INTERNATIONAL MOLYBDENUM ASSOCIATION
THE VOICE OF THE MOLYBDENUM INDUSTRY

Molybdenum keeps heat flowing

Heating and cooling systems depend on water to transfer heat through buildings, factories, and power plants. However, without proper treatment, the circulating water can gradually corrode pipes and equipment, reducing efficiency and shortening service life. Molybdate-based corrosion inhibitors help prevent this deterioration.



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Closed-loop heating and cooling systems, which circulate the same water continuously through a sealed network of pipes, pumps, boilers, chillers, and heat exchangers, are designed to operate for decades with minimal maintenance. These systems are used wherever heat must be delivered, removed, or recovered efficiently, including heating and cooling buildings, as well as industrial processes in manufacturing plants and power stations. A common treatment to keep these systems running optimally involves molybdenum-based, water-soluble chemicals known as molybdates.

Why corrosion matters

Water may appear harmless, but it naturally contains substances that promote corrosion. Dissolved oxygen is one of the main drivers of corrosion, while chlorides and microorganisms can accelerate metal attack. Water chemistry, temperature, and flow conditions all influence the rate at which corrosion develops, making proper water treatment essential. Even in closed loops where water never leaves the system, dissolved oxygen, salts, and other contaminants can trigger corrosion unless properly treated.

Corrosion is more than the gradual loss of metal. As steel and other alloys corrode, the resulting corrosion products accumulate inside pipes and heat exchangers. These deposits narrow the flow of water and form an insulating layer that reduces heat transfer. Pumps must work harder to maintain circulation, which increases energy consumption and decreases the heat exchangers' efficiency.

As corrosion continues, localized attack can eventually lead to leaks or complete system failure. For example, a 2018 investigation into the failure of a European bottle manufacturing plant found that corrosion caused extensive leakage in its cooling system, which led to repeated shutdowns and costly repairs. The researchers concluded that a relatively inexpensive corrosion-inhibitor treatment, such as one with molybdates, could likely have prevented the failure.

Because corrosion develops gradually, these problems often go unnoticed until performance has already declined or repairs become necessary. Preventing corrosion is therefore not only about avoiding leaks, but also about maintaining efficient heat transfer, reducing operating costs, and extending the service life of valuable equipment.

› **Corrosion products and sediment buildup inside a pipe.**



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Building a barrier with molybdates

One of the most widely used methods of protecting closed-loop heating and cooling systems is treatment with molybdate corrosion inhibitors. These water-soluble compounds, produced from molybdenum, help form protective films on iron, aluminum, and copper-based metals. For iron-based alloys such as steel, dissolved iron ions and oxygen react with molybdate at the metal surface to reinforce the naturally occurring oxide layer, creating a stable molybdenum-enriched passive film. The resulting transparent passive film limits further metal dissolution and protects the underlying metal from continued corrosion. Molybdates do not eliminate corrosion entirely but suppress it enough to allow closed-loop systems to operate efficiently throughout their intended service lives. Unlike many corrosion inhibitors, molybdates remain stable at elevated temperatures and do not readily break down in chlorinated systems, making them particularly well suited to industrial cooling systems where localized hot spots and chlorination are common.

Molybdates became widely adopted during the 1970s as chromate-based inhibitors were phased out because of their carcinogenicity and the associated environmental and occupational health concerns. In comparison, molybdates provide effective corrosion protection while posing a comparatively low toxicity risk, making them a preferred choice for many closed-loop systems. Today, the largest application of molybdates is in industrial cooling water treatment for power plants and other industrial facilities, although they are equally effective in commercial buildings and domestic heating systems. Their use is now so widespread that simple molybdenum test strips are routinely used by maintenance personnel to verify that inhibitor concentrations remain within the recommended range.

Compounding benefits

In practice, molybdate inhibitors are rarely used on their own. Although they can be used as a stand-alone treatment, the relatively high concentrations required for effective corrosion protection – typically around 200 to 300 milligrams per liter – make this approach less economical. Commercial water treatment products are therefore often supplied as pre-formulated blends that combine molybdates with other complementary additives. Nitrites work synergistically with molybdates to improve corrosion resistance, while azoles such as benzotriazole or tolyltriazole protect copper alloys. Phosphonates help control mineral scale, and other additives stabilize pH or suppress microbiological growth. By addressing several corrosion and water-quality challenges simultaneously, these formulations provide broader protection.

The benefits of molybdate treatment extend well beyond preventing corrosion; energy savings can also be significant. According to a study by the UK's Carbon Trust, cleaning and properly treating a dirty heating system can reduce natural gas consumption by up to 15%. This equates to avoiding around 90 kilograms of carbon dioxide emissions per home each year.

Across the millions of heating and cooling systems that rely on molybdate inhibitors, these energy savings translate into significant reductions in resource consumption and greenhouse gas emissions. It is another example of how small amounts of molybdenum contribute to sustainability by conserving energy and extending the life of essential infrastructure.



Sodium molybdate is a water-soluble molybdenum compound widely used in corrosion-inhibitor formulations.

The narrow flow passages of plate heat exchangers can accumulate corrosion products, restricting water flow and reducing heat-transfer efficiency. Molybdate inhibitors help limit this buildup by suppressing corrosion.

