ANODES FOR CORROSION PROTECTION

All metals corrode. But the rate at which they do so varies according to the metal and its environment. Water heater storage tanks manufactured from metal (including stainless steel and copper) can be very susceptible to corrosion. The combined effects of internal water pressure, temperature and water chemistry can create very aggressive environments. This Fact File describes how corrosion attacks water heater storage tanks and compares the corrosion protection method used by Solahart with other types of water heaters. In particular, the way the Solahart Anode works is explained.

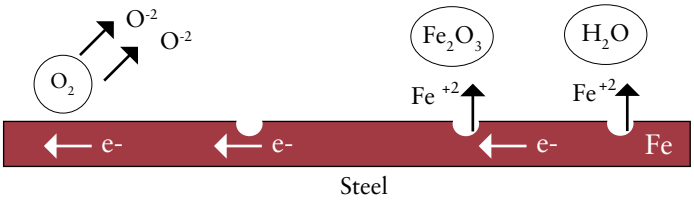
- What is corrosion?
- How can corrosion be prevented?
- Are there different types of corrosion mechanisms?
- What about the story of anodes and hydrogen?
- Technical Specifications
- Corrosion Mechanisms

What is Corrosion?

'Corrosion' is the technical name for the chemical reaction that takes place when a metal combines with oxygen. The metal "corrodes" or "oxidises". If the metal is iron or steel, it is usually said to "rust". Chemists describe the primary reaction by the equation:

$$4Fe + 3O_2 + 2xH_20 \rightarrow 2Fe_2O_3 \bullet xH_2O$$

It is read as: Four parts of iron (Fe) combine with three parts of oxygen (O_2) in the presence of water (H_2O) to form a rust, (iron oxide or Fe_2O_3) water mix. Although it is not clear from the equation, what is actually happening when a metal corrodes is that the metal atoms (in this case Fe) give up one or more electrons that in turn attach to the oxygen atoms. It is this transfer of electrons to oxygen molecules that is at the heart of the corrosion reactions.



How can Corrosion be Prevented

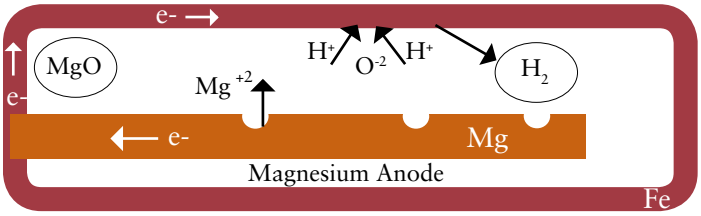
One simple way to prevent corrosion is inhibit the availability of oxygen at the metal surface - in the absence of oxygen, the corrosion reaction stops. One way to do this is to apply a protective coating over the metal surface. This creates a barrier between the metal and the surrounding oxygen. Paints, plastic coatings and ceramic glazes can be used for this purpose.

Some metals, such as stainless steel, copper and aluminium, form a protective coating. An oxide layer forms over the surface of these metals as they corrode. This oxide layer creates a barrier between the oxygen and the non-oxidised metal. If the oxide layer is without gaps and sufficiently stable, oxygen can be completely excluded and corrosion can be arrested. If the oxide layer has gaps, or is easily removed, corrosion can continue on the exposed, non-oxidised metal surfaces. Examples of where coatings are used to prevent corrosion include: paint on steel structures such as bridges; paint coatings on metal roof sheeting; ceramic-glazed linings such as Solahart Primaglaze® on the inside of water heater tanks, aluminium oxide layers on aluminium boat hulls, chromium oxide layers on stainless steel sinks.

In the presence of hot water, paint, plastic coatings and aluminium oxide can dissolve. Ceramic glazes do not readily dissolve in hot water. Ceramic glazes and stainless steel do have other limitations. These are addressed below.

How Does an Anode Work?

An anode provides a different method of corrosion protection. Rather than relying upon a physical barrier to separate the metal from oxygen, anodes protect by corroding in preference to the metal. This is achieved by selecting the correct anode material for the metal to be protected.



Steel tank

The easiest way to explain the process is by using the example of an anode in a Solahart tank. Although coated with a ceramic glazing, it may be possible for a small 'pinhole' in the coating to form. Therefore we need additional protection for the steel cylinder. A Solahart tank is fitted with an anode made from magnesium (Mg), a material that corrodes in preference to steel or iron. This means that the magnesium will more readily release electrons than steel. The anode is immersed in the tank water and connected to the steel of the tank to form a 'corrosion circuit'. The circuit is shown in the diagram.

The primary reaction becomes:
$Mg + H_20 \rightarrow MgO + H_2$

Instead of the Fe giving up electrons that attach to the oxygen (O_2) atoms, the Mg releases the electrons.The Mg and O_2 atoms combine to form magnesium oxide (MgO). A by-product of this reaction is hydrogen gas. The Fe does not take part in the chemical reaction other than through its role as the conductor of electrons. Provided it has not been fully consumed, the magnesium anode will prevent the tank steel from corroding.

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Are There Different Types of Corrosion Mechanisms?

There are four main corrosion mechanisms: galvanic, pit and crevice, stress and fatigue corrosion. The corrosion of a magnesium anode in preference to steel is an example of galvanic corrosion. Galvanic corrosion can occur wherever two dissimilar metals are in contact in the presence of water or some other 'electrolyte'. For example, galvanic corrosion can occur adjacent to the weld line of stainless steel sheets where the welding process itself has altered the composition of the weld-metal.

A detailed description of the three other corrosion mechanisms is beyond the subject matter of this Fact File. An in-depth understanding is however important when designing or selecting a water heater storage tank.The table presented below explains the effect of each mechanism on a Solahart Primaglaze® ceramic-lined steel tank.

What About the Story of Anodes and Hydrogen?

The release of hydrogen gas by an anode can sometimes occur. Small quantities of hydrogen are produced and what is produced generally remains dissolved and flushes away as hot water is drawn from the tank. Depending on the water quality and the area where the water heater is installed, there may be a degree of hydrogen build up in the tank if the water heater hasn't been used for two or more weeks. This is indicated by the spurting of a hot water tap when it is first opened.

Technical Specifications

Anode material	Magnesium
Anode purity:	95%
Anode mass:	280g/m^2

Primaglaze® Lined Steel Tank	
Protective coating	Three-tenths of a (0.3mm) ceramic lining fused to steel at 850°C.
Extent of pin-holes and crevices in protective coating	Pin-holes limited to one-hundredth of one percent (0.01%) of surface area of coating. Design avoids crevices.
Galvanic corrosion mechanism	Magnesium anode corrodes in preference to steel to protect steel at pin-holes.
Pit & crevice corrosion mechanism	Magnesium anode releases ions that attract chloride (Cl) ions, dissolved magnesium chloride (MgCl) flushes away.
Stress corrosion mechanism Fatique corrosion mechanism	Thick steel tank walls (2.0 to 2.5mm) are lightly stressed and less susceptible to fatigue
Mechanical fatigue	All pressurised water heater storage tanks are subject to pressure cycles that fatigue the tank walls. If corrosion failure does not occur first, fatigue failure will eventuate. Thick wall sections are less sussceptible to fatigue failure than thin sections.

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