MINIMIZING NOISE IN TRAWLERS

Part One

Like many others on the Willard list, I started my boating career in sailboats. For me, one of the great appeals of sailing was its comparative quiet. It is very difficult to escape from noise in our modern environment but while on the sailboat the loudest noise I had to contend with was the rattling of the halyards. My transition to trawlers provided a rude awakening. Trawlers are noisy. I was told by other trawler owners to live with it. It goes with the territory.

There are several approaches to dealing with a high trawler noise problem. You can simply do nothing, pretending you are driving a slow unlimited class hydroplane or a Harley with a gutted muffler. Of course you may need a hearing aid in a few years. An alternative approach is to use ear plugs or external "Mickey Mouse" sound absorbing ear protectors. These are cheap. Single use ear plugs such as those sold by Flents or E.A.R. sell for about 25 cents a pair. External ear protectors cost about $10. Both will provide about 30 dB of sound attenuation. Either can be bought at an industrial supply or hardware store or in a gun shop. The downside is that they attenuate all sounds and shipboard conversations must be carried out by signing.

If you are technically inclined you can try a noise cancelling system. This approach has been suggested for aircraft cockpits and luxury cars. A microphone picks up the ambient sound. An amplifier circuit reverses the phase by 180 degrees and drives a loudspeaker. The two out of phase sound waves cancel each other and comparative quiet reigns. The zone of silencing is limited in area. If you move very far from the loudspeaker, the sounds may no longer be out of phase and may even be amplified, creating a noisier environment than before. Normally automobile drivers and airplane pilots don't get out of their seats and wander around the cockpit. A more portable solution is a pair of sound cancelling earphones such as those sold by Bose. These cost about $300 each. A considerate skipper will provide a pair for each crew member and guest.

Naturally, if you throw enough money at the problem, it can be solved in a more direct manner. In its new line of fiberglass high performance powerboats, the DS 45 and DS 53, Linssen has achieved an astounding level of acoustic silencing. Even at 30 kts. Linssen advertises up to 40 dB of sound attenuation between the engine room and the boat's wheelhouse and living quarters. Of course these are luxury boats with a base price of over $1,000,000. Patrick Gerety, former manager of Willard Marine's recreational line once told me that the last W30 series of trawlers carried $10,000 worth of acoustical insulation because upscale buyers demanded silence. I tend to believe him.

But I suspect that Willard, and many other trawler manufacturers are going about sound and vibration minimization the wrong way. You can't just muffle a noise producing device cheaply. It takes sound absorption materials and mass, correctly applied in layers of sound insulation. Automobile manufacturers faced this problem years ago and came up with other solutions. Look under the hood of your car. You will find very little insulation to contain the sound and vibration of a lot of moving machinery. What the auto makers did was to develop ways of decoupling the noisy and vibrating components from the structure of the auto body. Only a small amount of acoustic insulation is necessary to keep the airborne noise out of the assenger compartment.

In my youth I trained as a physicist and, for a while specialized, in acoustics. I was a member of the Acoustical Society of America and published about a half dozen articles on sound and vibration control methodology. For a period during my obligatory military service I was in charge

of a program at the U. S. Army Acoustics Lab at Fort Knox devoted to silencing the interior of armored vehicles, a project which was terminated when the Army felt my services were needed on the front lines in the Korean War. That was nearly a half century ago but I used the few tricks I picked up in trying to make my own non-luxury boats relatively quiet.

BACKGROUND

Noise is simply defined as unwanted sound. The operative word here is UNWANTED. If you are a rock fan you may be perfectly happy blasting out Def Jam to the limit of your stereo speakers capability while your chamber music loving neighbor in the next slip is dialing the police with shaking fingers. The sound level in his boat may be one tenth of that in your saloon but to him it is still noise.

But, in addition to being irritating, loud noise has other effects. It can make it difficult to hear radio messages and acoustic navigational signals. Extended exposure to high level noise can inhibit the ability to concentrate and can cause ear damage, raise blood pressure and trigger other health problems.

Before we get too deeply into noise reduction, let's talk for a minute about how sound is measured.

Sound pressure is measured on a logarithmic scale using a unit called the BEL. Named, of course, after Alexander Graham Bell. Each BEL increase or decrease is a 10 times increase or decrease in the sound pressure. For convenience the BEL is divided into 10 parts or deciBELs (dB). A change of approximately 3 dB indicates a doubling or halving of the sound pressure level.

But those are physical measurements. They only loosely correspond to the perception of loudness of a sound. The human ear responds to changes in sound pressure with its own logarithmic system. The range of human hearing is enormous and covers a 120 dB range from the threshold of hearing to the onset of auditory pain. That's a trillion times difference in sound pressure. A 3 dB change, or halving of the sound pressure is barely noticeable. A 6dB drop in sound pressure will produce a trivial change in loudness. It takes at least a 30 dB reduction in sound pressure for a sound attenuation method to make a real difference. That represents a 1000 time reduction in the sound pressure level.

Manufacturers who sell sound reduction equipment rarely indicate the reduction in perceived loudness, merely the reduction in physical sound pressure as measured in dB. They hope that the typical user will confuse the two measures and believe that a 50% reduction in sound pressure corresponds to a 50% reduction in loudness. It does not. It is a barely noticeable change in loudness.

PART TWO

Powerboats are perceived as noisy for several reasons.

First, internal combustion engines are remarkably efficient noise generators. They operate by a series of explosions in the cylinders and release pulses of energy in the exhaust. Valves open and shut interrupting the flow of air in the intake manifold, each interruption creating a wave of sound. And the gears, pumps, turbos and injectors add to the cacophony.

Second, human ears are very sensitive. The threshold of hearing at 1000 Hz is .0002 dynes/sq. centimeter. To put it into terms more familiar to the average trawler owner that works out to .00000013 hp. A small amount of energy indeed. Ten watts of acoustic energy, a tiny fraction of a horsepower, in the middle of the hearing range, would drive us screaming from an engine room. Continued exposure would cause permanent hearing loss. No wonder so many band members are partly deaf from playing in front of their 150 watt sound systems. Unfortunately so are many of us from a lifetime of exposure to noise.

Finally, the boats themselves are effective at transmitting sound throughout their interior. Most of what we think of as noise in a fiberglass boat is really structure borne vibration which forces the relatively thin boat panels to resonate. Minimize structure borne vibration and you go a long way toward making a boat quiet. And it doesn't require $10,000 of after the fact noise insulation. Just a little attention to the physics of sound and vibration control will do it.

NOISE CONTROL ACTIONS

If you want to minimize the noise in recreational boats, you should take the following actions, arranged in rough order of importance.

First, and probably the most important, is to prevent engine generated vibration from being transmitted to the boat's structure. The engine should be mounted on soft rubber mounts designed to provide at least 80% vibration isolation. More isolation is better. Usually that means that the weight of the engine will compress rubber mounts by .05" to .1". But since the engine will move a fair amount with this level of isolation, a flexible connection with the drive shaft is necessary. Elastomeric doughnuts such as the Drivesaver or PYI between the coupling flange halves will provide a minor reduction in vibration. The best approach is to use a double constant velocity universal joint coupling. Examples are the Scania, the Aquadrive, and the Evolution couplings. These all include a thrust bearing that transmits prop thrust directly to the hull and spares the engine mounts the necessity of handling engine thrust as wall as vibration. All engine connections, fuel lines, and controls must be capable of dealing with engine motion.

Second, the engine should be provided with adequate mufflers both on the intake and exhaust. Exhaust muffling is handled relatively well in wet exhaust systems using an Aqualift type muffler. The injection of water into the hot exhaust cools the exhaust and extracts some of its energy. The large volume of the muffler smooths out the exhaust pulses. Additionally the long rubber hose to the exhaust outlet used by most boats further attenuates the sound. If the exhaust is not quiet enough after all this processing, an inline exhaust muffler, such as those sold by Vetus, can be added to the exhaust line. Dry stack exhausts must be muffled in the same manner as a car. The muffler should be a large chamber with baffles. Entry and exit pipes should be tuned to minimize sound at the cruising RPM. Just letting the exhaust exit through a tall pipe above the deck doesn't do it.

Intake mufflers are often overlooked in marine installations. The intake valves interrupt the air flow into the engine up to 50 times a second creating sonic pulses whose harmonics are well within the hearing range. If you look under the hood of your car you will see that the intake muffler/air filter consists of a large cylinder or box with a relatively small intake port. The combination of the air filter and restricted opening attenuates the intake sonic pulses. Run your engine with the air filter open or off and you will hear the difference. On many boat diesels the filter consists of an oil saturated metal gauze which works admirably to keep dust particles from the engine innards but does little to block the sound. An Airsep type filter does a better job of noise control.

It is amazing how much sound can get through a small hole. The bulkheads of the engine compartment are penetrated by many ducts and cables, each of which can offer a pathway for engine generated noise to escape. So the third step in noise control is to close all openings in the engine room leading to the living spaces aboard the boat.

Many of these openings can be sealed or gasketed with little interference with function. If a throttle or enclosed shifting cable runs through a hole in the engine room bulkhead, seal the gap with a blob of silicone caulking. The same for electrical wiring or conduits or even exhaust hoses. Silicone caulking is fireproof and can be pulled out if replacement or repair of the cable or wiring is necessary. Some openings are required for air intake and ventilation. These should exit outside the hull whenever possible and be covered by louvers directing the sound away from the living spaces.

Acoustical texts are replete with techniques of suppressing sound transmission through ducts. Most of these involve making several right angled bends in the duct and lining the interior with sound absorbent material. Few are practical for the engine compartment. What is practical is making a single right angled bend in ducts for air intake and ventilation, and using a sound absorbent lining. Alternatively, the hole in the compartment wall can be covered by a large baffle at least 6" in diameter greater than the hole. The baffle, covered with sound absorbent material on the side adjacent to the entry hole, should be spaced 3" from the hole by several dowels or spacers. This will permit air to enter or exit yet block some of the high frequency sound emanating from the compartment.

Part Three

The walls and overhead of the engine compartment and large panels in the living space should be treated so vibration is kept to a minimum. If vibration transmitted through the boat structure excites a panel or bulkhead into a sympathetic vibration, it doesn't matter how much effort you have expended in sound treating the engine room. It's just like having a loud speaker in the living space blasting out engine sounds. One way of minimizing panel vibration is to add viscous mass. In automobiles a rubber based undercoating is applied to thin metal panels to change their vibration characteristics. If a panel vibrates and the back side is accessible, this is a convenient and cheap solution. We used a modified undercoating in the inside of tanker's helmets to stop them from vibrating like a bell when the 50 caliber machine gun was fired. Auto grade undercoatings are generally not used in boat engine rooms because of the potential fire hazard. However, in the saloon, undercoating is no more dangerous than a teak panel. For engine rooms I have used Silent Running SR 1000, a USCG approved water based vibration and sound dampening material made by Current Composites of New Haven, CT (www.silentrunning.us). Other manufacturers make similar materials.

Another way of minimizing panel vibration is to stiffen the panel by gluing or screwing rigid battens to the backside. Shelves or picture frames fastened to the front serve the same purpose. What you want to do is change the natural frequency of the panel so that it does not vibrate in resonance with the engine. The best way to impede sound transmission between rooms or compartments is to use a brick and mortar wall. About 12" of brick and mortar will reduce the sound transmission by 60 dB. It goes without saying that this is only practical in the largest of boats, perhaps in the QE2 range.

Eventually, you will want to apply sound treatment to the interior of the engine compartment and living spaces. The mistake most people make is using sound absorbing material as the first step in a noise reduction program when it should come near the end.

Sound absorbing material is expensive and a great deal more will be needed if you don't control sound at the source. One of the best ways to do this is to construct a box around the engine using heavy materials. A heavy gauge steel or sturdy plywood enclosure around an engine would work extremely well as long as the box extends down to the engine bearers. This approach is impractical for most trawler main propulsion engines but is the method of choice for generators and auxiliary power sources. The interior of the box should be lined with heat resistant sound damping materials and the air intakes should be baffled.

All common sound absorbing materials work by converting the energy of vibrating air particles in the sound wave into heat which is then dissipated into the surrounding surfaces. To effectively capture the sound wave, the absorbing material must have a thickness of at least a quarter of a wave length of the sound in air. Since sound travels at approximately 1100 feet per second, a wavelength of a 1000 Hz sound is about 11 inches. This means that if we use a fluffy fiberglass absorbing material, it should be 2 1/2 to 3 inches in thickness. Higher frequency sounds require less material, low frequency sounds, more material. We can get by with a thinner sound absorbent layer if we add mass to the capturing medium. This mass is usually in the form of heavy particles distributed through the absorbing medium or by incorporating lead membranes between layers of foam or fiberglass. The sound wave is weakened by using its energy to move the mass. Lead membranes in sound absorbing material also reflect some of the sound back toward the source.

Typical non-weighted sound absorbing materials are made of foam or fiberglass covered with a mylar or vinyl facing. The acoustical properties of foam or fiberglass are the same but fiberglass is much more fire resistant and is suitable for engine compartments. USCG rated 2" thick fiberglass with an acoustic scrim facing costs about $4 a square foot, foam or non-USCG rated fiberglass between $2 and $3 a square foot. The acoustic material is available in sheets up to 4' x 8'. The material is attached to bulkheads and overheads with adhesive. One or two battens per section may be required to hold it in place for security. Particularly noisy engine rooms will profit from using lead composite insulation consisting of one or two lead membranes sandwiched between layers of foam or fiberglass. The lead composite material weighs 1 to 2 lbs per square foot depending on thickness. It is heavy stuff. A typical engine compartment in a 40' trawler might well use 200 lbs of lead composite insulation. Costs are higher than for plain foam or fiberglass. A square foot of 2" thick, 1 lb/sq. ft. fiberglass lead composite insulation with a white mylar overlay costs $6. The 2 lb/sq. ft. fiberglass lead composite insulation costs about $8.50 per sq. ft. As might be expected, lead fiberglass sandwiches using all USCG approved materials are more expensive, each square foot running $7.50 for the 1 lb. weight and $10 for the 2 lb. weight. These are retail prices. A search of the internet might find better values.

If you install fiberglass or lead composite fiberglass materials on the bulkheads and overheads of the engine compartment, be aware that fiberglass has a tendency to separate from itself. The edges of the panels should be wrapped with a mylar tape to hold the material intact. Most insulation suppliers will cut the material to a pattern and wrap the edge for you. Installation is by either adhesive, reinforced by judiciously placed mechanical fastenings; or, by covering the insulation with pegboard or perforated aluminum. For steel or aluminum boats, the insulation is usually cut to fit between the angle stiffeners.

The final step in silencing a boat is to use acoustic carpet underlays in the inhabited areas. I assume that your boat has carpets rather than teak and holly flooring. Acoustic carpet underlay material is similar to the sound insulation used for walls but is covered with a fiber carpeting material. It is also available in a lead composite composition. The material is sold in rolls, usually 4 1/2 feet wide, of unlimited length and is cut to fit on the site by the installer. Adhesive holds it in place. Your Persian rugs are placed over it. The cost for the fabric material is between $10 and $15 per linear foot of the 4 1/2 ft. roll. I would use this underlayment in any carpeted boat because it will suppress sound coming up from the mechanicals and it doesn't cost much more than normal carpet underlayment. The Persian rugs are optional. Then hang up a lot of drapes and soft fabrics to prevent reflections from hard surfaces and cover the overheads and bulkheads with fuzzy woolen carpet. Just kidding! I wanted to see if you were paying attention. (But it wouldn't hurt.)

There are a number of suppliers of acoustic treatment materials. The most complete listing is in a professional engineering magazine named "Sound and Vibration" available in most engineering libraries. You can also read it on the internet if you google "Sound and Vibration."

The order of steps taken to minimize noise should be:

1. Isolate and reduce engine vibration from the boat structure.
2. Close off all openings from the engine space to the living compartment.
3. Muffle the exhaust and intake.
4. Make sure all air intakes and ventilation ports open to the outside.
5. Minimize panel vibration.
6. Sound treat engine room and mechanical equipment compartments.
7. Carpet living areas. Use sound absorbing underlays.

8. Relax with a cold beer.

If you follow the sequence steps I have listed you can make your boat as quiet as the $1,000,000 Linssens. You may even be able to hear your cat purr.

Larry Z
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