Corrosion

Of all the complicated subjects one needs to know as a boat owner, this is probably the most difficult, and least understood.

This essay is intended to give you a fundamental understanding of the causes and effects of corrosion, as well as how to identify problems and correct them before they become severely damaging.

There are many types of corrosion that boat owners have to deal with. Well, actually, there are only two, but there are many different causes with different names. The two basic types are erosion and electro-chemical. The following descriptions have been simplified for clarity since most corrosion mechanisms are very complex. This is intended for laymen so if you are a scientist, kindly cut me some slack here.

Erosion is a strictly mechanical form of corrosion that is caused by friction. This can be mechanical corrosion, such as that of sandy water flowing around a bend in a pipe, which acts just like sand paper. Then there is another type of erosion, which is caused by high speed water flow. The pitting one sees on rudder blades behind propellers is an example of non-abrasive erosion. In fact, many people mistake this condition for electrolysis, a subject that I'll get to in a moment. This is caused by the stream of bubbles from the propeller hitting the rudder. High speed flow corrosion is rarely found in boats, other than this instance. The most frequent occurrence is within the cooling systems of engines.

Electro-chemical corrosion is the primary type of corrosion that boat owners have to deal with. First we need to understand that all corrosion except mechanical erosion is electro-chemical in nature. This is just as true of a drop of water on a piece of raw steel, as it is of a stray current leak going through a bronze propeller. There is no need to understand this phenomenon completely, but a brief description will help.

All particles of basic elements or compounds have electrical charges, be they positive or negative. If two different materials have the very same electrical charge, nothing will happen. These materials or substances are, we say, "compatible" as in joining certain types of stainless steel and bronze together. If two materials have a sufficient different charge, then a flow of current (electrons) will occur. This is the principle that makes a dry cell battery work. Dry cells use carbon and another metal to generate an electrical current flow between the negatively charged carbon, and a highly charged metal.

Electrolysis People generally do not understand this term, using it as a catch-all to describe any kind of corrosion below the waterline. Electrolysis is simply the result of stray current, and nothing else. Galvanism and electrolysis produce similar results, only they have different causes. We would be better off using the term "stray current corrosion" because this identifies the cause.

Galvanism This is the term applied to the flow of electrons when two dissimilar metals are mated together, as was described above.. Basically, there will be very little flow when two metals are mated together dry. But add water to the join and suddenly corrosion blossoms. That's because water is a conductor and becomes the facilitator of the current flow. This is why mating dissimilar metals is much less of a problem inside your house than it is on your boat. All forms of galvanism involve metals, but all metals don't look like metals. Carbon is a metal that is used in making rubber, and so carbon rubber when mated to stainless steel can produce quite a reaction.

Galvanism is a very complex issue. Boats, of course, have a lot of different metals in them, including those below the water line. This is complicated by the fact that all bronzes, brasses and all stainless steels are not the same. There is a very wide range of alloys -- meaning the mixing of different metals to achieve specific metallurgical properties -- between what we usually think of as basic metals. This accounts for why there is such a wide range of performance of these metals, and sometimes why they corrode when they shouldn't. If the right alloys aren't used, we have a problem.

We attach pieces of zinc to the underwater metals of boats to protect those metals. What actually happens is that the zinc reverses the normal flow of current between dissimilar metals. The zinc will emit current that raises and equalizes the electrical potential of all the metals in the system. It does this by releasing electrons, which are positively charged ions of the metal itself. This causes the zinc to erode and disappear. These ions will attach themselves to the other metals, which explains why your props and other metals may end up with a rough, scaly surface; they've become covered with zinc oxide.

Scale of Nobility Metals are rated on what is called a Scale of Nobility, which simply means the materials ability to resist this kind of corrosion. There is also a chart called the "galvanic series" which shows the electrical potential of metals in seawater. A more noble metal is one that has a neutral or negative electrical potential. It will not generate a flow of positive ions, and is called "noble." The reverse of this is the least noble metal, which has a high positive charge, and which will generate an electrical current. These include such metals as zinc, unalloyed aluminium and copper, iron and steel. Graphite and carbon bottom out the list, being the most highly charged metals.

Crevice Corrosion This is the most common form of corrosion found on fibreglass boats, and is the least understood. Electrical currents are generated anytime there is a change in chemical composition. That's why powerful explosives can be made of such ordinary things like plastic. As its name implies, crevice corrosion involves water, metals and crevices. For our purpose, a crevice is any cavity that will trap and hold water, while at the same time reducing or eliminating air exposure to the water/metal interface. Crevice corrosion is the same thing as galvanism, only it occurs under different circumstances.

Crevice corrosion on screws. The one on the right shows the typical wasting of the shank right under the screw head. The one on left was exposed to water both under the head, and on the inside of the hull where it has thinned at both locations. This is probably what the bolt in the photo below (top) would look like when removed.

This is also called "closed cell" corrosion by virtue of the fact that little or no air is allowed to get to it. The water/metal interface results in oxidation of the metal which concentrates the hydrogen content of water, and turns the water into an acid. This changes the electrical make up of the affected materials, generating an electrical current that "dissolves" the metal involved. These crevices or closed cells can become dynamic, meaning that the process can perpetuate itself for a long time -- either until the acidic water is exhausted or an oxygen source is created that lowers the acidity of the water and stops the corrosion. If no oxygen source is introduced, the corrosion process continues until the metal is completely gone.

This is one of the telltales of crevice corrosion in through hull bolts. The fact that this is Taiwan stainless only makes the problem worse.

This is what copper-based paint looks like when stray current is involved with these through hull bolts. The copper-based paint has reacted. You can't get a better indicator of a problem than this.

To illustrate this phenomenon, consider that you could hang a stainless steel bolt over the side on a string. It would hang there forever and nothing would happen to it. But put that fastener into the bottom of a hull and watch what happens (see photos below). Water gets into the screw or bolt hole where there is no free-flow of water, so that the small amount of water in the screw crevice turns acidic and creates a galvanic cell. This usually occurs right under the screw or bolt head, eroding the shank of the screw or bolt until it becomes loose. Once it does become loose, then a better flow of Ph balanced water is introduced, and the corrosion stops because the water is no longer acidic. Virtually the same thing will occur with stainless fasteners into an aluminium mast. But in this case, the corrosion stops as soon as the water evaporates from the crevice. In the case of an aluminium fuel tank, installed in such a way as that water gets trapped against the tank, like a foamed in place tank, or a tank sitting on a plywood deck, the very same thing happens. Which tends to leave us mystified why you could throw your aluminium parts over the side and they'd sit there forever without corroding, while the seeming protected parts on your boat corrode badly. Crevice corrosion always occurs in places you can't see, though it usually leaves telltale evidence.

Stress Corrosion is yet another form of corrosion, as it's name implies, occurs when a metal is under heavy stress. This is a combination of crevice corrosion cells combined with heavy loading. It most often occurs on sailboat rigging and power boat propeller shafts. Old style swage fittings on sail boat rigging combines both stress and corrosion cells from entrapped water within the swaged cable. It also occurs at mast rigging attachments where water is entrapped between the mast and bolt-on parts, or even getting under welded parts. See photo below.

Propeller shaft breakage has reach almost epidemic proportions these days. That's because builders are opting for low grade stainless shafts made of lesser alloys. All it takes is for a tiny pit to form on a shaft to initiate the crevice/stress corrosion cycle that will ultimately result in fatigue failure. This usually occurs at the stuffing box or keyway cuts, the natural weak points. Good propeller shafts don't break because they don't corrode. If you have this problem, it's ultimately a question of how many new shafts do you want to buy before you replace them with better quality.

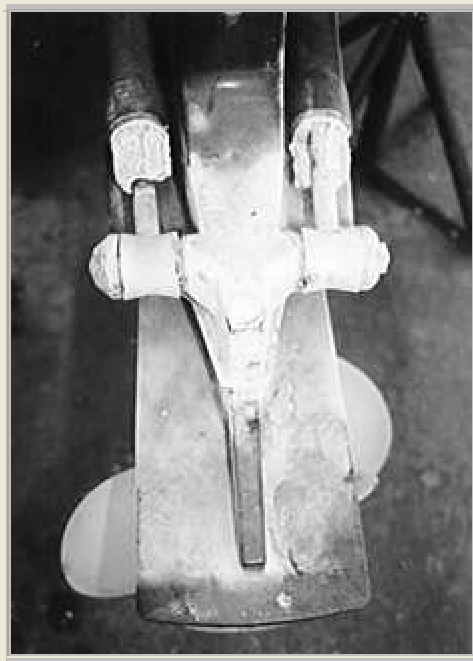
Highly polished stainless steel is more corrosion resistant than those without a mirror finish. The reason is that unpolished metal has machine marks on it that serve as crevices for corrosion to start. Polishing smoothes these crevices over. However, high polishing won't help much for lesser grades of stainless.

Micro photograph of stress corrosion cracking. Initially invisible to the eye, water gets into these fissures and hastens the destruction of the part.

It's All the Same All forms of corrosion are the same electro-chemical process caused by different circumstances. That there are so many different circumstances is why we have so much trouble understanding the nature of our corrosion problems. Every combination of metals in different locations on our boats corrodes for different reasons. And if we don't understand why, then there's little hope of preventing it, either by the boat builder, or the boat owner.

Stray Current The electrical systems on boats have improved sufficiently over the last 20 years that stray current corrosion is much less of a problem. It begins to show up in older boats because of all the jury rigged wiring and systems that get added on over the years. In newer boats, it usually occurs due to ground wiring faults on the dock.

The basic mechanism of stray current corrosion is the same as all other types, only this time the introduction of an outside source of electricity screws up the normal electrical balance of the boats metals, plus adding one other pernicious problem. Energizing all the underwater metals in the boat that raised electrical potential will seek a path to ground. And rest assured that it will find one. That path will be the piece or pieces of metal below the water line that are the weakest like. It will start with the zincs and once those are destroyed, it will move onto the next lest noble metal. That's usually a poor quality alloy of prop shaft, propeller or through hull fitting. In other words, it's likely to attack one specific piece of metal. As the current leaves the piece of metal on its way to ground, it is carrying bits of the metal with it, as well as the erosion that may occur from part to part.

	
The owner of this stern drive has a big problem, though he doesn't know it. A dry stored boat, the white stuff all over this drive is zinc oxide from the zinc collars around the hydraulic rams. This is the result of stray current and it won't be long before he's looking at a $3500 bill. This one is less than a year old.	**Classic crevice corrosion. In this case caused by a carbon rubber exhaust flapper clamped onto a stainless exhaust flange plate. Notice that the worst corrosion is where the clamp pressed the rubber the tightest.**

Stray current is the most difficult corrosion problem of all to identify and correct because the source could anywhere amongst that mass of wiring in your boat. The first thing that must be done is to meter out the dock circuit to make sure that it isn't feed-back from the dock grounding system (i.e. the grounding system is positively charged, which can feed back into your boat), or that the grounding wires are not reversed.

The conditions created by AC and DC current is not the same, with DC current being the most damaging. The reason for this is that AC current is pulse current that moves in two directions, greatly reducing the corrosion potential for reasons I won't get into here. Technically, AC current requires some kind of diode that converts it into DC current before it causes metallic corrosion. There are lots of naturally occurring diodes in crystalline forms of metallic oxides. Aluminium oxide is VERY good at converting AC to DC current. The aluminium oxides that form inside aluminium boats!

Yet AC current may be just as damaging because the voltage is so much higher. If you ever wondered why there is so much misinformation concerning AC current corrosion, this is why. Unless the right conditions exist to covert the AC to DC current, the corrosion does not occur. Thus, only some boats on a dock with faulty AC wiring suffer damage, while others don't. These are almost always older boats where corrosion is already present, as it is the crystalline nature of metallic oxides that exacerbates the rate of corrosion.

AC current corrosion occurs much less frequently, mainly due to the fact that the high voltage is dangerous, and it is treated with more respect. Moreover, if there is a 125 volt leak, the chances are that it's going to be found rather quickly as the boat owner doesn't appreciate the shocks he gets occasionally. Amongst the thousands of boats I have surveyed, the number that I have found with AC ground faults is amazingly few.

DC Current leaks are the most common form of stray current problem. The fact is that any boat that utilizes high quality underwater metals and has a good bonding system can tolerate a fairly high amount of stray current leakage. This is because the low voltage current rather quickly dissipates throughout the system. Like trying to wash your car with a cup of water, there isn't enough to go around to do the job. The small amount that finds its way to underwater metals is usually taken care of by the zincs, or dissipated by a large amount of metal.

Substandard bilge pump wiring is the most common source of stray current. So are batteries mounted in a wet environment, such as sitting on a wet deck. Take a fully charged battery and sit it on the floor of your garage. Come back a month later and measure the voltage. Surprise! It's dead! Where did the power go? Well, right out through the casing and into the damp concrete, that's where. Put that battery up on dry wood blocks and this won't happen. The same thing happens when you have wiring laying in a wet bilge. Plastic, you see, is not an absolute isolator. Just as your fibreglass hull will absorb water, battery casings and wiring insulation will absorb some water too, just enough to leak out a small amount of current. And cause you a lot of problems. Having said that, I needn't say any more about batteries and wiring. You now know what to look for.

Detecting Corrosion Forty years ago, the paint companies tried using pure copper in bottom paint. It stopped marine growth cold, but it turned the entire bottom of the boat into a bonding system. Well, the EPA has us back to copper again, only this time cupric oxides are the toxic agent. Fortunately, it works pretty good. It works even better as a telltale for stray current, as the photo above shows. These oxides are still highly conductive, and still contain not completely reacted copper, so that the paints will *corrode.* Don't worry about that because there is no material in this world that does not corrode, including you and me.

If you are getting white and/or green halos around your zincs or underwater metals, you have a stray current leak. Even a very small amount of current will cause a paint reaction, so we have a built-in litmus tester here in our bottom paint. You can judge the severity by these photos, as this degree of paint reaction is associated with very rapid wastage of the zinc. Also make note of the fact that differing paint formulations react differently. I've seen some that are so reactive that you'd think the whole boat was being dissolved, and yet only a small current (1/2 volt) created this result with no damage to underwater metals. Therefore, judge the severity by the condition of the zincs, as well as the paint.

The evidence of corrosion appears in one of three forms. The one that we are all familiar with is the appearance of oxides, the by product of a metal that has chemically changed. Copper-based metals like brass and bronze leave green oxides, white for aluminium, and reddish-brown for stainless steels. These are the telltales of ordinary oxidation corrosion.

However, we have these other forms of corrosion to deal with, and these have different affects. Galvanism and stray current are abnormal, the result of something that shouldn't be happening. When the current generated by galvanic action is weak, it will generate the usual corrosion by product, the oxide of the metal. Stronger galvanic and stray current will more often result in rapid erosion of the metal, usually to the point where there are no oxides present, but will leave an appearance of bright metal. If you see any part of any underwater metal that is showing bright, regard this as a red flag.

It's the indicator of very rapid erosion. Examples of this would be eroded, but shiny surfaces on zincs, or propeller blade tips that are bright yellow and showing a crystalline texture or pattern. It will look like frost on the inside of a window, only it is bright yellow.

The effects of galvanism most often occur very slowly with bronze or brass. Here, a condition known as dezincification occurs. Since copper is alloyed with zinc to make bronze, zinc is the weak link and will leach out of the alloy to leave raw copper. The result is metal that is pinkish in colour, is granular in texture and tends to crumble when probed. It is soft and very weak. Any pinkish looking copper-based metal is waving a red (pink) flag.

Problems with stainless is typified by the appearance of pits or very coarse tunnelling, creating cavities that are very rough, and which have very sharp edges. Stainless can be very quickly destroyed by stray current, so if you see any sign of pitting on things like shafts, rudders or trim tabs, you need to seek out the cause and eliminate it quickly. This is one of the reasons why we don't recommend the use of stainless for any sea water plumbing systems. Screws and bolts underwater will usually end up with rusty looking oxides around them when crevice corrosion is involved, but no telltale oxides when stray current is the culprit.

About Zincs You can have serious stray current problems and yet your zincs seem unaffected. Once again, understanding this is not easy. First, there are many alloys of zinc -- some are more durable than others. You may have gotten the wrong kind of zinc. Secondly, like aluminium, zincs tend toward self protecting. That means that as the oxide layers build up, the metal becomes insulated from the water, so that the corrosion rate diminishes or stops altogether. This layer can get as much as 1/4" thick. At this point, the zincs have lost their effectiveness. If there is still a large amount of zinc left, you can just scrape off the oxide and the effectiveness will be restored. This condition means that you don't have a stray current problem.

Very rapid zinc loss that results in bright, shiny metal being exposed is a clear indication of electrical activity, be it galvanic or stray current, usually the later, since galvanism rarely creates enough current to destroy zincs quickly . Bright zinc in association with heavily corroded bottom paint means you have a problem that needs to be addressed immediately(see photo above). The brightness of the zinc is telling you that there is too much current for the zincs to handle. Adding more zinc is NOT the solution.

This is how you can tell if your going to have an aluminium fuel tank problem. Sitting on a flat deck that gets wet, here you can see the corrosion stains coming out from under the tank. This one's days are numbered.

Crevice corrosion of through hull bolts. In this case, the water got at the bolts from the inside. The use of nuts with nylon inserts (shake proof type) accelerated the process. Notice that the acid etching leaves the metal very bright. This is a total lack of oxygen to the cavity, whereas the exposed threads look rusty and had more oxygen available. That's because the nut completely wasted away.

The vast majority of inboard powered and sail boats don't even need zincs. We put a few on as a precautionary measure, and to serve as a telltale should a problem develop. Why? Because on most boats everything is in balance without a lot of dissimilar metals creating electrical current. Do you need to put a zinc on every piece of underwater metal? No, you don't if your bonding system is in good condition. That means that the wire connections are still making a good electrical connection. If your boat is 10 years old and you have never serviced the wire connections, then rest assured that your bonding system is now useless. The wire ends to components like sea cocks, rudders, struts, etceteras, should be serviced every few years. If you have wire splicing tools, it will take you about an hour to redo your entire system.

Stainless trim tabs are the exception to this. Most often tabs are NOT tied onto the bonding system unless they are bolted, rather than screwed to the hull. That's because there's nothing to attach a bonding wire to. The screws are all on the outside.

Over zincing, putting too much zinc, on causes the opposite problem. It will reverse the flow of current in the other direction and actually cause corrosion.

Over zincing is discernable when you find your props all covered with a coarse layer of zinc oxide. It will feel like sandpaper. This condition will reduce your boat's speed significantly and increase fuel consumption. I'll bet that statement got your attention!!!

Which is better: using one big zinc on a central bonding system, or putting zincs on rudders, shafts, etceteras? A single large zinc tied to the internal bonding system is unreliable because of the internal corrosion problems to wiring. And you have no way of knowing, short of doing a conductivity test, to know if the system is functional. Surface area of zinc is the most important criteria, and you'll get more surface are with more small ones. Multiple zincs are far more reliable.

Bonding Systems The purpose of a bonding system is to equalize the electric potential of dissimilar underwater metals by tying them all together with wire or copper straps. The benefits of a bonding system are wide ranging but little perceived. One is that it serves to dissipate stray current leaks. 12 volts of current focused on a small piece of metal will result in rapid destruction. But that same 12 volts spread over a much larger surfaces, causes less damage in proportion to the size of the water exposed surfaces of the metal. Bonding systems can reduce the corrosion potential of metals inside and on the bottom of the boat. Boat which have all the hardware bonded, such as the railings, will suffer much less corrosion.

As mentioned above, bonding systems are not maintenance free. The wire connections corrode too, and need to be re-established periodically. This is done by cutting off the old terminal or connection, and then establishing a new one. It's as easy as standing on your head in the bilge ;-)

Corrosion in Systems Okay, so now well know all about corrosion and the underside of the boat, but we haven't even touched on all those internal systems <u>through which water passes</u>. Yep, I mean the engines, air-conditioning, and other expensive stuff like that. Anything that water touches has a potential corrosion problem. Some of these things we can perform preventative maintenance on; for others you wait until the part fails and replace it.

Those metallic components through which water flows also need some corrosion protection. That includes the engines, pumps, A/C units and so on. The metal chassis or housings of things like pumps and air conditioners also need to be tied into the bonding system. On an A/C system, the sea cock, strainer, and compressor chassis all need to be wired together. The same applies to all other metal housing pumps, but not to plastic housing pumps. The primary reason pumps fail so often is because (a) they're not bonded, and (b) they are located in places where they get wet. Pumps tend to have a lot of dissimilar metals in them, which is why bonding is so important. I'd be willing to bet that the pump motors on your heads aren't bonded, which is one reason why you've replaced so many pumps.

The general rule is that anytime a piece of metal plumbing or hardware is isolated in a system, as with a sea strainer that is joined by two hoses is electrically isolated, needs to be wired into the system. This can be done by daisy chaining items together, but it's a good idea not to include too many items in a chain. Obviously, at any point where a connection is broken, all those items upstream will be unprotected.

More On Stainless Stainless steel comes in a very wide range of alloys. Naturally the best are the most expensive because they contain higher percentages of nickel, which is very expensive. Ergo, builders don't like to pay for this stuff, and that includes all you screws, nuts and bolts. Stainless is quite vulnerable to crevice corrosion, and it's most often to be found on low grade fasteners. The better grades -- this doesn't mean the best and most expensive -- when used for deck hardware do not rust. If you have rusting stainless hardware, it's because it's a low grade. Most corrosion occurs via crevices, such as around screw holes, stanchion bases and sockets, rub rails, etceteras -- any place that can trap water and create a closed cell. There isn't anything you can do about this.

This stern drive cavitation plate was lightly scraped by a fork lift truck. With the aluminium exposed, the metal now begins to erode strictly as a result of stray current which has left the metal bright.

Previously banned, ABYC has recently approved stainless for use as fuel tanks. This is unfortunate for stainless has a very poor track record for use as tanks. Stress, corrosion cracking and welding problems are among the reasons why. Place a stainless tank flat on a deck and the same thing will happen to it as an aluminium tank. Water tanks are even worse; metallurgically altered metallic structure around the welds results in unacceptably high corrosion failure rates. Weld failures in stainless water tanks are legion and can't be stopped.

Stainless piping and other fittings for sea water use is not recommended. Not so much because it isn't any good, but because no one can tell what grade of material it is. If it's a low grade, there always exists the danger of failure. Bronze is easy to make and is not subject to the alloying problems like stainless, so when buying plumbing hardware, it's best to opt for bronze. The stainless that looks so pretty today, probably won't after a few years anyway.

Hose Connections Hose connections to metal pipes and nipples, and threaded pipe fittings are all subject to crevice corrosion. That's because of the tendency for water to work its way between hose and the part it's clamped onto. One of the reasons marine hose is so expensive is because it has to be made of butyl rubber, and not carbon rubber which is cheap while the former is expensive. The problem of leaking connections is particularly acute on engines because of the effects of heating and cooling, which changes the dimensions of the parts. When water gets under the connection, crevice corrosion begins. This is the reason why teflon tape is used on pipe connections, and why it's a good idea to use silicon gasket cement on hose-to-metal connections. These materials will greatly reduce the propensity for leakage, bearing in mind that small leaks ALWAYS become large leaks. Always.

Stiffer reinforced plastic hose is very good for plastic to plastic connections, but it should NOT be used for plastic to metal connections. Plastic hose is too stiff to form up a good seal with a metal pipe.

Hose Clamps No doubt you have wondered why they can't make a hose clamp that doesn't corrode like crazy. Well, they can't and the reason is that old bugaboo stress corrosion. No mater how good the stainless, stress corrosion will take its toll. For this reason, it is extremely important that all hose connections be properly fitted. If you have to use a ton of clamp pressure to make the seal, you will only cause the clamp to fail that much quicker because of the increased stress on the clamp. This is another reason why you shouldn't use plastic hose unless the plastic is quite soft and will deform easily like a rubber hose will. A good fit is one where little clamp pressure is needed.

Double clamping. For decades surveyors have parroted the need to double clamp hoses. The truth is that you don't, although it's a very good idea to have two clamps in place, the other not tightened up. Two very tight clamps will fail just as fast as one. Moreover, a properly fitted hose will fuse itself to the pipe connection so hard that you'll have a hard time getting it off. Tighten the second clamp just enough to hold it in place. When it's time to replace the first clamp, just tighten up the new one and remove the old one. If you're trying to clamp a hose with a bad fit, THEN you need more than one clamp. All engine cooling system and exhaust systems should be double clamped for obvious reasons. You NEED more clamping surface area here.

Aluminium Ugh. This inexpensive material has its uses on a boat, but it's used in too many unsuitable applications just because it is cheap. It makes lousy hardware but good sail boat masts and great fuel tanks, so long as they are installed properly. It makes for lousy trim and mouldings; it makes for lousy machinery casings like winches and spotlights. Aluminium cannot be cast in good marine grade alloys, thus all aluminium castings corrode like a banshee. Aluminium is extremely vulnerable to crevice corrosion, which is why so many aluminium tanks fail.

Don't blame the material, blame the installer for not doing it right. Done right, aluminium tanks will last forever. Fuel tanks, that is, not water tanks. AL should not be used for water tanks, period.

Aluminium is similar to Corten steel in that it develops a layer of self-protecting oxide. This layer is so thin you can't even see it, but it's there. Quality marine alloys don't corrode and fail, except where crevices may exist, and when joined to dissimilar metals. That's why it's nearly impossible to keep paint on aluminium window frames when secured with stainless screws.

Keeping paint on aluminium is extremely difficult, and requires very careful and proper preparation. All these boats with painted but corroding window and door frames are the result of just shooting the raw aluminium without proper preparation procedures, many without even the proper primers that are indispensable to making the paint stay on.

Worse, many boats these days simply use residential or recreational grade windows and doors that are not even a marine grade aluminium. There's no hope for this stuff.

Needless to say, this is what makes maintaining stern drives so difficult. Not only are they vulnerable to galvanism because of all the different metals in the drive, but it only takes a very small amount of stray current to cause serious damage, as shown in the photos above.

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