Ultrasonic anti-fouling for boats

Part 2: encapsulating the transducer and installation

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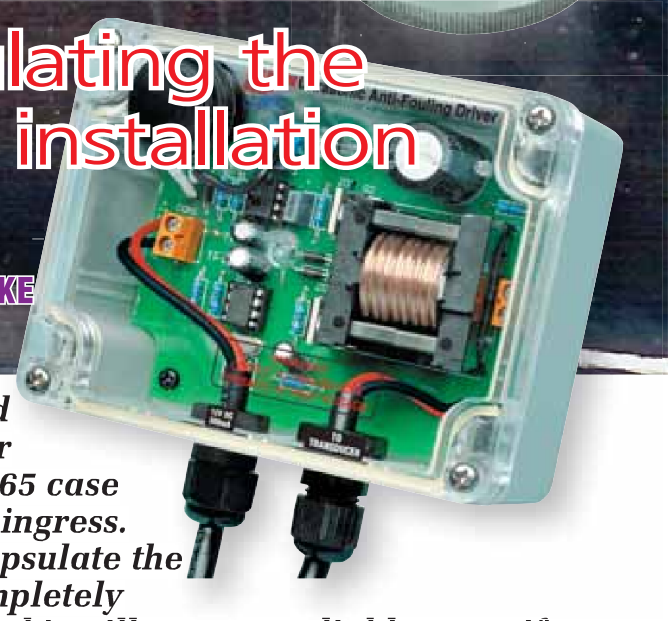


In the September issue, we published the details of the ultrasonic driver for this project, which is housed in an IP65 case for safety and protection from water ingress. This month, we describe how to encapsulate the ultrasonic transducer so that it is completely safe to handle. Once it is encapsulated it will operate reliably, even if it is submerged in the bilge of the boat. Plus, we sign off with a forum of some readers FAQs (frequently asked questions).

MAKE no mistake. The drive voltage applied to the transducer in this project is enough to give you a severe electric shock.

I speak from painful experience here, having inadvertently touched the top of an exposed transducer while it was under test, prior to 'potting'.

In fact, the shock I received was solely due to my own body capacitance to earth, since I only touched part of the circuit with one finger.

If the total voltage had been applied across both my arms, for example, I might not have been here to write the second part of this article. *So you have been warned!*

THIS PROJECT IS POTENTIALLY LETHAL! For that reason, we have come up with a very specific procedure for encapsulation of the transducer. **Please follow it exactly.**

Preparation

The first step is to obtain everything in the bill of materials, shown opposite. We start with a standard plastic plumbing fitting, available from plumbing outlets.

It is described as a '50mm BSP male valve socket'. BSP stands for 'British Standard Pipe' and you will find it is the same 50mm coarse thread as on the outlet pipe for your toilet cistern.

WARNING!

This circuit produces an output voltage of up to 800V peak-to-peak to drive the ultrasonic transducer and is capable of delivering a severe electric shock.

DO NOT touch the drive unit output terminals, the PC tracks leading to CON2 or the transducer terminals when power is applied.

To ensure safety, the PC board must be housed in the recommended plastic case, while the transducer must be correctly housed and fully encapsulated in resin as described here.

The largest outside diameter of the transducer is close to 44mm and therefore is a close fit inside the 48mm smaller inside diameter of the nominal 50mm male valve socket. The first step in the procedure is to use a rasp or coarse file to create a flat on one side of the plastic fitting. This needs to be done to slightly reduce the wall thickness of the fitting so that we can mount an IP68 6.5mm cable gland on it.

Once the flat has been filed, you need to drill a 12mm hole in the centre of the flattened section to take the 6.5mm cable gland. When fitting the cable gland, you will also need to chamfer the plastic nut on two sides so that it takes up enough thread.

Pass a length of the 2-core black sheathed cable through the gland and strip the wires as shown in Photo 4. The length should be sufficient to be neatly routed from the mounting position of the ultrasonic driver

Bill of materials – encapsulated transducer

1 piezoelectric transducer (Jaycar AU-5556)
1 black plastic flange washer
1 50mm BSP male valve socket (HR-P0175050 or Vinidex equivalent etc)
1 IP65 6.5mm cable gland (one of three required for the whole project)
~10 metres 2-core black flexible sheathed speaker cable (see text) [the same cable should be used for the DC input to the ultrasonic driver box. The exact amount will depend on the length of the boat] (eg Jaycar WB-1754)
1 small jar of petroleum jelly or Vaseline
1 40ml tube of non-hardening silicone grease (eg Fix-A-Tap waterproof lubricant)
1 piece of melamine-coated or Formica-coated pyneboard or MDF (say 150 × 200mm)
1 250g pack of 2-part polyurethane potting resin (Electrolube UR5097)
1 spray can of silicone mould release (Electrolube DAS400)
1 pack of J-B Weld high temperature 2-part epoxy
5 1mm-thick black plastic ‘spacers’ (see text)
4 stainless steel self-tapping screws (to attach ultrasonic driver box to bulkhead in boat)
1 small piece of cling film (say 150mm square)
1 piece of coarse-grade sand/emery paper

Photo 1: before we get under way, here are the chemical products we’re recommending. On the left is the Electrolube polyurethane potting compound, with instructions and the Electrolube silicone mould release. Centre is the Fix-A-Tap waterproof lubricant (available from hardware stores and pool shops) while on the right is the J-B Weld 2-part epoxy glue. It’s not easy to get – but it works!

Photo 2: here we’ve filed a flat on one side of the 50mm BSP male valve socket and drilled a 12mm hole, both of which are needed to accommodate the 6.5mm cable gland through which the wires pass from the driver to the transducer.

Photo 3: Unfortunately, on the threaded end there were some moulding dags – we need the base perfectly flat, so we trimmed these off with a sharp knife and then smoothed it off with some sandpaper.

Photo 4: next, we passed the end of the flexible 2-wire cable through this cable gland, leaving plenty of free wire on the inside. Leave the gable gland nuts loose at this stage to allow the cable to slip in and out.

Photo 5: the 6.5mm cable gland, when tightened up later, makes a completely waterproof entry point for the flexible cable from the driver unit. The recommended cable is double-insulated but still highly flexible.

Photo 6: next, we soldered the two bared ends of the cable to the lugs on the side of the transducer (disconnect from the driver unit first!). Make sure these solder joints are good'uns, because once potted, you won't be able to get at them!

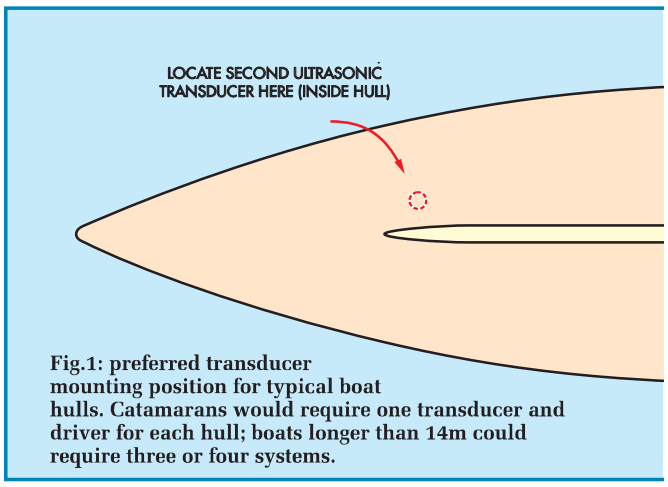


Fig.1: preferred transducer mounting position for typical boat hulls. Catamarans would require one transducer and driver for each hull; boats longer than 14m could require three or four systems.

to the planned mounting position of the transducer in the hull.

We suggest that you make the cable length at least 4m; perhaps more for a very large boat. You can always shorten it at the time of installation. Solder the wires to the transducer, as shown in Photo 6.

When the transducer is positioned inside the plastic valve socket and finally encapsulated, we want the encapsulating material to be no more than 1mm thick over the face of the transducer – therefore the transducer needs to sit up 1mm above the bottom of the socket.

To achieve this, you will need to glue some pieces of black plastic 1mm thick to the face of the transducer. We used Loctite Glass adhesive which cures on exposure to daylight (ultraviolet).

We glued five pieces, but four is probably enough. See Photo 7. These 1mm 'spacers' ensure the right thickness of the encapsulation, which will become evident as we proceed.

Flange it

Next, we work on the black plastic flange, ie, the 'Hansen SBN50LB black plastic flange washer' to make a jig for the encapsulation process.

This flange is a standard unit used on plastic water tank installations and will eventually be used to secure the encapsulated transducer to the hull of your boat.

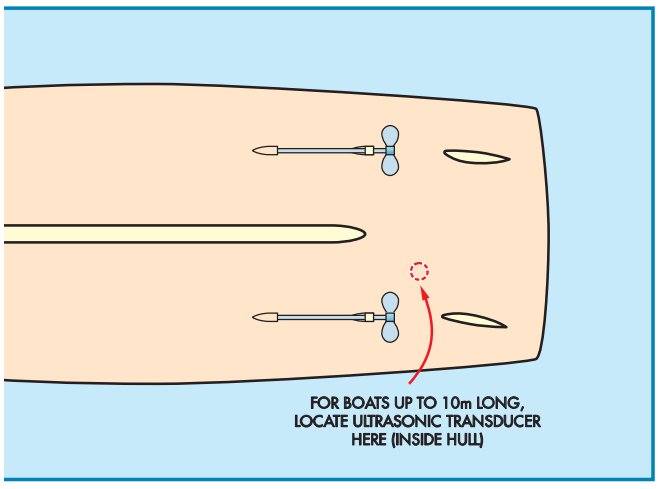
For now, we need to drill four 4mm holes to take 6G self-tapping screws, in the flange section. The flange is then attached to a piece of melamine-coated or otherwise sealed MDF or pyneboard. Before you do that, place a sheet of clingfilm between the flange and the baseboard, as in Photo 8.

Note that the screws used to attach the black plastic flange will be re-used when the ultrasonic driver unit is installed in the hull of the boat.

Having screwed the flange to the baseboard, spray inside the thread of the fitting and the cling wrap with Electrolube DAS400 silicone mould release, as shown in Photo 9.

Make sure the clingfilm is taut and has not become crinkled by the mould release spray.

Screw the male valve socket, with transducer attached by its leads, into the black plastic flange. Do not overtighten it. You now have a secure jig for the encapsulation process. The transducer should still be outside the valve socket, as shown in Photo 10.



It is now clear why we need the silicone mould release spray. We need to be able to detach the flange from the transducer/valve socket after encapsulation is complete.

Mixing the potting compound

We now mix the encapsulating compound. This requires one 250g pack of Electrolube UR5097 2-part polyurethane resin. It comes in a tough plastic pouch, which is partitioned into two compartments for the resin and the hardener.

You need to remove the plastic fittings from the pouch and then merge the two syrupy liquids together. Knead and roll the bag around for several minutes to thoroughly mix the resin.

Follow the instructions on the pack – although we found mixing took quite a lot longer than the instructions specified (probably because it was a rather cold September day when we did it). But eventually we were happy with the mix – a consistency of runny grease.

Now pour a small amount of the mixed resin into the valve socket so that it covers the bottom surface by a few millimetres. Then insert the transducer face down into the valve socket and push it all the way down. Remember that we want the encapsulation on the face of the transducer to be only 1mm thick. If at all possible, make sure that the transducer has equal clearance all round, inside the valve socket. Photo 7 shows this clearly.

When you are sure that the transducer is correctly positioned, push the leads down so that they will be fully covered by the resin.

Then pour in more resin until its level is just below (say a millimetre or so) the lip of the valve socket. Do not fill it to the brim, otherwise it will overflow as it warms and expands slightly during the curing process.

Leave it overnight to cure. The ambient temperature should preferably be more than 15°C, otherwise the curing process will take too long.

The cured resin is not really hard – it has some 'give' if you press it with a finger-nail. When cured, remove the four screws holding the flange to the MDF and lift it off. It should come away easily.

You should be able to peel the cling film off the face of the finished transducer, leaving a nice clean smooth surface. The finished transducer should look like that shown in Photo 15 and photo 16.

Photo 7: here you can clearly see the five 1mm bits of plastic we glued to the transducer surface to give clearance underneath for the potting compound when it is poured in later. The transducer should be a nice friction fit in the tube – we are just checking everything fits!

Photo 8: to make sure the potting mix doesn't stick to the baseboard, stretch some clingfilm underneath the flange. Remove any wrinkles or bubbles because you want the potting compound to be as smooth as possible. Note the four holes we drilled through the flange.

Photo 9: when you have screwed the flange on to the base board, spray some mould release onto the cling film and also on to the threads of the nut, again to make sure that the potting mix lets go later as it should. You'll probably find that the mould release causes the cling film to wrinkle a little – again, pull the cling film tight to make it smooth.

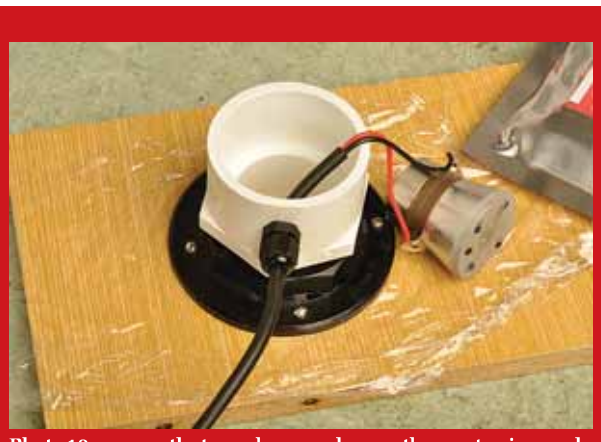


Photo 10: remove the transducer and screw the empty pipework into the nut. Make it firm, but not so tight that it bites into the cling wrap. You're now just about ready to pot the transducer so make one last check that your solder joints are perfect – once potted, it's very hard to remove !

Photo 11: the potting mix comes in a two-part pack which must first be combined and then thoroughly mixed before use. You need to knead it! On a cool day, this can take quite a few minutes to do, but if you don't mix completely, the compound may not cure properly.

Photo 12: once mixed, cut the corner of the bag off and pour just a small amount – say a couple of millimetres or so – into the transducer housing. Put the bag to one side for a moment (remember to keep the pouring hole up).

Installation in the boat

There are two steps to the installation in a boat. First, determine the optimum position, and install the transducer. Then select the location for the ultrasonic driver unit (last month) and install it.

The driver case needs to be mounted on a bulkhead or other position where it is unlikely to be splashed or immersed in any water which may be in the bilge. We will discuss installation of the transducer first.

Transducer location

As shown in the diagram of Fig.1, the encapsulated transducer must be installed inside the hull, near the running gear (ie, propellers and rudders). On the boat shown in the photos, the transducer was installed in the lazarette, under the floor of the transom. First, you must find a suitable flat section of the hull; on many boats, this will not be easy. Try positioning the black plastic flange (ie, without the transducer fitted) in a number of positions to get the best spot. Let us now go through the steps for installation.

Using coarse sandpaper and a sanding block, roughen the face of the black plastic flange, as in Photo 17. We want a good 'key' for the epoxy resin.

Use the sandpaper and sanding block to thoroughly scour the hull position where the black flange is to be mounted. Photo 19 shows the plastic flange temporarily in position on the hull after it has been sanded.

By the way, it is essential that the mounting area for the flange must be clean and dry, and free from dust and grease. And of course, there should be no possibility of exposure to bilge water while the epoxy resin is curing.

Mix a quantity of J-B Weld High Temperature 2-part epoxy resin. Do not use Araldite or any other epoxy mixes. We want to be sure of a reliable long-term bond to the hull, which won't let go with constant ultrasonic vibration. See Photo 20.

Apply a liberal coating of petroleum jelly (or Vaseline) to the thread of the plastic flange, as in Photo 18. We don't want any epoxy resin to adhere to the threads, otherwise the flange will not be usable.

Apply the mixed epoxy resin to the roughened surface of the flange, as in Photo 21. Then press it down onto the previously prepared section of the hull. Leave it to set for 24 hours. If the water (and therefore the hull) is very cold (eg, midwinter), leave it for longer.

Some adhesive will probably ooze out from under the flange – outside the flange it doesn't matter too much (apart from aesthetics). Inside, though, it should be carefully cleaned away without getting it on the threads so that the transducer (when fitted) will not sit proud of the hull.

Installing the driver unit

The next step is to install the ultrasonic driver module (last month). Its IP65 plastic case has provision for four mounting screws. To fit them, you need to remove the transparent lid of the case and position the unit in the spot where it is to be mounted. Preferably, it should be on a vertical bulkhead above the waterline, say between the engine compartment and the lazarette.

On the boat in the photos, this was not possible, so it was positioned on the horizontal beam which carries the hydraulic drive to the rudder (Photo 24).

It is most important that the ultrasonic driver unit be mounted above any likely spray or splashes from water in the bilge. On no account should you drill holes in the hull to mount the ultrasonic driver – that carries too much risk of you drilling right through the hull!

Photo 25 shows the ultrasonic driver being mounted in place. Use stainless steel screws – you can recycle those you earlier used to make the encapsulation jig.

Having mounted the ultrasonic driver in place, we now need to position the encapsulated ultrasonic transducer next to its mounting flange in the hull of the boat. Inevitably, this will involve running its cable through inaccessible holes in parts of the boat structure. If you can run the cable next to existing cable, so much the better. Lace the cable into position where necessary. It should not be allowed to flap about or hang in loose loops. Remember that boats experience severe vibration, and we don't want the cable to fail in the long term (Photo 27).

You may have to drill holes in bulkheads to run the transducer cable through. Make sure those holes do not have rough edges which can chafe the cable. If they do, fit suitable grommets.

Meanwhile, back at the hull

Now that the J-B Weld has cured, we can return to the transducer mounting.

First, liberally coat the face of the encapsulated transducer with a non-hardening grease. This is applied to fill any voids when the transducer housing is screwed down into the flange.

Before screwing in the transducer housing (a conventional clockwise thread), twist the housing anticlockwise the same number of turns as it takes to screw it in so that when the transducer is installed, the cable is in its natural (untwisted) position. Do not over-tighten it, but make sure that it is tight enough that it is not likely to shake loose over time.

Make sure that the transducer cable is neatly routed and cannot possibly interfere with the operation of any moveable parts, such as the rudder gear.

Finally, you need to make the supply connections to the house battery. Again, lace and anchor the supply cable securely. There is no need to fit an in-line fuse because there is already a 3A fuse on the PC board.

Note that since we are making a permanent connection to the battery, it must have a float charger or preferably, a 3-state charger so that it is always kept charged.

When power is applied, the green LED can be seen to be glowing through the transparent lid of the case.

Turn it on... and nothing!

You probably won't know that it's operating, but if you want to check that the circuit is active, just position a portable AM radio next to the driver and you should hear it squealing away. As discussed in the FAQs (overleaf) there may be some who will hear a few clicks or whistles but these would be unusual.

OVERLEAF: Answers to the many questions we've already been asked about this system!

Photo 13: now push the transducer hard down, into the potting mix, face down. About now you might find out that overfilling with potting mix makes a nice mess of your thumbs . . . try to get the transducer as centrally located in the tube as possible, although it's not vital. Pull the cable back through the grommet until about 10mm of outer insulation is showing inside, then tighten the nuts.

Photo 14: squeeze the potting compound out like toothpaste – not too fast, to be sure you don't get any bubbles trapped. Fill to a millimetre or so below the top of the tube – as it cures, it warms and expands. We found we used most of the 250g pack of resin.

Photo 15: when cured and removed from the jig, this is what it will look like (hopefully without the air bubbles, although these won't affect operation). The top of the potting compound is just below the top of the fitting.

Photo 16: and here's what it looks like from the underside (the bit that contacts with the boat hull). The 'rough' edge on the socket is actually a smooth edge – we removed some thread ends with sandpaper.

Photo 17: now we're moving onto the installation in the boat. After you remove the black plastic flange from your temporary jig, roughen the bottom with some coarse sandpaper. This is to give a good 'key' for the adhesive to ensure it won't vibrate loose when fixed to the boat hull.

Photo 18: it's important that glue doesn't get into the thread, where it would clog it up. We smeared a good coating of Vaseline right around the threads – make sure it doesn't get on the bottom of the flange where you *want* the glue to take!

Ultrasonic Anti-Fouling FAQs

The first article on ultrasonic anti-fouling for boats has prompted a deluge of questions from readers who could not wait until the second article. So here are the answers.

Q: How big a boat?

A: The single transducer driver and design presented here is suitable for boats up to 10 metres long. Longer boats, say up to 14 metres, will require two transducers, each with its own driver unit. Boats bigger than 15 metres, say up to 20 metres, will require at least three and maybe four transducers and drivers.

Catamarans up to 10 metres long will require a separate transducer and driver unit for each hull.

Q: Do I need to cut a hole in the hull for the transducer?

A: Definitely not – the encapsulated transducer is mounted on a flat surface inside the hull. For a boat up to 10 metres, the transducer should be mounted near the running gear (ie, propellers and rudders) so that it offers maximum protection from marine growth.

Q: Is ultrasonic anti-fouling suitable for all boats?

A: Ultrasonic anti-fouling relies on one or more transducers mounted inside the hull to excite it at various frequencies in order to disrupt the cell structure of algae. It works well with metal hulls such as aluminium and with fibreglass hulls. It does not work with timber hulls, as the timber is not a good conductor of ultrasonic energy. The same comment applies to ferro-cement or fibreglass hulls with a balsa sandwich or other composite construction (eg, closed-cell PVC foam).

Q: Does the ultrasonic anti-fouling unit present a risk of electric shock?

A: As stated in the circuit description, the ultrasonic transducer is driven with peak voltages up to 800V. If you make direct contact with the circuit or the ultrasonic transducer there is a very high probability that you will receive a severe electric shock. That is why the transducer itself must be completely encapsulated in a plastic fitting, as described elsewhere in this article.

Q: Is it necessary for the boat's hull to be cleaned of marine growth and conventionally anti-fouled before the ultrasonic anti-fouling system is installed?

A: Ultrasonic anti-fouling is unlikely to kill shell fish or molluscs already attached to the hull. Nor will it cause them to detach from the hull. Hence, there is no alternative to having the hull scraped and water-blasted to clean off all existing marine growth.

And if it is already on the slips for such cleaning and other maintenance such as servicing outboard legs and replacing sacrificial anodes, it probably makes sense to have conventional anti-fouling paint applied, although this may be regarded as optional.

We should also emphasise that, no matter how effective ultrasonic anti-fouling may be in keeping the hull clean of marine growth, it will still be necessary to do regular maintenance such as the already mentioned servicing of outboard legs (in case of boats with inboard/outboard motors) and replacing sacrificial anodes.

Q: Will ultrasonic anti-fouling keep propellers, rudders and other 'running gear' free of marine growth or is it still necessary to use anti-fouling compounds such as PropSpeed?

A: Ultrasonic anti-fouling should keep props and rudders free of marine growth. Overseas experience with commercial units has shown this to be the case.

Q: Does ultrasonic anti-fouling cause increased electrolytic leakage currents (electrolysis) and thereby increase corrosion on boats?

A: The ultrasonic transducer and driver unit are installed entirely within the hull of the boat and the ultrasonic transducer itself is transformer driven and is completely encapsulated to provide a high degree of insulation. There should be no leakage currents at all.

Q: Does ultrasonic anti-fouling harm fish or marine mammals?

A: This system causes no harm to fish or to marine mammals. Fish cannot hear it and while marine mammals certainly can perceive and respond to ultrasonic signals, they are not harmed in any way by the relatively low power levels which are likely to be radiated by the hull of the boat. Furthermore, the signal levels are much lower than those directly radiated by depth sounders and fish finders.

Q: Will I be able to hear the ultrasonic anti-fouling unit in operation, especially at night when the water is very still?

A: Unless you are a bat(!), you cannot hear ultrasonic frequencies directly. However, the transducer and the driving transformer do emit high frequencies and clicks

– continued

Photo 19: move the empty flange around the hull to determine the best transducer mounting position. When you're happy with your choice (see the text), roughen the fibreglass as you did the black flange – for the same reason. Here the flange is sitting in place but not yet glued.

Photo 20: did someone mention glue? We're recommending J-B Weld to secure the flange to the hull. It's not that easy to buy (try your local hardware store as distinct from the big chains) and it's not cheap – but it sticks like the proverbial.

Photo 21: apply a good layer of mixed glue all over the roughened base of the flange, again making sure you don't get any on the thread. You have quite a while before it starts to cure, so take your time!

Photo 22: it's almost inevitable that there will be some J-B Weld oozing out from under the flange as you press it in place. The secret is to apply only as much pressure as is really needed to ensure the glue spreads right around, then wipe any excess off before it sets.

Photo 23: once set (24 hours +), the transducer assembly is screwed into position with a good big dollop of Fix-A-Tap lubricant on the face. But before doing so, wind it anti-clockwise a number of turns so that the cable ends up without loops or kinks. Screw down as hard as you can with your fingers, but don't force it. Lace any loose cables.

Photo 24: the location for the driver unit is just as important as the transducer. It must be one which can NEVER interfere with any boat operation and one which won't be stepped on if you need to get into the area. Just as important, it must be one which won't be swamped by bilge water, despite the IP65 case.

Ultrasonic Anti-Fouling FAQs

at low levels. These are actually sub-harmonics of the ultrasonic signals and are most evident as the frequencies are continuously shifted up and down over the operating spectrum.

However, once the unit is installed, you will only be able to hear these sounds, if at all, by placing your ear directly over the ultrasonic driver or over the transducer. You might also be able to feel some slight vibration of the transducer itself.

Q: Is ultrasonic anti-fouling equipment likely to cause damage to the hull of a boat, especially those of fibreglass construction? Will it cause osmosis or de-lamination?

A: We know of no research into this topic and while it could be suggested that the continuous, albeit low-power, ultrasonic vibration of the hull could lead to de-lamination, such ultrasonic vibration is extremely low in amplitude compared with the severe hull vibration caused by propellers and diesel or petrol motors when boats are operating at high power, especially when 'on the plane'. Furthermore, hulls are placed under very high stresses when boats are being pounded by heavy seas or are repeatedly slammed though waves or hitting wakes of other boats at speed.

Many older fibreglass boats, say more than 20 years old, are subject to osmosis and de-lamination. Repairs are routine but expensive to carry out and the boat must be out of the water for many months to ensure that any water trapped in hull laminations is removed.

If a boat was fitted with ultrasonic anti-fouling and after years of use, there is subsequent evidence of hull osmosis or de-lamination, it would be impossible to determine if it were caused by normal wear and tear or other causes.

Ultrasonic anti-fouling is routinely fitted to brand new boats, but anyone contemplating such an installation would be wise to check that hull warranties are not invalidated. We make no warranties that ultrasonic anti-fouling does not cause hull damage.

Q: Will my boat batteries be damaged by the ultrasonic driver unit?

A: The ultrasonic driver circuitry described last month incorporates battery protection. If the battery is discharged to 11.5V, the circuit is disabled and will not resume operation until the battery is recharged.

However, since the ultrasonic anti-fouling driver is designed to operate continuously, the battery supplying it will need to be on permanent float charge. This will require 230V AC shore power if you are fortunate enough to have your boat in a pen or marina berth.