# Crevice Corrosion on
# Stainless Steel Propeller Shafts

## What is it?
## How to Prevent it.
## How to Repair it.

**A Quick Summary:**

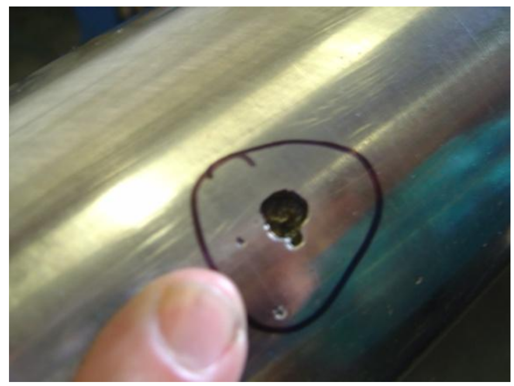
- **Stainless steel propeller shafts and running gear are subject to pitting & crevice corrosion**
- **It mainly occurs on vessels in warm, salt water environments**
- **It occurs when water remains stagnant for long periods of time (months)**
- **It mostly occurs in the stern tube, bearing or seal area where it cannot be detected until the vessel is hauled and shafts are removed**
- **The stainless steel and salt water change chemical properties and become corrosive**

- **It can be avoided or minimized by running engines weekly to flush stern tubes and briefly turning shafts**
- **It can be repaired, up to a point, with shaft cladding or welding**
- **More advanced damage requires replacement of the shaft**

www.HighSeasYachtService.com 954.975.8220
2001 SW 20th Street Bay 113, Fort Lauderdale, FL 33315

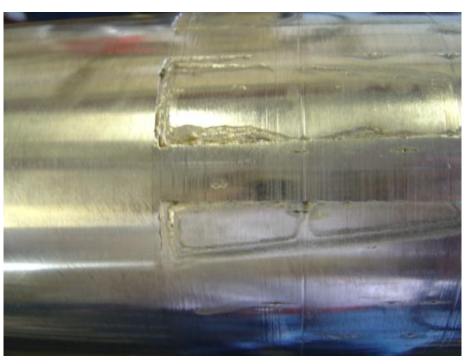
# Crevice Corrosion
# Chemistry 101

***I thought Stainless Steel prevented corrosion?*** The corrosion resistance of stainless steel is dependent on the presence of a protective oxide layer *(metal bonded to Oxygen)* on its surface, which can break down in very strong acids. Stainless steel resists corrosion by growing a hard shiny film of mostly chromium oxide to protect the base metal alloy from corrosion. This very thin surface film is not static but rather continually grows to fill in gaps and tiny scratches much like your skin continually grows and repairs itself. In the underwater marine environment stainless steel needs to get some of the oxygen which is dissolved in seawater to repair and grow this protective oxide surface film.



If there is too little oxygen available from the seawater- **Pitting** and **Crevice Corrosion** are usually the result. These are the most common forms of "Oxygen Depletion" corrosion which affect stainless steel running gear in the marine environment.

**Pitting Corrosion** can form on the surface of the stainless steel in salt water dependent upon the environmental conditions, surface finish, contamination and the composition of the steel itself. This pitting occurs under special conditions, involving sodium chloride (salt) in sea water and greatly exacerbated by the elevated temperatures found in tropical ocean environments. Once started these small pits can continue to grow and grow in a self sustaining cycle. Hydrochloric acid is produced by the corrosion which also attacks stainless steel, making a deeper crevice, which produces more acid, which produces a deeper pit, ad infinitum. Hence the honeycomb effect of the corrosion damage. The acid is heavier than water and as seen on stainless steel trim tabs and shafts with pits on the upper edge. Left undisturbed, they can propagate to amazing depth over a few months time.



**Crevice Corrosion** is a type of **Pitting Corrosion**, and a very special case where the initial "**pit"** is provided by an external feature such as rubber & plastic seals, gaskets and cutlass bearings or structural anomalies such a porous welds, surface contamination or overlapped mechanical joints. These potential "Crevice Formers" are present to some extent in almost all marine propeller & shaft assemblies. In this photo you can see how the flats of a rubber cutlass bearing initiated the crevice corrosion and left a imprint of the bearing shape.

## How Crevice Corrosion Forms on Stainless Steel Shafts - Six Chemical Stages

1. **Crevice Formation -** "Crevice Formers" must be present; examples of these features are sharp corners, overlapping metal surfaces, non-metallic gaskets or incomplete weld penetration. These can all form tiny crevices which can promote corrosion. To function as a corrosion site a crevice has to be of sufficient width to permit entry of the seawater, but sufficiently narrow to ensure that the seawater remains stagnant. Accordingly crevice corrosion usually starts in **gaps a few micrometres wide**, (less than 1/10,000 of an inch) and is not found in grooves or slots in which circulation of the sea water is possible.
2. **Oxygen Depletion -** Stainless steel depends on a thin oxide *(metal bonded to Oxygen)* film on the surface of the metal to resist corrosion. This film is not stagnant but "grows" using the oxygen from the surrounding sea water to rebuild and repair this protective oxide film wherever gaps or scratches occur. Within a tiny stagnant crevice the naturally occurring oxygen is gradually used up by the growth of the protective oxide film. The imbalance in oxygen concentration between the shielded crevice area where the oxygen has been used up to repair the oxide film and outside seawater sets up an oxygen concentration cell or "chemical pump" which drives much of mischief to follow.
3. **Acidification** *(The lower the PH the stronger the Acid)* The metal ions present or entering the moist environment of the tiny crevice hydrolyze, eliminating the hydroxyl (OH-) ions thus dropping the PH so that the crevice becomes very acidic as well as positively charged
4. **Chlorine Migration** Chlorine ions from the bulk sea water outside the crevice migrate inside to balance the charge resulting from the depletion of the hydroxyl ions during step 3 *(Opposite Charges + & - attract)*
5. **Initiation** Once the PH is low enough *(very Acidic)* and the Chlorine ion concentration is high enough *(very Salty)* the chemical breakdown of the protective film covering the stainless steel will begin. For stainless steels this critical point will vary by the composition of the metal for example type **304** will breakdown at a PH drop to **2.1** or less with a Chlorine concentration of **1.8 times** normal sea water while type **316L** remains resistant until the ph drops down further below **1.65** and the Chlorine concentration in the crevice rises to about **7.5 times** normal sea water concentrations.
6. **Propagation** After the initiation process has passed the critical point for the particular stainless steel in use the shielded crevice becomes anodic (acts like a tiny anode) with the remaining bulk of the stainless steel acting as the cathode and traditional galvanic corrosion is underway. In saline sea water environments galvanic effects favor deep penetration once the initiation phase has started in each individual crevice corrosion site.

### What Affects the Saltwater Crevice Corrosion in Stainless Steels?

In stainless steel alloys commonly used for marine propeller shaft applications, the proportion of **Chromium, Molybdenum, and Nitrogen** have been shown to have a dramatic effect on the susceptibility to crevice corrosion and pitting. The effects are summarized in the Pitting Resistance Equivalent Number (**PRE**) calculated as:

**PRE = % Cr + 3.3 x %Mo + 16 x %N**

**(Higher PRE = More Resistance to Crevice Corrosion)**

For reference 316L stainless steel exhibits a PRE of 22-28 while some specialty stainless steel alloys (ex AL-6XN) have PRE values of up to 45

| COMPOSITION | AQUAMET 17 | AQUAMET 19 | AQUAMET 22 |
|---|---|---|---|
| Chromium % | 14.50 - 16.50 | 18.00 - 20.00 | 20.50 - 23.50 |
| Molybdenum % | - | - | 1.50 - 3.00 |
| Nitrogen % | - | 0.20 - 0.30 | 0.20 - 0.40 |
| P.E.R. | 14.5 - 16.5 | 21.2 - 24.8 | 24.3 – 38.9 |

## How Can I Prevent it?

### Seven Simple Steps to Protect your Vessel from Stainless Steel Shaft Pitting and Crevice Corrosion

1. **Consider the Environment** - Low salt content and low water temperatures reduce or eliminate crevice corrosion problems. Tropical salt water environments greatly exacerbate this challenge.
2. **Avoid Surface Contamination –** Free Iron residue from the use of mild steel tools or wire brushes leave thousands of tiny particles of iron embedded in the surface of the stainless steel. Once in service each free iron particle can initiate a corrosion site.
    - **Never** Use a mild Steel Wire Brush on Stainless Steel Shafts.
    - Remove all contaminants, especially free-iron, by acid- passivation per the steel manufacture's specifications.

3. **Surface Preparation** - Prepare exposed stainless steel surfaces to best possible finish. **Mirror-finish** resists pitting best. Once properly cleaned consider use of an anti-fouling running gears coating such as "Prop Speed" on the exposed stainless steel underwater surfaces

4. **Enhanced Design & Repair Techniques** - In warm climates and ocean operation selection of more resistant materials (High **PRE** value) such as AQUAMET 22 should be considered for both new-build and replacement applications.

   Be sure to properly lap both the propeller and coupler taper joints each time the shafts are removed for service to reduce crevice formation in these necessarily overlapped joints.

   Design and fabricate to avoid crevices or trapped and pooled liquids Weld with correct consumables and practices and inspect to check for inadvertent crevices. Pickle with appropriate acid bath, paste or gel and rinse to remove all weld scale.

5. **Regular Operation** The initial phases of Oxygen Depletion, Acidification and Chlorine migration take significant time (weeks) to occur, regular operation of the equipment tends to interrupt this cycle before severe damage has been incurred particularly in sites formed by seals, gaskets and cut-less bearings.

6. **Eliminate Bio-Fouling** Barnacles and other forms of marine growth are very effective at generating "Crevice Sites". Regular cleaning and removal of marine growth from the running gear and hull can reduce Pitting & Crevice Corrosion on the exposed portions of the shafts.

7. **Cathodic Protection** Consider the use of cathodic protection, while there is little indication that this retards the critical first steps prior to the "Initiation Phase" of the crevice corrosion process in stainless steels, some experts suggest that cathodic protection may slow the propagation phase and it is often very helpful against other forms of marine corrosion

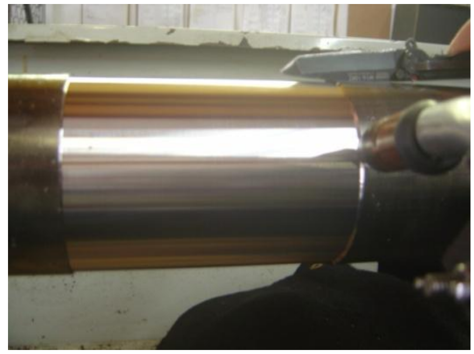
## OK. I Have Crevice Corrosion – How Can I Repair It?

Crevice Corrosion on a stainless steel shaft can be repaired. The region on the shaft that usually requires repair are in a lip seal or packing area and around cutlass bearings. The area on the shaft around the lip seal or packing must be repaired in order to prevent sea water intrusion and premature wear of the lip seal or packing. Similarly, a repair in the cutlass bearing is required when the corrosion forms a sharp edge that will cut or wear a new cutlass bearing. Pitting in open areas on a shaft, such as in the stern tube, typically do not require any repair.

Before starting the repair there should be an overall assessment of the shaft. Sometimes it is better and more economical to purchase a new shaft when weighting the cost to repair large areas, along with the shaft straightening costs.

The process of repairing is called ***Cladding*** or a weld-over. The process is *not* simple and should only be done by a highly skilled and experienced machinist.

It starts with machining in an engine lathe an area the length of the desired repair, the depth of the corrosion (usually no more than 0.125”) and fully around the shaft. This cleans and preps the area to be built up with new welding material



The area is then filled with a continuous weld using filler wire that is matched to the metallurgy of the shaft material.

After the new welded material has cooled it is rough cut in the lathe for handling. Next the shaft must be check in the shaft straightener. When applying the high heat of welding to the ends of the shaft a small bend usually occurs. A shaft that was perfectly straight (within 0.001” run-out from end to end) could have a 0.020” bend at the taper after welding.

The shaft must be straightened before proceeding. A shaft should be straight in order to prevent vibration and improve longevity of the bearings, seals and transmissions. It also must be straight for the final machining and polishing in the lathe. It is impossible to machine the welded area to blend with the original shaft if the shaft is not running true in the lathe.

## In Summary:

- **To Avoid Shaft Crevice Corrosion Run the Engines and Turn the Shafts Every Two Weeks.**
- **If you get Corrosion it can be Repaired with Cladding – Give us a Call**

StraightLine Marine

www.HighSeasYachtService.com 954.975.8220
2001 SW 20th Street Bay 113, Fort Lauderdale, FL 33315