HANDBOOK OF NOISE CONTROL MATERIALS

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SECTION I.

BASIC CONCEPTS OF BLOCKING AND ABSORBING SOUND.

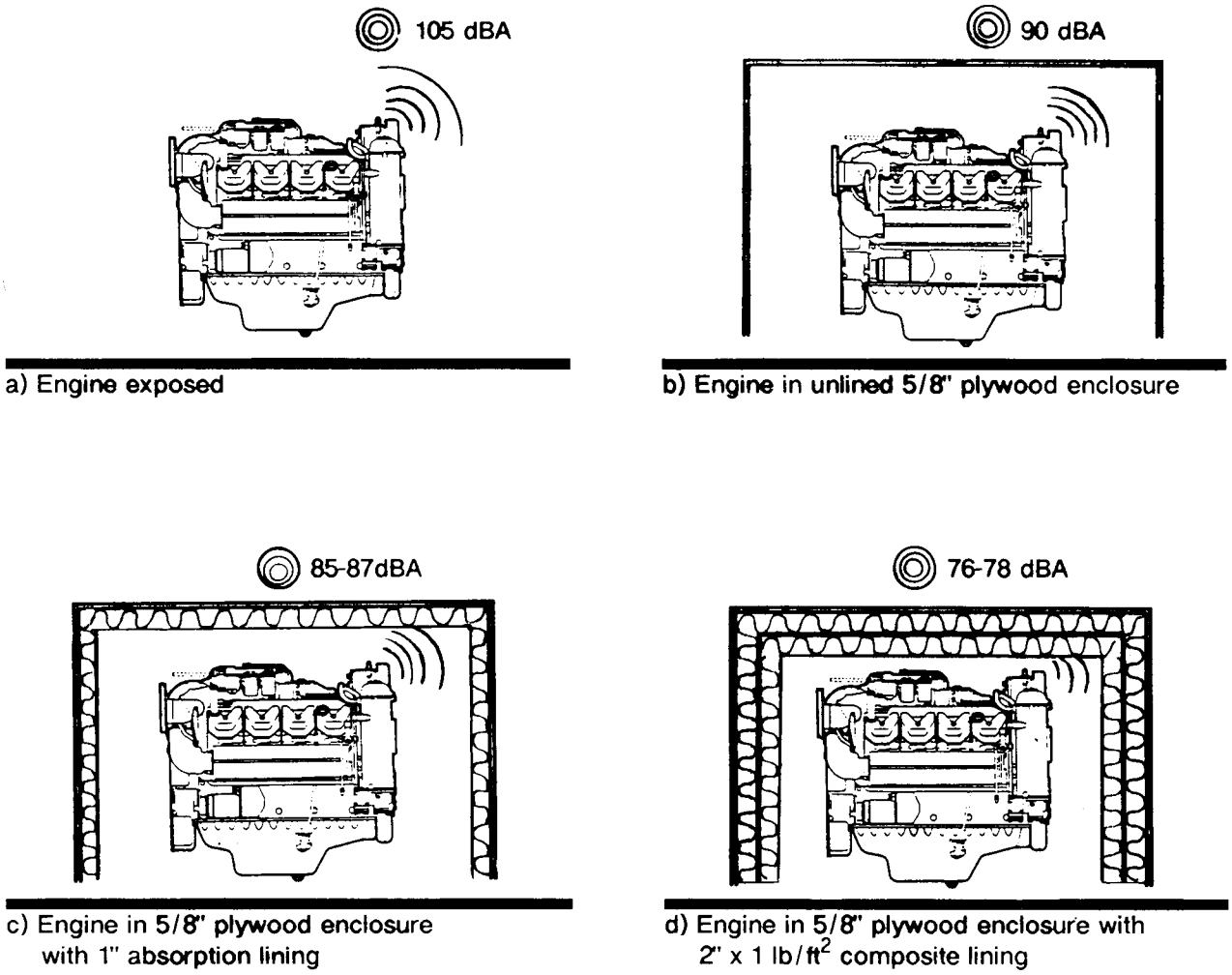
Acoustic insulation materials work by two processes: absorption of sound energy, which dissipates sound as heat energy, and reflection, which deflects noise away from a location where quieting is desired. Often a single composite insulation material will be effective as both an absorber and a reflector.

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 side 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 surfaced room. The noise near the engine, inside the box, is actually louder after the box is installed due to the reverberation effect.

The reverberation within the box can be reduced by absorbing a large fraction of the sound each time a wave strikes one of the walls. This is done by placing sheets of acoustic absorptive materials on the walls of the box. These are soft materials, such as fiberglass batts or open cell soft foam, with little stiffness or weight. If we install one inch 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 lead 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 lead, 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.

* dBA is an abbreviation for the A-weighted decibel loudness. This is the most widely used scale for rating loudness of different noises.



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

Fig.1 FOUR STAGES OF ENGINE BOX TREATMENT

SECTION II.

VARIABLES AFFECTING PERFORMANCE

The most significant variables for noise control materials are weight of the reflecting elements and thickness of the absorption and decoupling layers. Other factors such as protective surface facing materials and materials for the mass layer and the particular type of acoustic foam or fiberglass are 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 frequencies sounds of turbo chargers, gearboxes, engine valve chatter, and engine rattle, etc. are reasonably attenuated with an enclosure lined with a thin light weight composite. A composite using 1 lb/ft^2 of lead sandwiched between 1/2" 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 composites.

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

For the design of composites, mass layers are available at weights of 1 and 2 lb/ft^2 and the thickness of decoupling layers varies from 1/4" to 2".

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/ft² material on 1/4" decoupler is effective only above 500 Hz, and is generally not satisfactory for noise reduction in boats, except for special applications. The 2 lb/ft² material on 1/4" 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 it is generally necessary to use a decoupler thickness of 1/2" combined with 2 lb/ft² mass layer, or 1" decoupler with 1 lb/ft² mass layer. Greater thicknesses of the decoupler increase the bass frequency effectiveness, while heavier mass layers increase effectiveness throughout the entire frequency range.

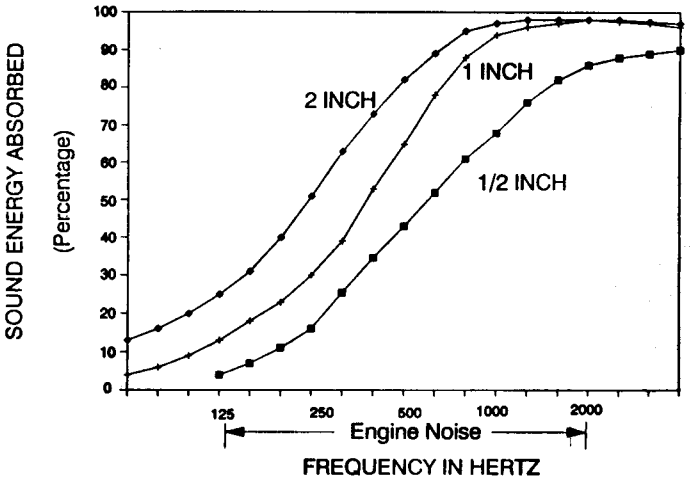


Fig. 2A Typical sound absorption values for fiberglass and foams of various thickness

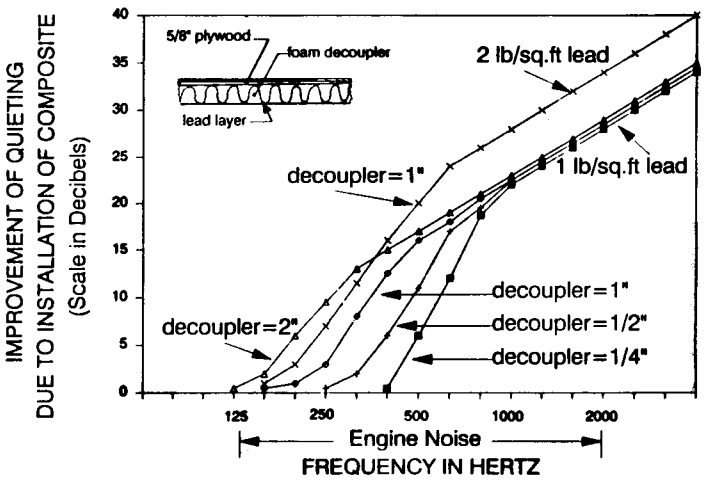


Fig. 2B Improvement of quieting due to addition of composite materials inside and engine box constructed of 5/8" plywood
(Varying decoupler thickness & weight of lead sheet)

SECTION III.

MULTIPLE MASS LAYER COMPOSITES (DOUBLE LEAD)

Many of the companies offering acoustic composites offer "double lead" products containing two mass layers, two decoupling layers, and a single absorption facing. These materials are very effective for high frequency noises, such as those from turbojet engines or locally generated around a turbocharger. However, because the installation of the second mass layer is introduced within the space of the ordinary single decoupler space, the double lead treatment ends up with two decouplers of one half the thickness of the corresponding single lead treatment. The consequence is that double lead treatments using 1 lb/ft² lead with two 1/2" decouplers provide a small improvement over a 1 lb/ft² single lead treatment for typical boat noise problems. For decoupling thicknesses of 1/4" or less, these materials are not appropriate for the most common problems of noise in boats, and generally, if the two decoupling layers are not each 1" or thicker, it is more effective and less expensive to purchase a composite using a 2 lb/ft2 mass layer and a single, thicker decoupler.

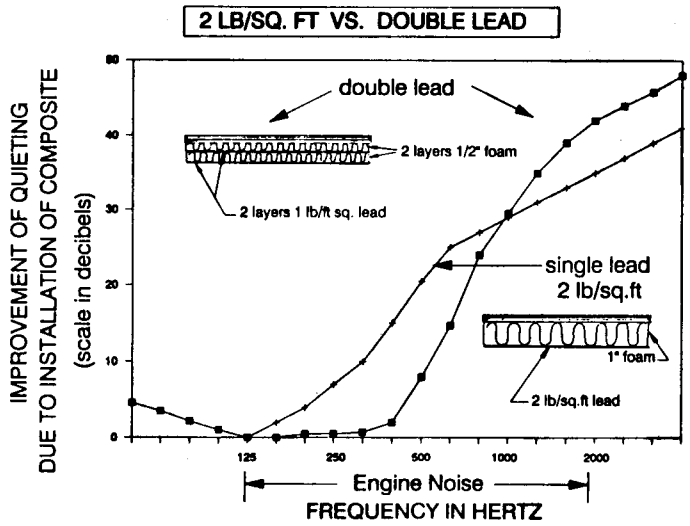


Fig. 3 Comparison of quieting improvement due to addition of composite materials inside a 5/8" plywood engine box.

SECTION IV.

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, and they should have protection against liquids and vapors (see facing), 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, therefore fiberglass materials must often be installed using mechanical fasteners and protective facings.

In most applications where Coast Guard inspection 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 light weight 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. Because of its high density and low stiffness lead is one of the best noise barrier materials and is the most commonly used mass layer in the composite insulations. Plastic sheets loaded with lead or mineral compounds are another type of mass layer. These plastics have their best application in places where the mass layer must withstand very high physical abuse.

SECTION V.

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.

Reflection barriers - The reflection barriers, including both the wooden engine box and the mass layer within the composite, act as containers for the noise, and 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 seal. The necessary openings for ventilation should communicate to the deck or topsides through ducts or channels having linings of acoustically absorptive materials.

SECTION VI.

NOISE TREATMENTS INSIDE CABIN

Treatment can be installed within the cabin to further reduce the noise. An absorptive overhead material such as the perforated vinyl over 1/2" to 1" of foam reduces cabin noise caused by the engine, in the same fashion which acoustic ceilings in a kitchen work. 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 saloon or when the engine mounts are carrying vibration into the cabin sole. In this situation a flooring pad consisting of a plastic mass layer over a foam pad of 1/4" or 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.