isolated. The corresponding transmissibility curve shows that vibration isolation begins to the *right* of the point where TR crosses the reference (0 dB) line. More specifically, the frequency at which isolation begins is about 1.4 times the natural frequency of the system. Isolation or attenuation of vibration is provided only above this frequency.

*Resonance* is the point of maximum response amplitude in an isolated system and can be a disruptive, as well as destructive, phenomenon. Damping, in the form of an isolation material, provides the only means to control resonance. Presently, damped materials specifically formulated to minimize resonance problems are available and should be used whenever machinery will be operated at or near the system's natural frequency. Highly damped materials also excel at controlling or preventing rebound, thus making damped isolation mounts ideal for controlling shock problems.

Examples of isolation mount uses are numerous, including engine mounts for vehicles and aircraft, pump and compressor mounts, punch press shock mounts, and even small grommets used in computer disk drives.

## Structural Damping

Structural damping is to structural vibration what absorption is to airborne sound. That is, it provides a means for eliminating mechanical energy by converting it to heat. Damping materials are applied directly to the surface of a structure using adhesive and may often be painted to improve appearance of the final product. Properly designed damping treatments can produce dramatic results, especially for impact noise, where reductions of 20 dB(A) or more are common.

Damping materials are available from various manufacturers in sheet form, adhesive form and as trowel-on compounds. Sheet materials can be die-cut for easy assembly (into OEM components) or as retro-fit packages. Most sheet goods can be supplied with pressure-sensitive adhesives, which further

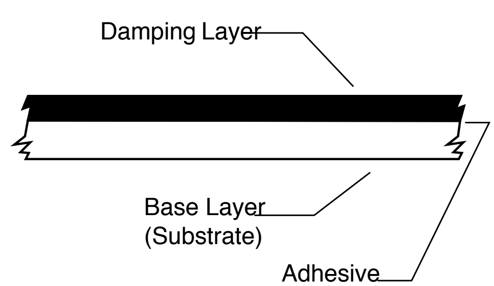



*Figure 6: Extensional (Free-layer) Damping Construction, Cross Section*

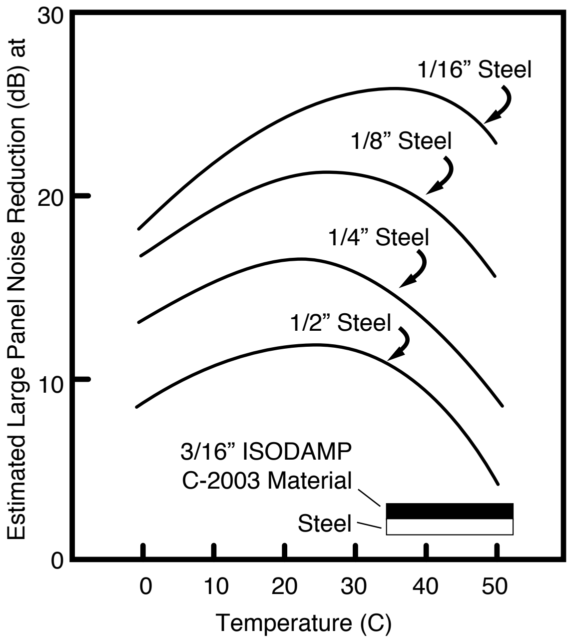


*Figure 7: Estimated Large Panel Noise Reduction for Extensionally Damped Steel Plate*

improves their application convenience. Coverage need not be total in order to be effective, and impact noise reductions of 10 dB(A) or more can be achieved with as little as 25 percent surface coverage.

For simple free-layer installations, sometimes called *extensional* damping, four parameters determine the amount of damping and noise reduction (refer to *Figure 6*):

1. Base material and thickness (e.g., steel or aluminum)
2. Damping material characteristics at temperature and frequency of the application
3. Ratio of damping material thickness to base material thickness
4. Percentage of surface area covered

Performance of free-layer damping systems is measured in terms of system loss factor $\eta_S$, and *large panel* impact noise reduction in dB(A) (refer to *Figure 7*).

Notice that for the thicker base materials, loss factor, and therefore expected noise reduction, are reduced if the damping layer is too thin relative to the base. Some manufacturers offer various thicknesses of a given material to suit the requirements of heavier constructions.

## Conclusion

The best, and often least expensive, noise control is achieved by working as closely to the source of the noise or vibration as possible. This means extensive use of vibration damping and isolation materials for motor-driven devices and impact operations. For fan noise and containment of workplace noise, enclosures or barrier systems including absorption materials should be considered. Care should be used in selecting materials which will not degrade over time. This is particularly true for materials that are porous, such as foams or fiberglass, and materials that require a high performance adhesive to function properly, such as damping sheet.

Choosing the right materials for a particular noise problem does not require magic, but can be sometimes tricky. A reputable, quality noise control products manufacturer will have in-house technical and field staff to assist in the correct choice of materials and installation methods for most applications.

Aearo Technologies LLC manufactures a complete range of materials—the broadest selection offered by a single source—for noise and vibration control applications. Aearo's proprietary vinyl and urethane formulations can be produced as foams and solid materials, in sheet, roll and bun form, as die-cut and molded custom parts and in multi-layer composites.

E-A-R TUFCOTE™ acoustical foams, barriers and composites offer exceptional performance, durability and versatility for a wide variety of noise and vibration control applications, from HVAC systems to golf cars to Class 8 trucks. The foams are manufactured by a proprietary thin-sheet casting method that affords superior processing control. It also allows economical in-line, adhesive-free bonding with barrier and damping materials to form multi-function composites and with backings, facings and reinforcements.

Mechanically strong and durable, ISODAMP™ and ISOLOSS™ brand sheet damping and isolation materials, and VersaDamp™ molding materials effectively address impact noise and structureborne vibration under diverse physical and environmental conditions. As standard and custom-molded parts—grommets, bushings and stud mounts, for example—these highly damped materials virtually eliminate unwanted energy from a system, ensuring precision, shock protection, noise control and vibration isolation.

Assistance with specific applications, technical questions or design problems is available from E-A-R's Engineering Department. Product literature and samples also are available by contacting the Customer Service Department at (651) 575-0151.

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