Cut That Racket!

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If, as the saying goes, your engine gets quieter every year, it may be too late for this information to help you save your hearing. However, if you are concerned about reducing sound levels inside your vessel, here are some points to consider.

First, a few words about sound. Sound is simply energy passing through a medium—air, wood, or whatever, and exciting molecules of those materials to vibration. Sound is measured in frequency and intensity, or loudness. For example, engine noises range in frequency between 125 Hz (herz = cycles per second) and 2,000 Hz. Intensity ranges from 60 decibels (dB), the level at which a whisper can be heard, to 140 dB, which causes pain in the ears, and beyond. Some diesel engines produce as much as 130 dB at operating speeds.

There are two kinds of sounds on a boat. Airborne sound, typically caused by main engines and generators, tends to be of relatively high frequency and radiates from its source through the air. Structural or inherent vibration also caused by engines, props, and other running gear, is of lower frequency and travels through the hull, decks, engine beds, and other structural components.

High frequency airborne sound from turbochargers, blowers, valve clatter, and exhaust noise is the more irritating of the two, but also easier to suppress. Structural vibration is a tougher problem and requires a different approach.

Principles of Sound Suppression

Sound suppression comes in four forms: reflection, absorption, isolation, and damping.

Any relatively rigid object, such as bulkhead or cabin sole, that is interposed between a source of sound and the boat's occupants will reflect some of that sound, and the more complete the barrier, the more effective. A wooden box built around an engine will reduce ambient sound levels by as much as 10-15 dB, a significant reduction but not enough to make living with a working diesel engine pleasant. Starting with, say, 110 dB, a 15 dB reduction is still going to leave you with a noise level high enough to cause stress, fatigue, and discomfort, and prevent normal conversation on board. Solid materials like plywood and fiberglass reflect some of the sound but pass on most of it, and in fact become something of a sounding board.

Most engine rooms have some type of sound insulation, usually either board of fiberglass batting or semi-open cell foam, contained behind a quilted metallic surfacing. These sound insulation materials provide some additional reflection, but more importantly they absorb or trap sound energy and dissipate it as heat. Absorptive materials are pretty effective on airborne, high-frequency noise, but less so on structural vibration.

Flexible engine mounts, flexible shaft couplings, and isolation drive systems which include a set of bearings that absorb thrust will reduce the transfer of engine and driveline vibration to the hull by isolating the noise-generating machinery from the structure. By isolating engine, reduction gear, and shaft vibrations (including some of the noise caused by prop cavitation) from the structural members, these "soft" or flexible mounting systems can reduce machinery-induced hull noise in some cases by more than 90 percent. Also, they may reduce engine installation and shaft alignment problems and can even prevent gear, shaft, and prop damage due to hard shifting and striking objects in the water.

Builders of custom yachts and high-speed passenger vessels are using special floor and wall materials to isolate passenger space from hull vibrations. Some are even building vessels with passenger and berthing compartments that "float" within the hull and superstructure on dense jelly-like mounts, to isolate occupants from inherent engine and drive train vibration, and from the sound of water passing over the exterior surfaces of the hull.

Sound damping is used effectively, particularly in aluminum boats but also in fiberglass and steel vessels. Some damping materials are self-adhesive and can be installed in a variety of locations. Any flat panel without support is a good candidate for damping, but damping materials can be applied in a cost-effective manner to hulls, bulkheads, tanks, cabin soles, and ducting. Butyl rubber materials like Dexdamp are impermeable, so there is no risk of inducing corrosion by trapping moisture against metal surfaces. Complete coverage isn't necessary; 50-60 percent is adequate. The damping material should be at least one-fourth the thickness of the metal being damped.

Inside the Engine Room

Installation of open-cell soft foam or spun glass acoustic insulation will absorb some airborne sound and reduce ambient levels by a few decibels; the thicker the layer the more effective. Acoustic fiberglass board and acoustic foam are products that are modestly effective and fairly inexpensive.

More effective sound materials contain a very thin but dense inner layer. Lead sheeting was used in the past but for environmental reasons, lead is being replaced by a heavy vinyl composite material. This mass layer or limp mass is typically one pound per square foot and sometimes as much as two pounds. It serves as a barrier and greatly increases the absorption effectiveness. A one-pound-per-square-foot mass layer sandwiched between two 1 inch layers of foam or fiberglass will reduce sound intensity by 12 to 14 dB, according to information published by Soundown Corp., one of the leading manufacturers in the field.

That means that a $^{5}/_{8}$ inch plywood box or engine compartment lined with this level of sound insulation will reduce engine noise by 20 to 30 dB, bringing it down into the level where spoken voice communication is possible.

The soft foam or glass layers are called decouplers, and are necessary to create sound-absorbent space between the mass layer and the rigid surface to which it is mounted. The greater the thickness of the decoupling layer the more effective it is, especially against the lower-frequency

noise. The thickness of the decoupling layer is just about as important as density of mass layer, and usually it is more cost effective (and installation is easier) to use acoustic insulation with thicker decoupling layers than more or denser mass layers. Insulation with two lead layers provides an advantage against higher-frequency (above 1,000 Hz) noise, such as might be produced by turbochargers. The density or weight of the reflective layer and the thickness of the absorptive and decoupling layers are the two factors that determine effectiveness.

In most applications the combination of one-pound-per-square-foot mass layer, and a one- to two-inch decoupling layer is satisfactory, provided installation is done correctly and the material is used in conjunction with other sound suppression efforts.

If fuel tanks are inside the engine room, and especially if they are metal wing tanks alongside the engine, you might consider applying self-adhesive sheets of Dexdamp 432, TC95, or a similar sound-damping material. Damping disrupts the resonant vibration of the walls of the tank. It doesn't have to cover the entire surface of the tank, only half of the side facing the engine. Damping materials are also effective on steel or aluminum bulkheads, plastic panels, and other surfaces that acquire vibration.

Dry-exhaust systems impart a great deal of sound into the engine room and compartments through which stacks pass. Exhaust insulation pads or blankets, custom-made to shape and laced on with stainless lacing hooks and copper wire, will have sound-dampening effect on exhaust pipes. They also lower engine room temperature, protect people from burns, and prevent fire in the case of a ruptured fuel, oil, or hydraulic line.

Muffler choice is an important consideration. Cheap, thin-walled mufflers radiate a lot of "shell noise" while more heavily-built units like the premium Cowl mufflers are considerably quieter in enclosed spaces. The muffler should be located as close to the engine as possible, where space provides. Where the exhaust stack or muffler is located inside a fiddley (vented compartment within the cabin area), barrier and absorbent insulation lining the inside of the passage makes a big difference. Just be sure not to block ventilation with insulation.

Wet exhausts are inherently quieter, but since they are also cooler, Dexdamp or other sound-absorbent material can be wrapped around to reduce sound levels significantly.

Barrier 104 combines absorption, decoupling, and a loaded mass layer to reduce noise.

Baffles placed in air intakes that twist the noise 180° can reduce the amount of noise that escapes the engine room to the exterior of the vessel. Just take care not to restrict the flow of air.

Materials

Several manufacturers make similar acoustic insulation materials. Supreme Sonolead, Leaded Hullboard, and Navy Hullboard all have a one-pound limp mass (lead or vinyl composite, depending on manufacturer) sandwiched between two acoustic fiberglass boards. The surface intended to face the noise source can be either perforated or a white or aluminized polyester film. The non-perforated plastic facing, designed to be a moisture and oil barrier, should always be used in engine rooms. Fiberglass acoustic insulation normally comes in panels, typically 2×3 feet.

Barrier 104 and similar products consist of a one-pound loaded mass layer between decoupling and absorption layers of semi-open-cell urethane foam. A couple of different thicknesses are offered. It is sold in sheets, typically 32×54 inches, and can be easily cut to size. Barrier 104 and similar products by other manufacturers also have an aluminized polyester film oil-barrier surface.

The choice between fiberglass and foam is based on several factors. For similar sound-suppression qualities, fiberglass is a little thicker, slightly more expensive, harder to cut and fit to shape without tearing and flaking off, and it requires mechanical hangers to hold it in place. Its biggest advantage is that it is resistant to chemicals and vapors, and some types, such as Hullboard, are fireproof. Inspected vessels (such as passenger boats) are required to have fire-safe machinery spaces, and some Coast Guard inspectors specify fireproof fiberglass insulation. Foam insulation is flame-retardant or self-extinguishing, and generally quite safe to use in engine rooms, it is technically not fireproof. It is easier to work with and usually can be installed with contact cement or spray-on adhesives.

Ordering and Installation

The most cost-effective way to buy acoustical insulation is to measure the dimensions of all the surfaces to be covered, draw them out on paper, and send the paper to a dealer who can cut the panels or sheets to the correct size. That way you pay for only what you use. Most people just estimate the area to be covered and buy the sheets or panels, and cut them when they are ready to install them. They can use scraps to insulate lockers, to stuff into wire and hydraulic line chases, and behind removable panels.

It is much easier and less expensive to apply acoustic insulation when a boat is under construction, or during a major refit when machinery, tanks, decks, and so forth are removed. But sound suppression materials can be effectively installed in an existing vessel if you have the patience to remove items attached to the bulkheads and wriggle into tight spaces to fill all the absorptive space voids.

Application of fiberglass boards requires use of specially made hanger pins with washers, which are installed at about 18-inch intervals, or one per square foot. Edges have to be taped to protect against chafing and to ensure a snug fit. Perforated aluminum

panels or grates may be used, particularly on overhead spaces, to keep fiberglass boards in place. These have to be held in place with screws.

Foam sheets can be cut with a razor or sharp knife, and the loaded vinyl layer with scissors. If spray-on or brush-on adhesive is properly applied, the sheets will stick immediately. Be sure not to use more than the recommended amount of adhesive, or the excess will soak into the foam and reduce the bond. Over time there is the risk that foam insulation could separate and drop onto hot manifolds or spinning pulleys and belts, so it is a good idea to use some hanger pins with washers to keep it firmly attached to overhead surfaces.

Where you need to install a connector through either type of insulation, such as for a filter bracket or cable clamp, it's best to slice through the insulation to make a mounting space rather than to put a screw or bolt through and compress the insulation to tighten the connection.

To contain engine noise, the overhead and all sides, including the hull, have to be insulated. The barrier or reflective covering must be as complete as possible, and all acoustic leaks should be sealed. As little as 15 percent of the reflective space open can allow as much as 50 percent of the sound out. That means that engine rooms or compartments must be fully enclosed, with tight-fitting and preferably gasketed hatches or doors, and no gaps in corners or around chases for wiring or plumbing. Air vents must open to the outside, not into the living space, and should be baffled with acoustic material. The hull sides need only an absorber, not a sound barrier layer, so that sound can dissipate and pass out

In the Living Space

Insulating the inside of the engine compartment is the biggest but not the only part of reducing ambient sound levels. Several types of loaded vinyl barrier material can be used as backing pads between the carpet and the cabin sole. One, called WB10, is simply a 1/16 inch dense vinyl sheet. Barrier 155 and Barrier 662 have acoustic foam layers attached and consequently are thicker. They come in four-foot-wide rolls and can be easily cut to any shape. In addition to floor matting, they can be used to line enclosures or as sound baffles in places like air ducts. Carpet alone will not block much sound.

Since sound essentially bounces off all hard surfaces inside the boat, it can be useful wherever practical to apply sound deadening materials to the interior. One easy way is to use perforated vinyl headliner over a half inch to one inch of acoustic foam for the cabin ceiling. Damping material can also be applied to surfaces that transmit structure-borne noise, inside lockers, behind helm panels, and against the inside of the hull in trunk cabins.

It may not be possible to do a complete sound reduction job all at once. Install a primary insulation and damping system, then run the boat at different speeds and loads while listening for the sources of noise. It may help to wear ear protectors to filter out the ambient noise to help you locate particular point sources. Then, go back with extra materials and plug up those sound leaks.

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