Volume 19 Issue 5

Overview | Feature | Publisher's Page | Technical Article | Marketplace | Boatlines

Technical Article: Corrosion

This article outlines some of the causes and cures of metal destruction in the marine environment.

New South Wales-based naval architect and wooden boat builder **Christopher Murman** delves into the topic of

CORROSION

Electrolysis and galvanic corrosion are frequently confused. Galvanic corrosion is caused by two dissimilar metals being in contact with each other, in the presence of an electrolyte, such as seawater. Electrolysis is caused when an external current, called a stray current, finds a path between two metals in the presence of an electrolyte. The two metals may be of exactly the same type or different types.

The destruction of metals aboard any yacht is a never-ending process and requires constant vigilance. With a basic understanding of the many and varied causes, much can be done to arrest this on-going process.

OXIDATION

All metals are subject to oxidisation. Oxidation is the natural process of the metal returning to its base elements by combining with oxygen from the atmosphere or the local environment, for example, oxygen from the surrounding seawater. Some metals use the oxidation process to protect themselves, while the process destroys other metals. Rusting is the common name for the metallic flaking of steel and iron, however it is still oxidation.

This new bronze skin-fitting (above) is beginning to oxidise. Note the characteristic green colour. The skin-fitting should have been mounted on a block to provide additional strength to the local area of the hull.

A large rust patch was started by water getting under the protective paint work at the edge of the hole and has resulted in substantial damage.

The effects of oxidation on metals such as mild steel are immediately apparent and are very destructive to the metal component. Metals such as stainless steel, titanium and anodised aluminium are protected from further destruction by the oxidation process as they form a thin oxygen-impervious layer over the surface. As long as a supply of oxygen is available from the atmosphere or the surrounding environment, for example seawater, the thin oxidation layer is self-healing if subjected to scratching or abrasion.

The rate of oxidation of steel is approximately proportional to the amount of oxygen available. So if the steel component is in an oxygen-starved environment, the rate of deterioration will be dramatically reduced. Layers of surface rust hinder the development of further rusting by inhibiting access to the oxygen supply. However, constant abrasion will remove these layers and thus accelerate the oxidation process. Metals that are destroyed by the oxidation process should be protected by a suitable two-pot epoxy painting system or galvanised, depending on the application of the metal component. I would always recommend consultation with a reputable paint manufacturer before purchasing and applying any painting system. I have always found the technical staff at reputable paint manufacturers most willing to provide assistance.

PITTING

Pitting frequently occurs in metals that use an oxide layer to protect themselves. Metals such as stainless steel tend to pit in seawater if the mechanism that maintains the film breaks down for any reason. The hindering of the self-repairing film is usually the result of changes in the environment over the surface of the metal. Some examples include: differences in temperature, variations in the oxygen supply over the surface, or an uneven flow of water over the surface of the metal component.

Pitting frequently starts in a crevice. Some examples of man-made crevices include threads, two plates overlapping each other, or wherever dirt can be trapped. This is sometimes called crevice corrosion. The dirt then holds moisture, which forms a galvanic cell (see Galvanic Corrosion). The 300 and 400 series of stainless steels are particularly susceptible to pitting, for example 316 and 304 stainless steel.

Left: The corrosion of this steel keel is so severe that it has penetrated the metal at the top, near the leading edge. Note the water pouring out of the keel on the starboard side, due to another hole.

The local area that sustains the damage becomes the anode and the large surrounding area becomes the cathode. Once started, the cell tends to feed on itself. Thus the pit grows ever larger.

Pitting can be minimized by using metals that are less susceptible to this form of attack and also by using fabrication techniques that minimize the opportunity for the development of galvanic cells. Table 1 indicates the typical susceptibility of metals to pitting in the marine environment.

The correct installation and maintenance of anodes (zinc alloy blocks) can dramatically reduce the risk of pitting. Another practice that reduces pitting is to use zinc grease on all threads. The grease prevents the penetration of water, thus eliminating the presence of an electrolyte. The zinc also acts as an anode.

Stainless steel is less susceptible to pitting as the electrolyte becomes more alkaline. This is what happens when cathodic protection is operating properly. An electrolyte also becomes more alkaline as the salt content in the water decreases.

Pitting of noble metals is dramatically reduced when the water velocity increases above two metres per second (7.2 kilometres per hour). This is because of diminished marine fouling and also because the surrounding water is highly likely to be aerated, providing additional oxygen to the surface of the metal.

CAVITATION

Cavitation occurs when the local water pressure falls to near zero. This causes cavities or bubbles in the water. If the bubbles collapse on the surface of a metal component, such as a propeller blade, the implosion is so violent that the surface is mechanically attached and some of the metal is plucked from the surface, resulting in a pit on the surface.

Some metals have a greater resistance to attack from cavitation than others. The more noble metals are much more resistant to cavitation attack than metals such as mild steel (see Table 2). As a general guide, cavitation resistance is increased with the hardness of the metal.

Left: The small red patch at the tip of this propeller is de-zincification. The large pitted area close to the blade tip is caused by cavitation.

Below: This zinc block has been seriously eaten away. It should be replaced immediately

Cavitation can be a very serious problem with propellers, as they are frequently made to work in less than optimal conditions. In addition to the characteristic pitting which results from cavitation, other side-effects include additional noise, loss of speed and in extreme cases, intermittent engine racing.

Propeller cavitation usually starts around the blade tips or near the root of the blade. Cavitation issues should be addressed by a naval architect or cavitation specialist as this is a complex subject.

Metals in fast flowing water:

While the more noble metals are protected in fast flowing water

This skin-fitting is suffering from well-advanced de-zincification and should be replaced immediately. The owner did not replace it when advised and it nearly caused the sinking of the vessel.

environments (greater than two metres per second or 7.2km/h) the copper-based alloys start to lose their protective coatings and corrode rapidly. The rate of corrosion of metals such as aluminium, lead, steel and zinc also increase in faster flowing water. Fast flowing water can be found in onboard systems such as, pump housings, exhaust systems, engine cooling jackets and piping, to name just a few. Ship board piping systems typically have water velocities from 1.2 to 3.6 metres per second. Pump housings typically have water flow velocities from 9.1 to 24.4 metres per second.

Copper piping should be avoided when the water velocity exceeds approximately 1.2 metres per second. Piping made of a more resilient metal should be selected or a larger diameter should be used to reduce water velocity and subsequent damage.

GALVANIC CORROSION

Galvanic corrosion is caused by two dissimilar metals that are in contact and in the presence of an electrolyte.

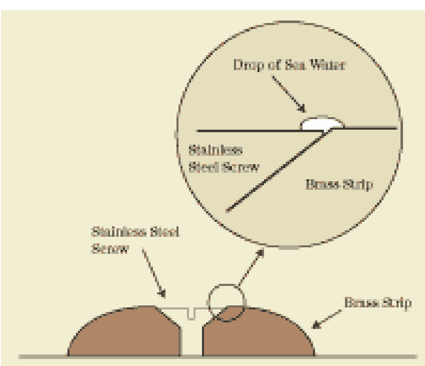

Diagram 1: Galvanic corrosion is caused by two dissimilar metals that are in contact and in the presence of an electrolyte.

Diagram 1 illustrates an example. This generates an electrical potential, that is, an electrical current. The less noble metal, called the anode, is eaten away. The other metal, the more noble metal, is called the cathode and is protected. Thus the cathode is protected by the anode. In the marine environment, the electrolyte is usually seawater, although rainwater can also act as an electrolyte. Very pure water will not operate as an electrolyte as it cannot conduct electricity. Seawater has approximately 2.5 per cent salt content, which facilitates the conductance of an electric current through the water. Water will generally act as an electrolyte as it contains some form of impurity or pollutants.

Table 1:
The typical susceptibility of metals to pitting in the marine environment

Metal	Pitting Characteristics
Nickel Chromium Molybdenum Alloys Titanium	These metals are rarely susceptible to any form of corrosion.
Maganese Bronze Aluminium Bronze Some Brass Alloys Cast Iron	Pitting is unlikely, but the first three metals tend to de-alloy.
Austenitic Cast Iron Nickel-aluminium-bronze (NAB) Alloys Tin Bronze (commonly called Gunmetal) Silicon Bronze Copper Nickel Copper Remaining Brass Alloys Lead	Pitting will be small if at all.
Monel Stainless Steel (type 316) Nickel Chromium Alloys Nickel Stainless Steel (type 304) Stainless Steel (400 series)	Pitting can be severe. This list is roughly in order of susceptibility, stainless steel (400 series) being the most susceptible.

Table 2:
Common marine metals showing their resistance to cavitation pitting

Metal	Resistance to Cavitation Pitting
Titanium Stainless Steels Nickel Chromium Alloys	Excellent
Monel Nickel Aluminium Bronze (NAB) Alloys	Good
Tin Bronzes (commonly called Gunmetal) Magnesium Bronze Copper Nickel	Fair
Cast Steel Cast Iron Wrought Iron Aluminium	Poor

Table 3 details the typical galvanic series for metals used in the marine environment. The metals at the top of the table are said to be more noble while the metals at the bottom of the table are less noble.

As a general rule, the further apart the two metals are in the galvanic series the more they will react with

Table 3: The Galvanic Series for metals where the electrolyte is saltwater

Metal
Cathode End
Platinum
Titanium
Alloy 825
Stainless Steel (types 316 317)
Monel
Stainless Steel (types 302, 304, 321, 347)
Silver
Nickel 200
Silver Braze
Nickel Aluminium Bronze (NAB) Alloys
Copper Nickel (70 – 30)
Lead
Stainless Steel (type 430)
Copper Nickel (90 – 10)
Nickel Silver
Stainless Steel (400 series)
Tin Bronzes (commonly called Gunmetal)
Silicon-Bronze
Magnesium Bronze
Aluminium Brass
50/50 Solder
Copper
Tin
Most Brasses
Aluminium Bronze
Nickel Cast Iron
Low Alloy Steel
Mild Steel and Cast Iron
Cadmium
Most Aluminium Alloys
Zinc
Magnesium
Anode End

each other and the faster anode will be destroyed. However, this is not a hard and fast rule as there are other issues to be considered. These issues can become convoluted and are outside the bounds of this article.

Aluminium, zinc and magnesium are at the bottom of the table. This is why they are used in an alloy to make sacrificial anodes and thus protect all other metals. Because aluminium is very close to the bottom of the table, it is imperative that all aluminium vessels be carefully protected with anodes at all times. Aluminium hulls can be subject to vigorous attack from galvanic corrosion.

The risk of galvanic corrosion can be reduced by minimizing the number of different metals used. Galvanic attack can also be dramatically reduced by ensuring sufficient sacrificial anodes are correctly installed and maintained. I would always recommend replacing all of the anodes at every annual haul-out, unless they are in near new condition. The efficiency of the anode is significantly reduced as the zinc alloy block is eaten away. Annual replacement of the anode is very cheap insurance against galvanic corrosion and a sound preventative maintenance procedure.

Anti-fouling paints containing copper-based biocides can cause extensive galvanic corrosion to aluminium hulls, outboard legs and any other aluminium alloy components, such as below hull instrumentation sensors. Special barrier paints can be applied to insulate the aluminium component from the copper-based anti-fouling paint. There are also anti-fouling paints specially developed for aluminium hulls. I would always strongly recommend contacting a reputable paint manufacturer before proceeding.

ELECTROLYSIS

Electrolysis and galvanic corrosion are frequently confused. Electrolysis is caused when an external current, called a stray current finds a path between two metals in the presence of an electrolyte. The two metals may be of exactly the same type or different types.

If two dissimilar metals are subject to a stray current, the more noble metal may not necessarily be protected, as with galvanic corrosion. If the stray current is sufficient to overcome the natural galvanic current then the

Damage or corrosion to propeller blades can sometimes be repaired, but it requires the skill of an expert. Do not try to do this yourself

more noble metal may well become the anode and is thus destroyed. The rate of electrolysis attack is dependent on the amount of current present. A stray current caused by a short circuit can 'eat' metal components away in a very short period of time.

The risk of electrolysis attack can be minimized by always ensuring all electrical systems, including wiring, switches and all electrical equipment are installed correctly and are maintained in good working order. Another good preventative maintenance practice is to always isolate all batteries before leaving the vessel. Isolating the batteries can also assist in optimizing the life span of the batteries. Batteries should be kept clean and dry and this includes the battery posts, casing and the battery box as dirt can act as a pathway to facilitate a current leakage, which may result in a stray current.

Top of Page