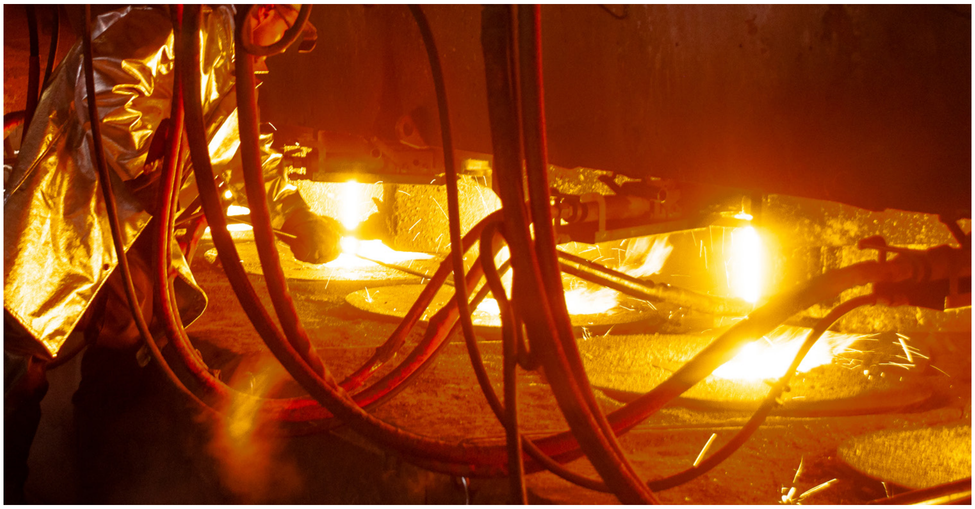
CASE STUDY

eROI℠ by Ecolab

North American steel mill eliminates pitting corrosion in non-contact cooling water system using Nalco Water technology



TOTAL VALUE DELIVERED

ENVIRONMENTAL RESPONSIBILITY

Reduced phosphate discharges into the environment by 53%.

ASSETS

Reduced pitting corrosion below detectable levels.

PRODUCTIVITY

Reduced corrosion helped avoid unscheduled downtime and premature equipment failures.

$35,000/yr

BACKGROUND

A North American steel manufacturer made a big bet on a sixty-year-old mill in 2017. Historically a producer of rebar and similar materials, the company invested $180 million to increase capacity to meet growing demand in the midwestern United States. In 2019, the company committed an additional $40 million to construct a new continuous caster to improve product quality and expand the mill's product catalog. A year later, the global pandemic disrupted those plans. Installation of the Italian-designed caster required on-site expertise by a team of international experts. Restrictions on international travel during the pandemic required that work to be done remotely, a tremendous challenge. The mill was brought online, but in the complex pandemic environment, exposure of the water systems to stagnant conditions and incomplete passivation created a corrosive environment.

SITUATION

Differentials in electrochemical potential — anodes and cathodes — create localized corrosion cells which manifest as pits on metal surfaces. Although the amount of metal wastage associated with pitting corrosion is small, this type of corrosion causes equipment to fail more quickly than general etch corrosion. It is also more difficult to inhibit chemically.

Elemental iron (Fe^{+0}) in steel reacts with oxygen to form ferrous iron (Fe^{+2}), releasing two electrons. Those electrons flow through the metal from this area of positive potential (the anode) to an area of negative potential (the cathode) where, at the metal surface, they react with oxygen. The now-reduced oxygen gains two electrons and forms OH^- ions. The rate of metal wastage at the anode depends on the conductivity of the water, flow, pH and the concentration of chlorides, sulfates and other ions in the cooling water.

Breaking the electrochemical cell requires anodic and cathodic corrosion inhibition. At the anode, inhibitors facilitate the formation of a stable oxide layer which prevents the interaction of iron and oxygen. At the cathode, cathodic inhibitors prevent the reduction of oxygen by preventing oxygen from reaching the surface.

For decades, anodic inhibitors have relied on orthophosphate. When oxygen interacts with iron at the surface forming Fe^{+2}, orthophosphate forms a slightly soluble complex which then catalyzes the formation of gamma iron oxide (FeOOH), a dense, strong, passive film.

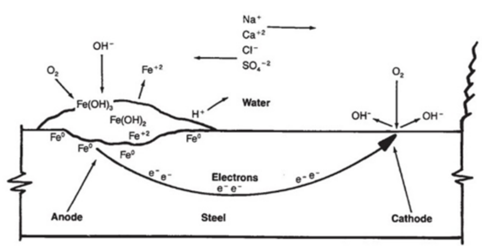


FIGURE 1: An electrochemical corrosion cell. Iron (Fe^0) is oxidized at the anode, releasing two electrons.At the cathode, oxygen gains electrons forming OH^-.

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At the cathode, many cooling water inhibitors have relied on organic phosphates or metals like zinc to form a barrier between the cooling water and the metal surface. Corrosion can be inhibited by preventing the interaction of oxygen with the surface at both the anode and the cathode.

As effective as those treatments are, both metals and phosphate present performance, environmental, regulatory and, in some cases, operational challenges.

Limitations of phosphate and metals-based corrosion inhibitors

Phosphates

- Contribute solids
- Nutrient source for bacteria and other aquatic life
- Limited by permits
- Can contribute to mineral scaling if poorly controlled

Metals

- Often limited by regulation
- Can cause health and environmental concerns

Environmental Concerns

Phosphate, a nutrient source, fosters algal growth. Algal blooms reduce the penetration of light into water, preventing photosynthesis by plants underneath it. Over time, the plants and algae die and sink to the bottom where bacteria decompose them. Decomposition depletes oxygen, killing more aquatic life, including higher life forms like fish and shellfish. This process, called eutrophication, affects both fresh and salt waters. It can be prevented in many cases by limiting the addition of phosphate to the water.

Metals such as zinc also present environmental concerns. There are various zinc release sources from both natural processes and human activities, so it is important for regulatory agencies to limit zinc discharge when possible. Zinc does not biodegrade. Released into the environment, most settles into soils and can seep into the groundwater. Animals can increase their uptake of zinc by ingesting soil or drinking water where a small amount dissolves or exists as fine suspended particles. High levels of dissolved zinc can bind to fish gills and cause suffocation. It can also bioaccumulate within the bodies of fish if they are continuously exposed to high concentrations.

When ingested in excessive amounts by humans and animals, zinc inhibits the absorption of copper which can lead to copper deficiency. Copper deficiency can cause anemia.

RESULTS

Nalco Water helps customers achieve their goals by equipping on-site technical experts with innovative technologies. At this steel mill, operational and performance goals were not being met with traditional chemistries. A zinc-based program might have delivered better results but was not acceptable for environmental reasons. Applying relatively high concentrations of phosphate failed to deliver the results the mill wanted. Pitting corrosion rates on the incumbent program were high. Addressing those issues with a new technology made the program change attractive.

The new program combines several polymers to inhibit both deposition and corrosion, an azole to protect yellow metals and a small amount of pyrophosphate for cathodic corrosion inhibition.

Nalco Water controlled the new low-phosphorus, non-metal corrosion inhibition program with Nalco Water's 3D TRASAR™ cooling water technology and monitored results using ECOLAB3D™. The results were dramatic. Phosphate concentrations in the cooling water declined 53% and pitting corrosion was reduced in the mill's non-contact cooling water system to non-detectable rates.

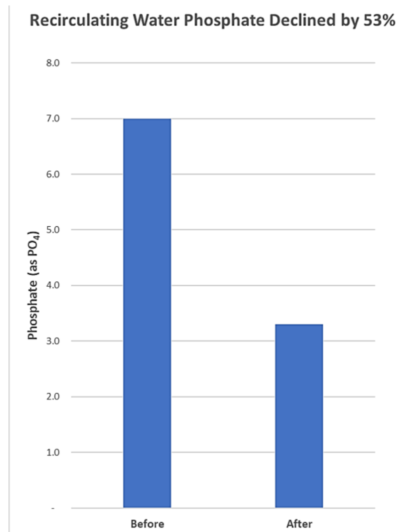


Figure 2: Changing to the low-phosphorus program reduced phosphate concentrations in the recirculating water by 53%

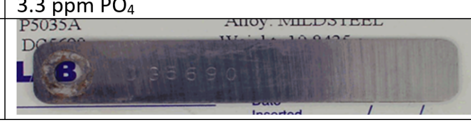
Prior Program	New Program
7.0 ppm PO_4	3.3 ppm PO_4
	

Figure 3: Phosphate concentrations declined 53% and pitting corrosion was reduced to below measurable rates using the new low-phosphorus program

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