Handbook of Noise Control Materials

Contents

SOUNDOWN
FOR PEACE AND QUIET

SECTION 1

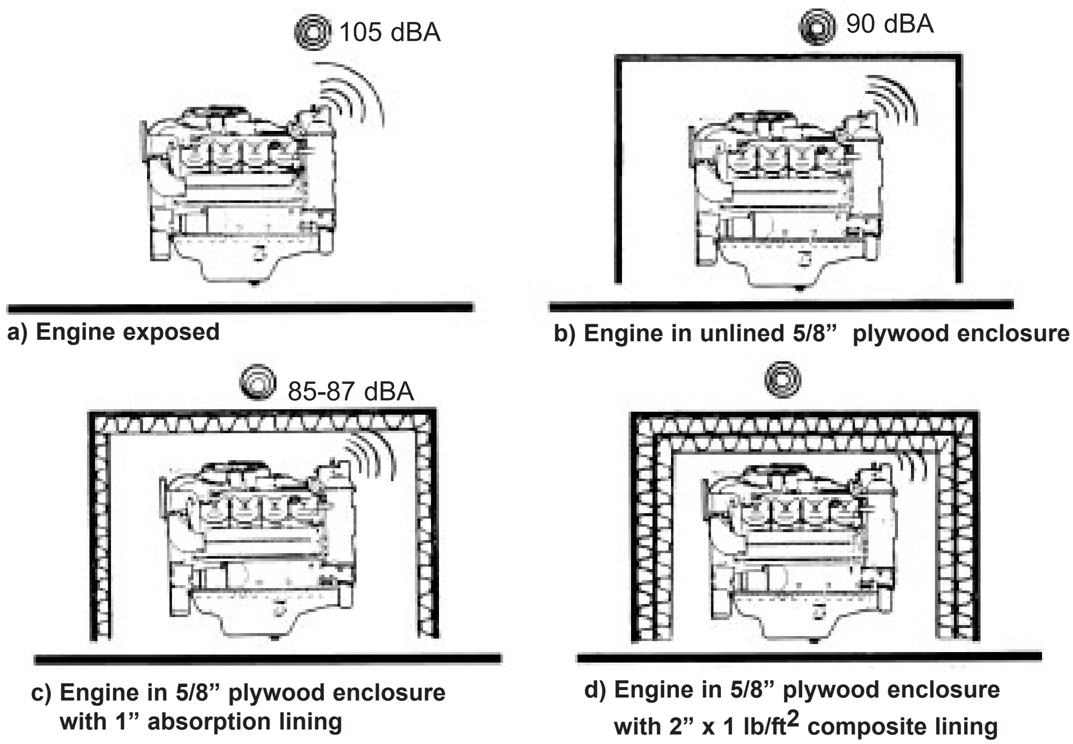
A. BASIC CONCEPTS OF BLOCKING AND ABSORBING SOUND

Acoustic insulation materials work by two processes: absorption of sound energy, which dissipates sound as heat energy, and reflection, which reflects noise away from a location where quieting is desired. A single composite insulation material will be effective as both an absorber and a reflector.

Considering the example of an engine in a boat, if it is sitting open with no enclosure around it, it will create a very loud noise throughout the boat, perhaps as much as 105 dBA . If we install an engine box around the motor using 5/8" thick plywood, we might reduce the noise to 90 dBA in the boat, as the mass of the plywood box reflects the sound back into the enclosure (generally the more mass in a panel, the better). Within the enclosure the sound waves bounce off the plywood walls and a reverberation occurs, similar to that experienced in any hard surface room. The noise near the engine, inside the box, is actually louder after the box is installed due to the reverberation effect.

Absorbing a large fraction of the noise each time a sound wave strikes one of the walls can reduce the reverberation within the box. This is done by placing sheets of acoustic absorptive materials on the walls of the box. These are porous materials, such as fiberglass batts or open cell porous foam, with little weight. If we install 1" of absorptive material on the top and four sides within the engine box, the noise in and outside the box may drop by 3 to 5 dBA, giving us a range of 85 to 87 dBA in the boat.

If, in place of the simple absorptive material, we install a composite material using a mass layer of 1 lb/ft^2 of barrier sheet sandwiched between two 1" layers of foam or fiberglass, we may achieve a 12 to 14 dBA reduction of noise, giving us 76 to 78 dBA in the boat. The composite material achieves this result by combining the effects of absorption and reflection: the free layer of foam material facing into the enclosure acts as absorption against reverberation; the barrier, separated from the enclosure wall by the bottom layer of the composite (often called the decoupling layer) acts as a second reflecting wall in addition to the plywood sides. This type of composite insulation is the most commonly sold acoustic insulation for marine use.



a) Engine exposed

b) Engine in unlined 5/8" plywood enclosure

c) Engine in 5/8" plywood enclosure with 1" absorption lining

d) Engine in 5/8" plywood enclosure with 2" x 1 lb/ft^2 composite lining

Insulation using a single mass layer plus a thick decoupler is generally optimal for quieting noise of diesel and gasoline engine compartments. Optional composite constructions using multiple mass and decoupler layers, stacked on top of each other, are normally not as effective over the critical range of frequencies characteristic of engines when compared to a single mass material of the same overall weight and thickness.

B. VARIABLES AFFECTING PERFORMANCE

The most significant variables for noise control materials are weight of the reflecting barrier layer and thickness of the absorption and decoupling layers. Secondary factors are the protective surface facing materials and materials for the mass layer. The particular type of acoustic foam or fiberglass is of lesser importance among the legitimate and effective acoustic materials available.

The universal problem in attenuating noise of marine engines, generators, and propellers is reduction of mid and bass frequency rumbles. High frequency sounds of turbo chargers, gearboxes, engine valve chatter, and engine rattle, etc. are reasonably attenuated with an enclosure lined with a thin lightweight composite. A composite using 1 lb/ft^2 barrier sandwiched between ½" layers of foam added inside a 5/8" wood enclosure will give good reduction of these noises if the engine compartment is reasonably leak-free. However, the mid and bass frequency noises associated with cylinder combustion rate, engine rotation, and propeller noise require more careful attention to weight and thickness of materials used in the composite.

The effectiveness of absorptive materials increases directly with thickness, in both the amount of energy absorbed and the range of frequencies over which absorption occurs (See Fig. 2A). Bass frequencies require thicker absorptive layers. For engine noise ½" is generally a minimum useful thickness while 1" is good, and 1-1/2" to 2" approaches an optimum with in the practical considerations of effectiveness and space available.

For the design of composites, mass layers are typically at weights of 1 and 2 lb/ft^2 and the thickness of decoupling layers varies from ¼" to 3".

The effective frequency range of these materials varies with the square root of the weight of the mass layer times the thickness of the decoupler (See Fig. 2B). The 1 lb/ft^2 material on ¼" decoupler is effective only above 500 Hz, and is generally not satisfactory for noise reduction in boats, except for special applications. The 2 lb/ft^2 material on ¼" decoupler moves the effectiveness range down to 350 Hz (this is a construction generally recommended when there is minimum space available for the composite treatment). For a high level of effectiveness the decoupler layer should be 1" or greater and for the highest effectiveness this should be combined with 2 lb/ft^2 mass layer, as demonstrated in Fig. 2B. Greater thick nesses of the decoupler increase the bass frequency effectiveness, while heavier mass layers increase effectiveness throughout the entire frequency range.

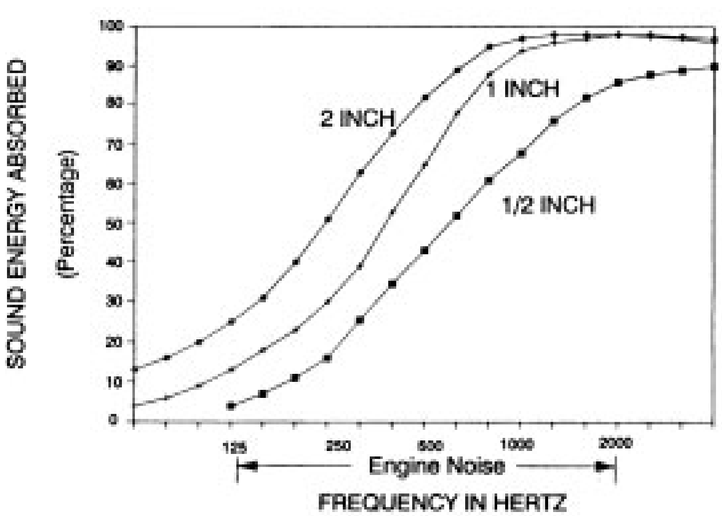


Fig. 2A Typical sound absorption values for fiberglass and foams of various thickness

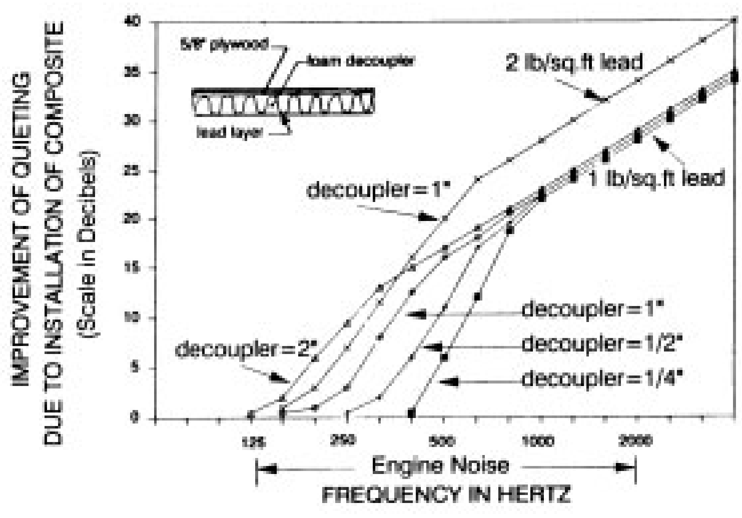


Fig. 2B Improvement of quieting due to addition of composit materials inside and engine box constructed of 5/8" plywood. (Varying decoupler thickness & weight of lead sheet)

SECTION II

BASIC DISCUSSION OF VIBRATION DAMPING TREATMENTS

Damping materials absorb vibrational energy from resonating panels in a direct analogy to sound absorbing materials interacting with noise in the air. By absorbing energy, damping reduces the structure-borne noise radiated from the panel to which it is applied. Damping also reduces the structureborne noise traversing the treated panel and traveling to more remote parts of the boat (structure). Methods of vibration damping include "extensional" and "constrained layer" treatments.

Extensional damping materials are applied as a single layer direct to the treated panel.

Constrained layer damping materials, are applied sandwiched between the treated panel and an additional cover material, usually of the same material as the treated panel (wood/damper/wood or aluminum/damper/aluminum), but the constraining layer is usually thinner than the treated panel.

Damping materials of either type must be intimately bonded to the panels they are intended to damp, so that the vibrational energy of the panel is transmitted to the energy absorbing damping treatment.

Selecting the appropriate method of damping for a given surface, is more complicated than the selection of sound absorbing acoustic materials. Following are some guidelines regarding boat surfaces normally found to benefit from the application of damping materials. These gudelines do not hold for all situations and should be reviewed based on the specific application.

Panel Size:

Minimum, panel size (small dimension), to benefit from damping:

- 4" for panels up to ¼" thickness.
- 8" for panels greater than ¼" thickness.

Typical panels beneficially treated with extensional damping:

- Engine girder webs
- Hull bottom over propellers
- Spray rails and chines in the wave slap zone
- Bulkheads and decks enclosing the engine room
- Tank-tops adjacent engine room.

Typical panels for use of constrained layer damping treatments are:

- Soles having a damping layer sandwiched between the structural sole panel and a teak finish surface
- Safety glass with a plastic core between sheets of hardened glass
- Metallic deck damping by use of latex concrete finish surface poured over a damper which is adhesively bonded to the deck structure
- Joiner panels of sandwiched damped construction.

Damping treatments, when appropriately applied often generate noise reductions in the 3 to 5 dB range. In certain cases greater reduction can be achieved. Technical advice should be sought from a knowledgeable damping material supplier, by new users inexperienced in the use of these materials.

SECTION III

MATERIALS

A. Absorption -The two common materials for acoustic absorbers are open-cell urethane foams and fiberglass. High-quality panels in urethane and fiberglass are of about the same acoustic effectiveness for the same thickness.

1. **Foams -** Urethane foam has the advantage of being both tough and flexible, which makes it easier to handle and install than fiberglass. Urethane foams used in boats should be flame retardant, polyether and they should have protection against liquids and vapors, as the materials may age and crumble or become an oil ladened fire hazard if not so protected.

2. **Fiberglass -** Fiberglass has the advantage of being highly resistant to fire, chemicals, and vapors and it is non-wicking. Fiberglass is generally not resistant to rubbing and other physical abuse and is not strong enough to support mass layers attached by adhesive. Fiberglass materials, therefore, must be installed using mechanical fasteners and protective coverings such as Perforated Aluminum.

In most applications where Coast Guard inspec tion is required of vessels carrying passengers for hire, fiberglass must be used because of its high resistance to fire.

B. Mass Layers - Mass layers must be non-porous and limp for maximum effectiveness. Plywood and other stiff lightweight materials do not block sound as well because their stiffness properties allow them to transmit noise through sympathetic vibrations, i.e. the panel becomes a sounding board. Plastic sheets loaded with mineral compounds are the most common type of mass layer. These plastics have their best application in places where the mass layer must withstand high physical abuse. Because of its high density and low stiffness, vinyl is one of the best noise barrier materials and is the most commonly used mass layer in composite insulations. Lead sheet is an excellent sound barrier, which is non-combustible. Because it is classified as hazardous material, its use is generally limited to application mandating non-combustible materials.

C. Damping - Damping materials are typically in sheet and tile format, as well as sprayable and bushable compounds whether for extension or constrained treatments. Marine applications require attention to water and oil resistance as well as fire safety.

For attachment of tile and sheet damping adhesive systems must be matched to the stiffness characteristic of the treated surface. Easily applied peel and stick (PSA) is appropriate for thinner surfaces. Thicker, stiffer materials require bonding with high stiffness structural adhesives.

SECTION IV

PRACTICAL CONSIDERATIONS

Absorption - The acoustic absorptive materials act as sponges to soak up sound waves bouncing around in the engine compartment. Absorption materials may be omitted from small sections of the compartment wall without causing a significant increase of noise.

Barriers - The reflection barriers, including both the engine box and the mass layer within the composite, act as containers for the noise. Any leakage in either surface can cause a severe increase of noise transmitted to the cabin. For this reason it is very important to seal all of the acoustic leaks in the box and composite skins. The most critical leaks are those penetrating both the box and mass layer surfaces, as occur at an ungasketed access door. The necessary openings for ventilation should communicate to the deck or topsides through ducts or channels having linings of acoustically absorptive materials.

Damping - The primary consideration in determining the possible effectiveness of vibration damping treatment is the amount of resonance of the surface, prior to damping. If the surface has resonant booming, buzzing, or ringing, damping treatment may be useful. If the surface is completely rigid or already damped to " thud quality," due to its construction, addition of damping will give doubtful benefit.

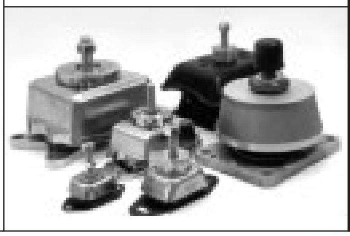
The primary factor, which limits the achieving of the full damping capability from installed damping, is ineffective bonding of the damping layer to the structure. Great care must be taken in selecting adhesives, preparing surfaces, and applying the materials.

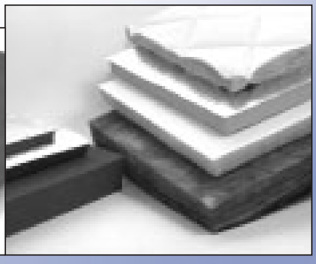
SECTION V

NOISE TREATMENTS INSIDE CABIN

Treatment can be installed within the cabin to further reduce the noise. An absorptive overhead material such as perforated vinyl over $\frac{1}{4}$" to 1" of foam reduces cabin noise caused by the engine, in the same fashion as acoustic ceilings work in a kitchen. These foam-backed materials also provide useful thermal insulation.

Noise may radiate from cabin flooring, as often happens when the engine room is located below the salon or poor engine mounts are carrying vibration into the cabin sole. In this situation an underlayment consisting of a plastic mass layer over a foam pad of $\frac{1}{4}$" or $\frac{1}{2}$" thickness can be placed below the carpet, giving a reasonable reduction of noise coming from this surface. Carpet alone will not give this effect, as carpet alone adds only absorption to the space.

17 Lime Street Suite 1
Marblehead, MA 01945
1-800-359-1036
www.SOUNDOWN.com

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3005 S.W. 2nd Ave. #102
Fort Lauderdale, FL 33315
1-954-761-9188
sales@soundown.com