MARINE CORROSION

It is not unusual to hear yachtsmen and marine professionals recount frightening stories about the complete disintegration of a metal propeller, stern drive or entire aluminum hull by a condition they often wrongly refer to as electrolysis. It is in fact corrosion, an electrochemical phenomenon, that can cause extensive damage to the submerged sections of a vessel. The two principal types, galvanic corrosion and electrolytic corrosion, are well known in the marine environment and can be controlled with adherence to modern construction and outfitting practices. Today's yachtsmen are not the first to discover the destructive effects of corrosion. In 1761, as an experiment, the British Navy fit copper plating below the waterline of the HMS Alarm to help prevent the infestation of the wooden hull by woodworm. The experiment was successful as far as the woodworms were concerned, but the officers were shocked to discover that the iron fastenings of the rudder and the iron nails used for the fastenings were totally corroded, to such an extent, in fact, that the ship lost its false keel. Copper has the ability to attack and destroying iron when the two metals are immersed in salt water. The two metals in galvanic couple is thus created.

by Eric Ogden

GALVANIC CORROSION

This phenomenon is the result of the difference in potential between the two metals that, when in contact or linked by a conductor and immersed in an electrolyte, in this case salt water, form an electrical battery. The positive electrical current comes out of the metal with the lowest
potential (the anode) and passes through the electrolyte to the one with the highest (the cathode).
The anode will be wasted for the benefit of the cathode. This phenomenon can only start if the two metals come in contact with each other and the electrical circuit is then closed. On board a boat, the potential of each immersed metallic element can be measured in comparison to a reference electrode, generally of Silver/Silver Chloride (Ag/AgCl), immersed in salt water and connected to the negative pole of a voltmeter. The other pole (positive) is connected to the metallic element to be considered (valve, seacock, propeller shaft bracket or even hull plating or the elements of the structure of a metal hull). Surveyors use these measurements to look for the origin of corrosion or to check the efficiency of the cathodic protection system on a boat sitting in salt water.
A metal is considered to have sufficient cathodic protection when its potential, measured in relation to the reference electrode, is from _200 to _250 millivolts in comparison with the values given in the table. For the most commonly used metals, the acceptable values vary between _ 800 to 1050 millivolts for steel, between _850 and _950 millivolts for aluminum alloys and between _500 and _700 millivolts for bronze. A potential too low (more negative than 1050 mV) can, however, provoke the formation of alkali which may attack paintwork. Furthermore, certain tensile steels can become fragile and cracks can appear. It is therefore imperative to respect certain principles in the choice and assembly of materials used onboard in order to eliminate the risks of galvanic corrosion. For example, on hulls constructed in aluminum alloy, bronze or stainless steel valves and steel pumps must be carefully insulated from the hull or other aluminum structural parts by inserts or supports made from an insulating material. Even better, these days they can be replaced by equivalent installations manufactured from synthetic material.

The following table indicates the average potential values of various metals immersed in salt water in comparison to an Ag/AgCl reference electrode.

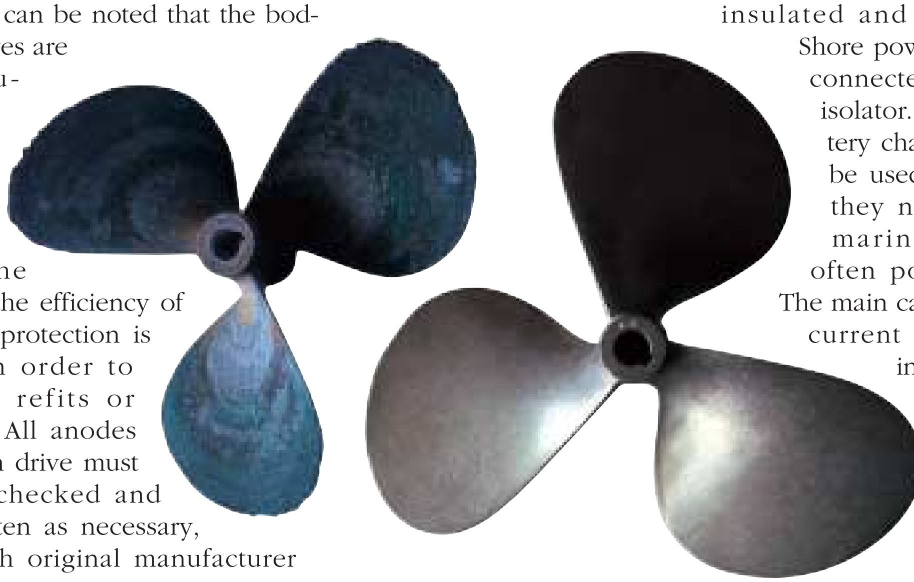
METAL	Potential (millivolt)	METAL	Potential (millivolt)
Graphite	270	Brass	-300
Titanium	20	Copper	-310
Stainless steel type 316 (Passive)	-30	Tin	-310
Monel	-60	Stainless steel type 316 (Active)	-390
Stainless steel type 304 (Passive)	-60	Stainless steel type 304 (Active)	-490
Silver	-100	Mild steel	-630
Nickel	-130	Aluminium alloy (Marine grade)	-750
Aluminium bronze	-160	Zinc	-1000
Lead	-200	Galvanised steel	-1100
Bronze coppernickel	-250	Magnesium	-1600

CATHODIC PROTECTION

Two forms of cathodic protection are readily available to the modern yachtsman. The first is the common installation of sacrificial anodes at different places on the hull. They are usually made from zinc, a metal less resistant than most others to the effects of corrosion, and as a result we refer to these anodes as “zincs”. This metal is used because it is anodic in comparison to all other materials used in naval construction. Its electronegative potential is from _1000 mV (see the table). Aluminium anodes are sometimes used on steel hulls because they are lighter and less costly. On the other hand, for yachts used on inland waters it is recommended to protect them with magnesium anodes to take into account the variations of potential between salt and fresh water. Professional guidelines govern the precise placement and mounting of these anodes and they must be checked regularly as much for their deterioration as for the efficiency of their positioning. The number and the mass of the anodes must be adapted according to the size of the hull. Abnormally rapid deterioration indicates a problem that must be identified and corrected as soon as possible. It is strongly advised that all submerged metallic equip-

The anode on the left was eaten away in less than 8 days.

ment installed on the hull (seacocks/valves, stern glands, propeller shaft bearings, propeller shafts, flaps, etc), but equally the bilge pumps, sea water pumps and engine should be linked together by a wire or a strap also connected to the anodes. This set-up allows an equalization of the potentials and considerably limits the risks of galvanic corrosion. The conductor used should have a minimum #10 AWG.
A second type of cathodic protection called "by induced current" is used on large vessels. This system transforms the structure to be protected into a cathode by inducing an inverse current through an inert anode. A permanent measuring device allows the control and regulation of this current according to the measured difference of potential. Mercruiser stern drives are equipped with a system of this type called MerCathode. It can be noted that the bodies of stern drives are built of aluminum alloy and are therefore particularly sensitive to corrosion. The monitoring of the efficiency of their cathodic protection is imperative in order to avoid costly refits or replacements. All anodes fitted to a stern drive must be regularly checked and replaced as often as necessary, preferably with original manufacturer parts. Cathodic protection is not only limited to hull fittings and stern drives; anodes are commonly fitted to engine components to protect cooling systems and heat exchangers. Again, failure to replace wasted anodes can cause internal corrosion and lead to overheating and its well-known grave consequences.



ELECTROLYTIC CORROSION

Electrolytic corrosion is not caused by a difference in potential between two dissimilar metals. It is due to leaks of direct or alternative currents, which artificially create a cathode and an anode sometimes even with the same metal. As in the case of galvanic corrosion, the metallic part or fitting will be wasted to the advantage of the cathode, but in this case, the damage will often be more severe and occur faster. Where the effects of galvanic corrosion can take months or years to appear, those of electrolytic corrosion will be visible after a few days or even a few hours in certain extreme cases.
On all boats, but especially on those built in aluminum, non-compliant installations or any electrical "DIY" can have dramatic consequences. Current leakage can provoke severe deterioration of structural parts by electrolytic corrosion. It is therefore essential that the electrical installations be fitted with great care and according to standard practice. They must include insulators and efficient protection. Wiring should be of the two wire type, and conductors must be carefully fastened and/or run through sheathing above bilge level in order to avoid contact with bilge water. All the circuit breakers and switches must be have two poles, and the electrical devices must be insulated and waterproofed. Shore power lines must be connected to a galvanic isolator. Household battery chargers should not be used onboard boats; they not designed for marine use and are often poorly insulated. The main causes of electrical current outflow are an inversion of polarity, poor wire insulation, presence of water or salt crystals in a connection box,


This propeller shaft suffered from DC stray currrent corrosion.

conductor wiring running in the bilges, and poor or non-existent bonding of certain equipment. An electrical leak can be difficult to detect since the origin is usually well hidden. While it's not unusual to detect a leak in a poorly insulated bilge pump on one's own boat, what may be surprising is that the electrical currents that cause corrosion can originate from one or several neighboring boats or even the marina's power supply. In effect, all the boats connected to a dockside terminal are interconnected via its ground connection.All the engines, and their propeller shafts are thus inter-connected and create one or several galvanic couples. The anodes fitted on certain boats then protect the propeller shafts and stern drives of other boats that do not have anodes or whose anodes are wasted.

Furthermore, an electrical current outflow or an inversion of polarity on a neighboring boat can also effect the electrical installation on your boat, but a galvanic isolator and an isolation transformer can limit the risks. It is also recommended not to keep the shore power connected for extended periods of time.The most effective way to prevent marine corrosion is to comply with the industry standards for construction, installation, and wiring, and to monitor the boat's electrical system and anodes as recommended.