

Reactive Metals in Chemical Water Treatment

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In recent years we have seen new alloys and new applications of familiar alloys in recirculating water systems. Sometimes these applications present challenges which can stretch the limits of water treatment chemistry. Zinc, aluminum, and magnesium are metals considered reactive in treated systems, in part relating to water conditions, and in part because the larger portion of the mechanical system will usually be alloys of steel and copper.

A high school chemistry experiment is to immerse two plates of dissimilar metals in an electrolyte (highly conductive solution) and measure the electrical current generated with a voltmeter. Different metal combinations generate higher or lower voltage. This is a battery. There is a chart which predicts the relative strength of the electrical current that will result. This is called the galvanic series. The farther apart metals are on this chart, the more current will be generated. The most noble metal used will be the cathode, or electron recipient, and the least noble metal will be the anode, or electron donor. A given metal or alloy becomes anodic or cathodic relative to the other connected materials of construction in the system.

When low carbon steel and copper are connected in a piping system the low carbon steel is less noble, and becomes the anode. The anode is sacrificial; it corrodes away as electrons are donated. The larger the cathode compared to the anode the more rapid the anode corrosion. Designers of chillers specify very thick steel tube sheets in part to allow for the steel corrosion that will result from the large cathodic surface area of the copper tubes compared to the small anodic surface area of the steel tube sheet. Also, because steel is anodic in the presence of copper, many applications require isolative

fittings between steel and copper piping to alleviate steel corrosion.

There are metals in the galvanic series, which are less noble than both steel and copper, and will always become the anode in steel and copper systems. Three such metals are mentioned above: zinc, aluminum, and magnesium.

Zinc is most often found as a galvanized surface in recirculating systems, especially in evaporative cooling towers. The purpose of zinc in this application is to function as a sacrificial anode, thus protecting the low carbon steel sheet metal to extend the life of the cooling tower to 20–30 years. Old galvanizing was 95% zinc, 4% lead, and 1% impurities. The lead in the alloy modified the rate and nature of the sacrificial corrosion so that the galvanized coating was resistant to rapid corrosion. The new galvanizing alloy—95% zinc, 4% aluminum, 1% impurities—does not resist rapid corrosion nearly as well, and maintaining pH near or less than 8.3, along with several other adaptations, proves to be a problematic chemical patch on a metallurgical problem. The old galvanizing alloy is no longer available because of the potential to discharge lead and chrome as the alloy sacrifices. So, galvanized sheet metal went from one of the best materials of construction for a cooling tower to a less effective material. Smart buyers are requiring new cooling towers be constructed of alloys or composites which will not experience this “white rust” corrosion.

Aluminum is even less noble than zinc, sufficiently so that it finds use as a sacrificial anode, to be connected to steel as an aluminum block anode in highly corrosive

environments, a recirculating brine system for example. The sole purpose of the aluminum anode in this application is to corrode away and thus alleviate steel corrosion in the localized area.

In addition to this galvanic attack, there are other factors which can also increase aluminum corrosion. The aluminum anodizing process depends on the fact that in presence of D.C. current, controlled pH, and

temperature, an aluminum surface will corrode to an aluminum oxide surface in a matter of minutes. Anodizing is a controlled corrosion process. Aluminum is easily corroded. Alloying aluminum can help to increase corrosion resistance, but many alloys and cladding processes are primarily to increase strength and have little beneficial effect on corrosivity. More corrosion resistant aircraft aluminum alloys and specialized coatings are usually impractical for recirculating water system applications.

Realizing aluminum's tendency to corrode, at the same time aluminum has other properties as a metal, which make it desirable in HVAC applications. It has wonderful heat transfer capability, is easily machined, and ductile. When heat exchange gasses or fluids on both sides of the heat exchanger result in a non-corrosive environment, and when completely isolated from any possibility of galvanic corrosion, aluminum is a material of choice. Accomplishing all of that can be easier said than done.

Aluminum alloys are now being employed in hot water boiler heat exchange applications. This would seem a natural progression, given ever-increasing heat transfer efficiency requirements. Isolating the aluminum from more noble metals by use of isolative fittings would be absolutely essential to preventing predictable galvanic attack. The chemistry of the recirculating water is a challenge. A manufacturer of aluminum exchanger hot water boilers states, and other sources confirm, a pH maximum of 8.5, as higher pH initiates aluminum corrosion. The desired pH for steel

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protection in recirculating loops is 8.0–10.0 with higher being better. Copper fares well between 7.0–9.5 pH. The cumulative pH requirement for a typical multi-metal system including aluminum is 8.0–8.5, an impossibly tight range in practical application. Water supplies across the U.S. vary from below 7 to over 10 pH. Since the pH scale is exponential, it is easy to maintain a high pH with one or more universal products, but very hard to maintain a pH at the moderate and tight 8.0–8.5 range. The use of molybdate, nitrites, azoles, silicates and organic inhibitors all help. But, especially in the presence of boiler temperature and conductance, the need for pH control to prevent waterside failure of the aluminum boiler heat exchange surface is not erased.

In this application, it would not be possible to guarantee a product to be “aluminum safe” because of the variability of water quality and the possibility the exchanger is not properly isolated from galvanic corrosion. Then, if there happens to be an excess of corrosive anions in the water, chlorides or sulfates, practically nothing will stop the aluminum exchanger from becoming sacrificial.

That being said, if the aluminum exchanger boiler was my own system, I would be diligently researching whether installation of magnesium anodes would be beneficial in reducing aluminum corrosion. Magnesium is even less noble than aluminum. I do not know if the difference is enough to be effective. If it is determined that this is a good recommendation, then I would:

- Properly install and set up a preventive maintenance schedule for replacement of magnesium anodes.
- Assure that the aluminum exchanger and magnesium anode installation are, as a unit, properly isolated from the more noble materials of construction.
- Chemically treat the system with a combination of molybdate, nitrite, azole, pH buffering and possibly additional inhibitors.
- Having selected a good and knowledgeable water treater, accept and acknowledge the fact that no one can guarantee the absence of aluminum corrosion in this application.

Magnesium is the most reactive and least noble of our subject metals. Magnesium has no place as a material of construction in any treated water system. Magnesium’s only function is as a sacrificial anode to protect other

more noble metals, which includes just about all metals, within close proximity. Magnesium’s only flaw in this assignment is that in a highly corrosive environment it can corrode away so quickly that it can become hard to keep up with replacement, in which case the slightly less reactive aluminum anode may be a good alternative.

As water treaters we need to keep an eye out for galvanized and aluminum materials of construction in systems we treat so that we can advise our customers of their choices and alternatives. Galvanizing is usually pretty easy to spot because it is most often found in open evaporative cooling towers. Aluminum, on the other hand, may be well hidden from view. Although it is the customer’s responsibility to tell us the materials of construction of a system, especially if we ask, some just don’t know. Our products are designed to be as broad spectrum as possible. However, at the same time we are doing a wonderful job of protecting steel and copper alloys, it is probably unwise to guarantee to be able to prevent corrosion of zinc (galvanizing), aluminum, or magnesium in any system. ☺

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