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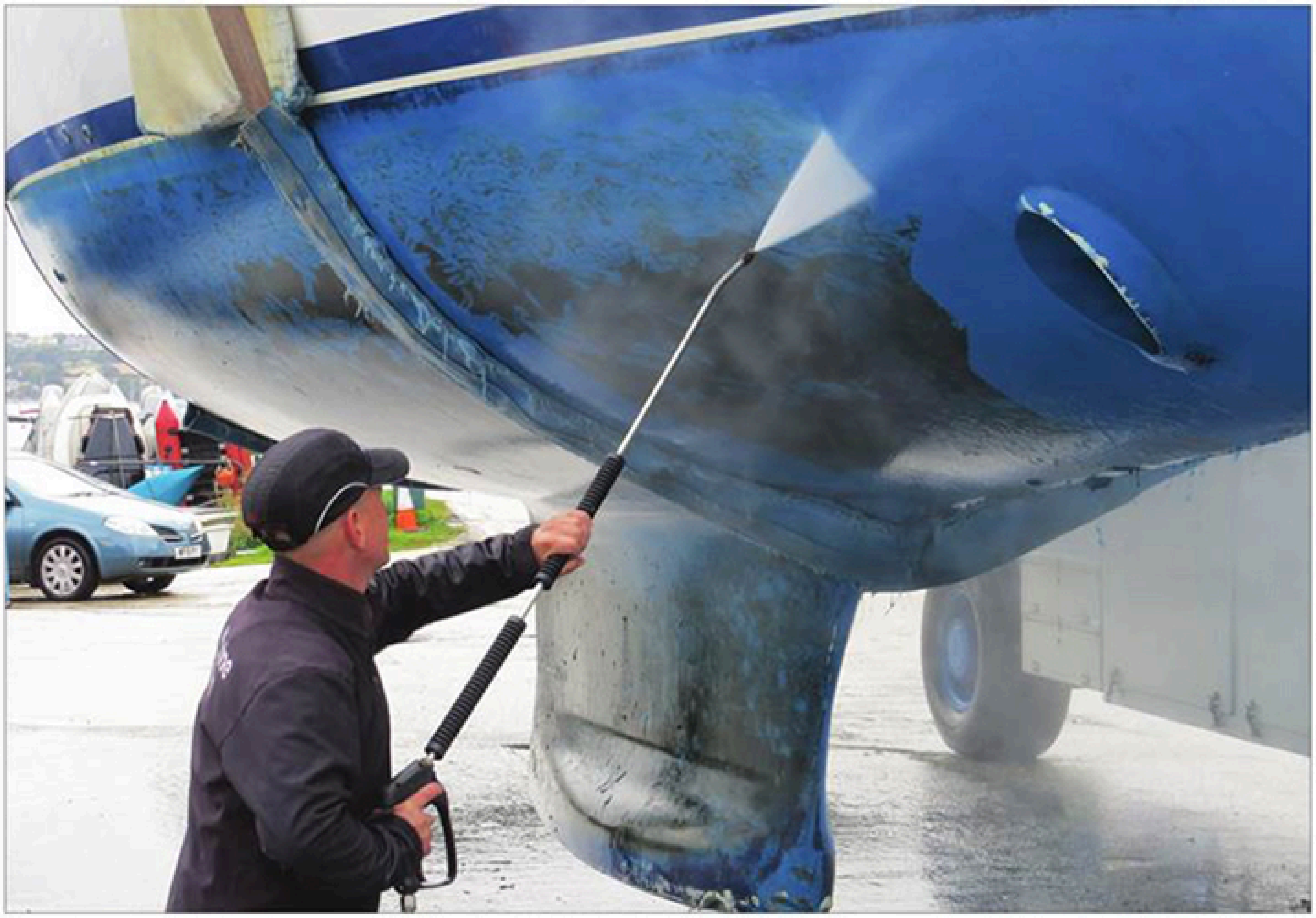
INFUSION REPAIR
SOLAR PROPULSION
ULTRASONIC ANTIFOULING
TAMPA YACHT MANUFACTURING



Frequencies of Fouling

The author finds promise in ultrasonic antifouling technology as a nontoxic supplement to traditional copper-based paint.

Text and photographs by Nigel Calder
(except where noted)

Minor fouling that settled on the hull in spite of the ultrasonic antifouling is easily swept from the bottom of the author's boat during an annual haulout. Note the complete absence of hard fouling such as barnacles.

Over the decades, I have experimented with several different antifouling products and approaches. These have almost always been disappointing, and as a result I have invariably defaulted to the highest-copper-content antifouling paint I can find, with my favorite being Pettit's Trinidad. Its red paint has 75%-cuprous-oxide content, while the blue has less. Unfortunately, the paint is shockingly expensive, with a list price of over $400 a gallon (although it can often be found at around $250 a gallon), and increasingly environmentally unacceptable. Legislatures are beginning to take action. Beginning in January 2018, Washington State will ban the sale of new recreational boats less than 65′ (19.8m) in length with copper-based antifouling paint, and it is requiring copper-based antifouling paints to be phased out on all recreational boats by 2020. The search for a viable alternative continues.

Two years ago we installed an ultrasonic antifouling system on our boat. At least five manufacturers have jumped into this technology—Sonihull, Ultrasonic Antifouling, Ultra-SoniTec, CMS Marine's SonicShield, and Harsonic. Our system comes from Sonihull, a United Kingdom-based company with considerable experience whose products are distributed in the U.S. by Seattle-based PYI. I chose Sonihull because I have a great deal of respect for PYI and the research it does before taking on board any new products. System costs run roughly between $2,000 and $3,000.

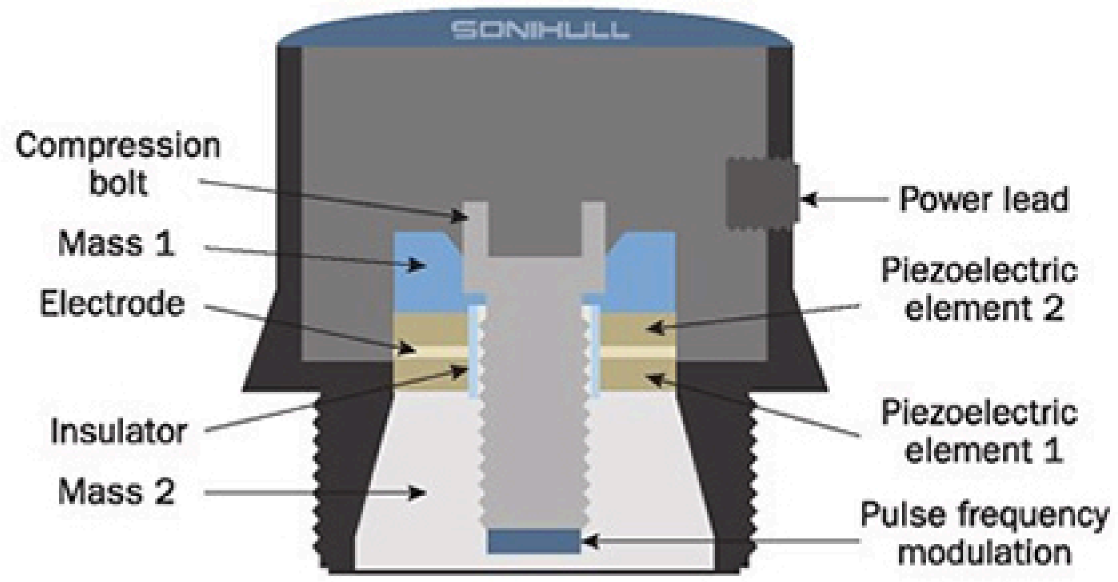
The Theory

There is nothing new about the technology itself. You can find technical papers on the Internet going back to the late 1960s describing how it works. (My dentist father was using it to clean his instruments decades ago.) According to Wikipedia, the initial research on antifouling was prompted by sonar tests conducted by the U.S. Navy in the 1950s in which it was found the areas surrounding the transducers were cleaner than the rest of the hull. Recent research has been stimulated by the changing regulatory frameworks governing the use of antifouling paints, and the cost-effective adaptation of modern electronics to this application. Concurrently, there has been significant research into which acoustic frequencies, at what power levels, and for what durations, are required to effectively deter marine growth.

Here's the theory. All the devices on the market create pulsating acoustic waves in a *piezoelectric* transducer that is rigidly connected to a hull or other solid medium such as pipework, valves, or heat exchangers in a cooling system. (Although I look only at hulls, Sonihull and others have had considerable success preventing fouling in seawater and freshwater cooling systems, including at an industrial scale on ships and ashore.) The transducers cycle through a range of frequencies from 20 kHz (20,000 cycles a second) up to as high as 100 kHz. The acoustic waves are transmitted through the hull, agitating water molecules in contact with it. This discourages algae (the building blocks within the food chain that result in seaweed and barnacle attachment and growth) as well as cyprids (larval barnacles) from settling on the hull.

For the algae and cyprids that do manage to settle, there is an additional defense mechanism. The critters each have a natural frequency. And when they coincide (or resonate) with the varying frequencies transmitted into the water by the transducers, a considerable amplitude of the vibration results, causing cell damage and death. In the absence of live critters, the food chain is disrupted and no other growth occurs.

Certain frequencies cause microscopic cavitation in the water around the boat—the formation of tiny bubbles—while other frequencies cause the bubbles to collapse, generating microscopic shock waves. These shock waves also damage cells and help to dislodge dead critters from the hull surface. Some minimal growth is washed off when the boat is under way. Any remaining debris is easily brushed off.



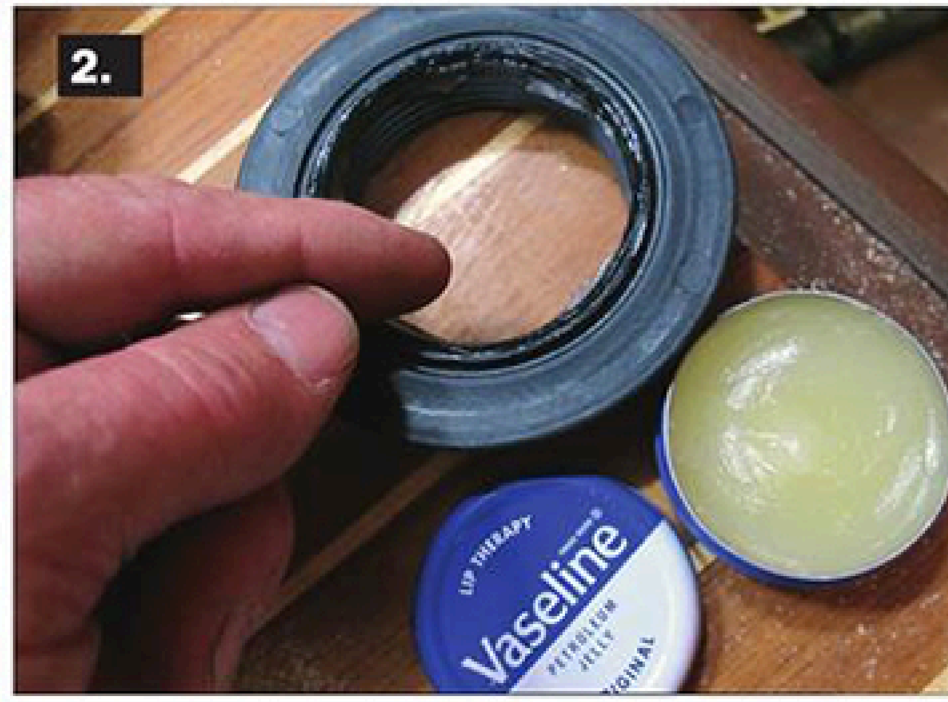
Mounted on the inside of the hull, a typical piezoelectric ultrasonic transducer (this one from Sonihull) cycles through a range of frequencies that are transmitted through the hull to disrupt the adjacent water molecules, thereby inhibiting the growth of algae and larval barnacles, among other common forms of marine fouling.

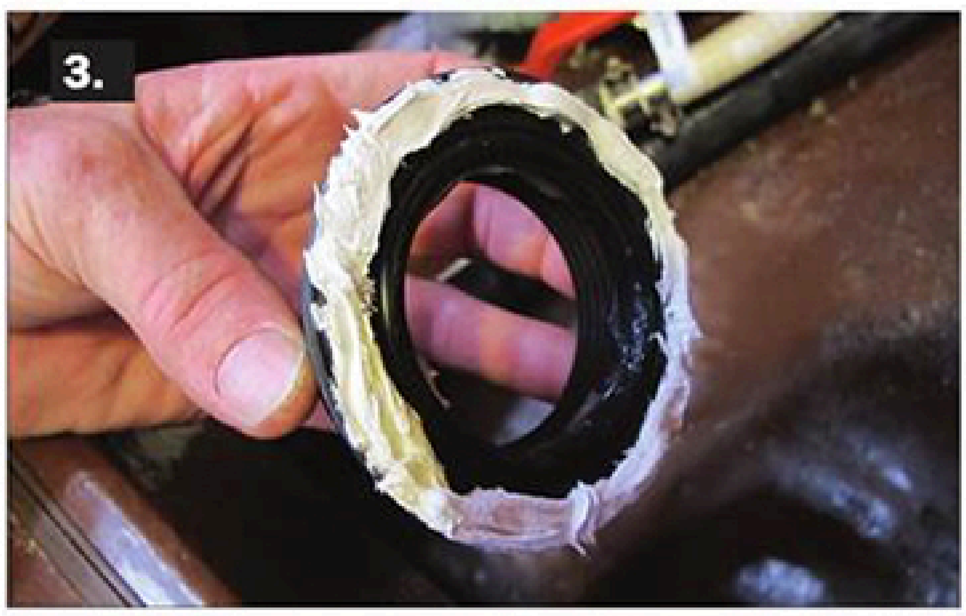
Transducer Installation

The equipment for ultrasonic antifouling consists of two core components: the control module, which generates the acoustic signals, and the transducers, which transmit the acoustic waves to the hull. Installation involves bonding the transducers to the hull, plugging them into the control module, and supplying power to the control module.

Because transducers need to transmit acoustic energy directly to a hull, they do not work if installed over cored sections. For installation in cored laminate the core must be stripped out and the inner skin bonded to the outer skin in the transducer location. Ultrasonic antifouling systems will not work on wooden hulls, because the wood absorbs the signals. They work best on single-skin fiberglass hulls and on metal hulls, although in metal hulls it is important that transducers be located at least a foot (305mm) away from bulkheads and other structures such as integral tanks fastened to the hull, as these will tend to dampen the acoustic vibrations. Careful engineering will be required on larger metal-hulled vessels with thick plating.

Good performance depends on getting a solid surface-to-surface connection between the face of the transducer and the hull.





1—The first step of installing the transducer is to prep an area of interior hull laminate with a thorough cleaning and light abrasion. 2—Prep should also include applying petroleum jelly to the mounting ring's internal threads to prevent any excess squeezed-out epoxy from sticking to them. Take care not to get any on the face of the ring. 3—Next, the face of the transducer or the mounting ring, depending on the model, is prepared with a generous amount of epoxy. 4—The ring, or transducer, is bonded directly to the hull and allowed to cure. 5—Lastly, the cables are connected to the transducer. In models where cables are permanently attached, take care to bundle them out of the way while the transducer is screwed in and to allow plenty of slack to accommodate future transducer adjustment and maintenance.

Good performance depends on a solid surface-to-surface connection between the transducer and the hull. One way to assure this is to cover the face of the transducer with epoxy and bond it directly to the hull, allowing the uncured epoxy to fill any unevenness to create a solid, void-free connection. The other is to bond a mounting ring to the hull into which the transducer is screwed once the epoxy has set up. Some models employ petroleum jelly or a similar material to fill the voids between the transducer and the hull; others a metal disc smeared with epoxy and inserted into the mounting ring before the transducer is screwed in.

Some transducers come with attached cables that must be held in a bundle and rotated with the transducer until it seats fully into the sealing ring. Others come with plug-in cables. The attached cables are generally preferred, as this creates a watertight cable connection; the plugs on plug-in cables can be difficult to thread through tight wire chases. If the cables are attached, during installation a sufficiently long loop of cable should be left at the transducer to enable it to be unscrewed if necessary. If this is not done and the transducer needs to be unscrewed or tightened for any reason, the cable will have to be disconnected at the control module and at least partially withdrawn from its cable duct or harness (which, depending on the installation, may not be easy) to provide enough slack. In most cases, transducer installation is remarkably easy, does not require a boat to be hauled out of the water, and takes very little time.

Isolated components and appendages are often not well served by ultrasonic systems. Locating a transducer directly over the rudder, or so that it resonates through the rudderstock, helps make it more effective.

How Many Transducers?

Common systems require from one to four transducers for most installations on pleasure boats up to 60′ (18.3m). Additional transducers can be used to cover vessels of just about any size, and a number of superyachts up to 200′/61m, and one or two commercial ships, now employ these systems. As you might expect, those with fewer transducers claim they have more powerful or effective systems that don't require additional transducers, while those with more transducers claim they get better results. I have no way of judging competing claims.

The theoretical coverage of the commonly used 50-watt transducer is a circle around the transducer with a radius of 15′ (4.6m), but the practical radius can be substantially less. Bill Hadley of Ultrasonic Antifouling (Poole, United Kingdom) notes: "The reports overall have been quite favorable, with the exception of those that installed too few transducers for the size of their boat, and/or have installed systems with low-power transducers. They tell us that where the transducers are installed they are getting good antifouling coverage, but there are areas of their hulls that are not being treated. On visiting a few of these vessels, it was confirmed that the areas of influence were obvious, as there was absence of growth, with a tapering off of coverage, and peripheral areas experiencing heavy growth."

Hadley continues: "We have also found, not surprisingly, that the area of influence is not symmetrical, and is affected by internal structure. On a retrofit installation, there is really no easy way of mapping the projected resonant signal to optimize the coverage area. We have found that, even with our 50-watt-peak-output transducers, it is best to use a 15′-diameter [7.5′/2.3m radius] rule of thumb to design coverage. This has yielded an overlap of coverage in virtually all installations, with the exceptions being fuel, water, and waste tanks that are integral to the hull, in which case the signal is highly attenuated and must be taken into consideration in the placement of transducers to optimize coverage. For all the foregoing reasons, we suggest our customers submit their hull plan to us for our engineers to suggest the best transducer layout."

Transducer location is a key to thorough coverage. The author reports good antifouling results on his propeller from a transducer installed inside the hull essentially right over the prop but not resonating directly with the shaft.

The effectiveness of ultrasonic technology extends only a short distance beyond the hull surface it is protecting. As a result, isolated components such as propellers, shafts, and rudders are generally not well protected by hull-mounted transducers. The best method of protecting these is some mechanism to mount a transducer such that it resonates through the propeller shaft and propeller, and through the rudderstock and rudder. (Different manufacturers have different ways of doing this.) With respect to the rudder, the installation should not obstruct the mounting of an emergency tiller or make it difficult to remove the rudder. Note that there are reports of successful installations on pod drives and jet drives, both of which can suffer a serious loss of performance from biofouling.

Control Modules

The control module generates the acoustic frequencies. There will be a central processor programmed to control one or more generating devices, which feed the signals to the transducers. Some systems have a single generating device with multiple transducers wired in parallel to it, but most have separate generating devices for each transducer, which is preferable in terms of performance and redundancy. In some systems with separate generating devices, transducers are synchronized to create the same frequency at the same time, which helps boost the effect at the signal-overlap areas farthest from the transducers; in other systems they are deliberately not synchronized, so the power drain is not reduced at any given time. Other differentiating features are degrees of waterproofing of control boxes, connections, and switches; and the sophistication of display devices and the information available to the user.

As noted earlier, the generating devices cycle through a range of acoustic frequencies, starting around 20 kHz, which is just above the audible range for human hearing, and going as high as 100 kHz (the Sonihull produces 13 different frequencies in a 5-second cycle). In theory, the systems should not be audible, but in practice there is some noise at the transducers, which varies significantly from one brand to another. You can just hear the Sonihull transducers on our boat if you are close to them, whereas I have had reports of transducers in other systems being noisy enough that they are shut down at night. (Some systems have a "sleep" button, which may be a clue that they can be noisy.) If the transducer is sealed to the hull with petroleum jelly or similar, a noisy transducer may be quieted simply by screwing it down a little more tightly.

The systems are reportedly not harmful to fish or marine mammals. However, I found this posting on the Internet from an otherwise enthusiastic supporter of the technology: "When I installed it I dived under the hull to see if I could hear anything. When closer than 20cm [8"], I heard an ear-splitting high-pitched sound, probably transmitted through the skull rather than eardrums. I moved away quickly, but I suffered tinnitus [ringing] in both ears for the next 24 hours. It was highly unpleasant, and I won't be doing it again. It was like the day after a rock concert, but worse."

Energy Needs

How much energy will it take to run one of these systems? Most transducers have a peak power output of 50 watts (although some are as low as 25 watts, which limits their effectiveness), but this is only intermittent. Average power demands run from 2.5 watts to 5 watts per transducer. If we take a 40′ boat as a reference point, depending on the system and the number of transducers, this translates to an overall continuous load of somewhere between 0.6 amps and 1.1 amps at 12V (halve this at 24V). This does not sound like much, but it adds up to between 15 amp-hours (Ah) and 26 Ah a day at 12V, or between 450 Ah and 800 Ah over the course of a month. If a boat is without some auxiliary source of power—solar, wind, a small fuel cell, shore power—the batteries will discharge to the shutdown voltage of the ultrasonic system, at which point the system will turn itself off. In theory this will protect the batteries. In practice, because the running load of the system is so low, the batteries will be deeply discharged by the time the shutdown voltage is reached. If most lead-acid batteries are left in this discharged state for any length of time, they will sulfate and suffer lasting damage. In our case, we have more than enough solar to indefinitely keep up with the load.

Some systems run on AC power as well as DC, and have an automatic transfer switch that preferentially selects AC when it is available. Some systems vary the output to the transducers based on the available power, ramping up the energy levels when AC power is available or battery voltage is high, and tapering down the energy levels if battery voltage is falling. All have a low-voltage cutoff threshold (at which point you have no ultrasonic antifouling).

The energy being transmitted into the water is acoustic energy, not electrical energy. It has no corrosion significance and will not affect sacrificial anodes, although it may improve their effectiveness by keeping them cleaner. The electrical frequencies in the generating devices should not interfere with other onboard electronics, although some come with a recommendation not to install transducers close to depthsounders. Check any new system for compliance with FCC and EU EMC emissions tests before installation.

A Partial Solution

It is important to note that none of the systems on the market claims to be a complete antifouling solution. All recommend the use of conventional antifouling paint in conjunction with the ultrasonic antifouling system. Which raises the question: If you have to pay for the haulout and paint job, why bother with the ultrasonic system? Here are a couple of good reasons to install one of these systems if they work as advertised.

1. You will be able to extend the intervals between antifouling paint jobs to two, three, four, and maybe even five years. Depending on the marine growth in your area, and how often you typically need to renew the antifouling paint, you should be able

Key Questions

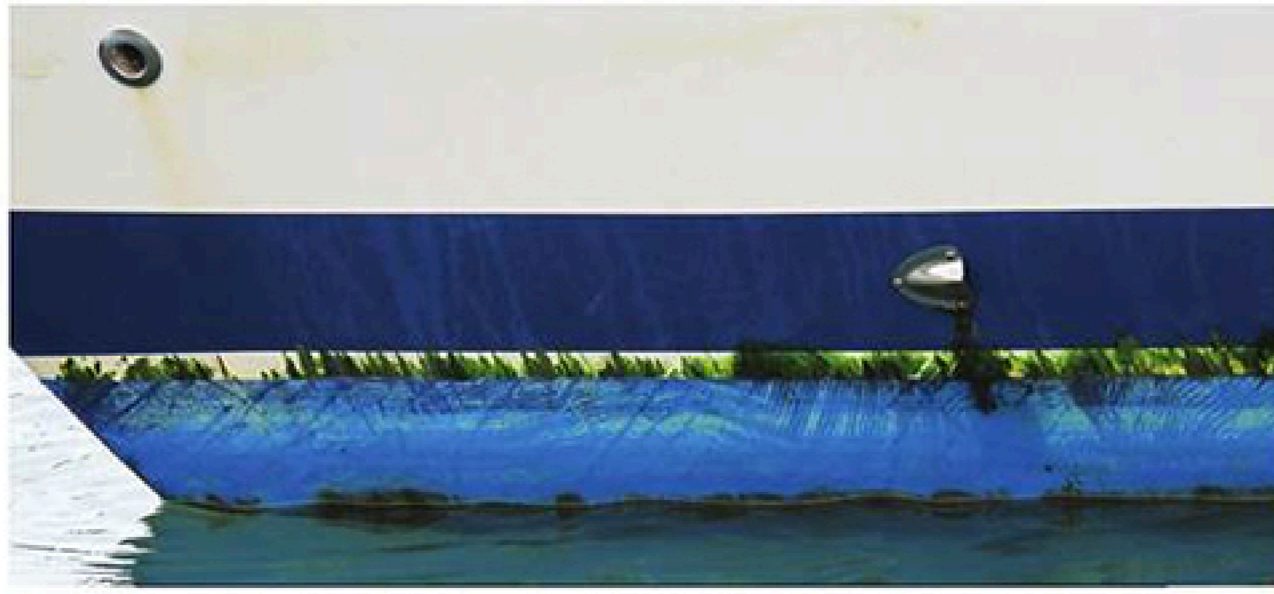
Here is a list of considerations when choosing an ultrasonic antifouling system.

- Are the generating devices rated at 50 watts?
- Are there separate generators for each transducer? Are these generators synchronized?
- Are the transducer cable connections watertight?
- How noisy are the transducers?
- What is the level of waterproofing on the control box, its cable connections, display devices, and any external switches?
- What level of information is provided on the display devices?
- What is the power consumption on a daily/weekly/monthly basis?
- Does your boat have the necessary energy resources? What is the real cost of providing this energy?
- Can the system run on shore power, and if so, does the power supply have an automatic DC/AC transfer switch?
- Will the system ramp up the transducer energy levels when there is a plentiful supply of power?

—Nigel Calder

to skip every other paint cycle. This alone will pay for the ultrasonic antifouling system in just one or two skipped cycles.

2. The ultrasonic system will keep the hull and running gear (struts and propellers) cleaner between paint cycles. This will improve boat speed and/or reduce fuel bills. If you currently pay a diver to periodically clean the hull and running gear, it will reduce these costs, and eliminate the paint loss that occurs at each scrubbing, extending the life of the paint. Keeping propellers clean will also reduce vibration caused by fouling, reducing stresses on the running gear and extending its life expectancy.



Ultrasonic systems can't combat some algae around the waterline where sun and air exposure create ideal conditions for growth.

The technology suffers from several broad shortcomings: Ultrasonic antifouling systems work on only those parts of the hull that are immersed in the water. Some growth will still occur around the waterline, which is regularly exposed to air and gets plenty of sunlight, encouraging algal growth. Typically, an ultrasonic system will partially treat it, making the growth relatively easy to remove. In some tidal regions, boats are allowed to sink into the mud at low tide, in which case the acoustic waves will be blocked, allowing growth to start. Even on other parts of the hull bottom where growth is inhibited, staining is likely over time, which may be unsightly but will have little effect on performance. Finally, dead matter created by the system itself or that may be floating in the water can stick to the hull. Movement through the water or a light brushing will generally remove this.

Does It Work?

Over the past several years these systems have been installed in thousands of boats up to superyacht size, and also in ships. The feedback is generally positive. In our case, I am becoming increasingly convinced of their efficacy. We have had a two-transducer Sonihull system for the past two cruising seasons (we haul out in between) and have not renewed our antifouling paint for three years (we used to do it annually). Right away that represents a saving equal to the cost of the system ($3,000). Installation took just a couple of hours and was remarkably easy. We sanded the hull in the forward cabin and the engine compartment (more-or-less above the propeller), glued the transducer retaining rings to the hull with the supplied epoxy, coated the transducers with Vaseline once the epoxy had set, and screwed them in place. We installed the control unit more-or-less amidships and plugged in the transducers. The longest part of the job was running the 24V-power-supply cable to the control unit, because I had no suitable cable duct in an appropriate location to get the cables from the navigation station to the bilge area.

After two seasons' use we have had a very small amount of live growth at the waterline (as expected and predicted) and some streaks of what is almost certainly dead matter, which washed off immediately at our annual haulouts, and would have been just as easy to remove by scrubbing in the water.

Our propeller (which we had also treated with Forespar's lanolin-based LanoCote in year one but left completely untreated for year two) has been spotless, even without a transducer operating directly on the shaft and propeller. (As noted, we have one of the hull-mounted transducers more or less directly above the propeller.) We have not cleaned the speed log paddle wheel in two years. (Previously, it would periodically foul; I am frankly surprised it is staying clean, because it is semi-isolated from the hull by its bearings and shaft.) There are various areas of the hull that now have no antifouling paint but rather a clean gelcoat. We have had not a single hard growth of any kind anywhere on the hull,

Boatbuilder Installation

Some boatbuilders are now looking at installing ultrasonic antifouling systems as original equipment. Here are some potentially significant benefits:

1. The system can be fully engineered to optimize transducer placement.

2. If the boat has a cored hull, the necessary removal of core and bonding down to a single skin can be done in the factory.

3. It will be easier to run the transducer cables at the time of construction rather than in the aftermarket.

4. The boatbuilder can offer the customer an environmentally friendly technology that reduces operating costs and improves fuel efficiency and/or sailing speed; this could prove to be an excellent marketing tool.

A basic boatbuilder offering might include prepared transducer locations with suitable access and pre-installed cable ducts for the transducer cables, enabling a fast and cost-effective aftermarket installation.

—*N.C.*

While ultrasonic antifouling doesn't eliminate the need for bottom paint, it makes it possible to get multiple seasons out of a good paint job, saving the cost of reapplications and reducing the amount of noxious paint going into the water.

rudder, propeller, or anything else.

This year we are again not renewing the antifouling paint. If the hull comes out clean at the end of the season, we will have already more than covered the cost of the system in reduced bottom-painting costs and will be well ahead financially. (There *are* some significant hidden costs in increased battery cycling, which rise dramatically if the energy required for the system has to be generated by running any kind of fossil-fuel engine.) For powerboaters, the savings in fuel could be substantial from cruising on a clean bottom. Our contribution to the environment of noxious antifouling paint is already down by 4 gallons (15 l). It is my hope that this time next year I will be able to report an additional barnacle-free year, at which point any lingering doubts I may have about this technology will have fully evaporated. PBB

***About the Author:** A contributing editor of* Professional BoatBuilder, *Nigel Calder is the author of* Boatowner's Mechanical and Electrical Manual *(the 4th edition was recently released) and other marine titles (including, earlier in his career,* Marine Diesel Engines*), and is a member of the American Boat & Yacht Council's Electrical Project Technical Committee.*