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Closed-Loop Systems Water Treatment

Introduction

Closed-loop water systems are water circulation systems that function in a contained environment where the water remains isolated from the atmosphere and the makeup requirements are minimal, typically less than 5% of the system's total volume in a year. These systems are used in modern buildings' heating and cooling systems to transfer thermal energy from one process or space to another without mixing the water with external sources.

Closed-Loop Water Treatment Challenges

Makeup Water

While closed-loop water systems are meant to be sealed, they can still suffer significant and undesirable water loss – losing 25% of system volume per month is not uncommon. This is typically due to minor leaks in mechanical seals or overflow from expansion tanks. The makeup water added to compensate for these losses introduces impurities like minerals, entrained air, dissolved gases, organic matter, microorganisms, and suspended solids. These impurities can exacerbate issues related to corrosion, scaling, fouling, and microbiological growth.

Microbiological Growth

Problematic microbiological growth, especially denitrifying and sulfate-reducing bacteria, can thrive in closed-loop systems and cause fouling, corrosion, and reduced heat transfer. Stagnant areas, like dead legs, are especially susceptible. Additionally, nitrite, commonly used as a corrosion inhibitor in closed-loop systems, provides a nutrient source for denitrifying bacteria.

Corrosion

Corrosion can manifest in closed-loop systems due to various contributing factors, including the presence of dissolved oxygen and low pH levels. Dissolved oxygen, which can infiltrate the system either through makeup water or system leaks, causes a chemical reaction with iron in steel pipes that leads to rust.

Furthermore, an acidic or low pH environment fosters the degradation of the protective metal oxide passivation layers, which hastens metal surface corrosion within the system. The low pH environment leads to an increased concentration of hydrogen ions, which further accelerates the corrosion rate of the metal surfaces. If left unaddressed, corrosion progressively deteriorates and weakens the metal surfaces within the system. This deterioration can result in equipment damage, reduced operational efficiency, and higher maintenance costs.

Chemical Treatment

Chemical treatment involves injecting or pumping specialized chemicals into the closed-loop water system to control the water chemistry, preventing corrosion and microbiological issues. A non-exhaustive list of chemical treatments typically includes oxygen scavengers, corrosion inhibitors, pH boosters, scale inhibitors, and biocides.

Oxygen scavengers, such as sulfite, react with and remove dissolved oxygen. Corrosion inhibitors, such as nitrites and azole, are used to form a protective layer that keeps steel and copper from corroding. Biocides kill or control microbial growth such as bacteria and biofilm. Automated control systems utilize real-time sensor data to adjust chemical dosing rates for optimal treatment, ensuring that chemical levels are appropriately balanced.

Closed-Loop System Monitoring

Water Test/Analysis

Water testing and analysis includes both real-time sensor readings and periodic water sample lab analyses. These tests and KPIs are performed to assess the quality of the water in the system and to identify any potential issues. A non-exhaustive list of important KPIs to monitor are pH, temperature, conductivity, dissolved oxygen, total hardness, and bacterial count. Regular water quality monitoring helps track changes over time and ensure that treatment measures remain effective.

Corrosion Coupons

Corrosion coupons are a testing method to measure system corrosion rates. They are small sacrificial metal strips, representative of the system's alloys, that are placed within the system's coupon rack for 90 days. Afterward, they are extracted and analyzed to determine the corrosion rates and types occurring within the system.

Microbiological Testing

Microbiological testing assesses the presence and concentration of bacteria within the closed-loop system. Water samples are collected in sterile containers from stagnation-prone spots like dead legs or low-flow areas. These samples undergo lab analysis, using tests such as ATP, total bacterial count, and specific microbial identification. Regular microbiological testing is important to track changes in microbial populations over time and ensure that control measures remain effective.

System Cleaning

In older buildings that lacked proper water treatment, closed-loop water systems may exhibit partial blockages due to the accumulation of corrosion products. To restore efficiency, a cleaning program may be necessary. Various chemical cleaner methods are available, including acidic, caustic, and neutral pH cleaning processes.

Additional Reading

Lane, R. W. (1993). Control of scale and corrosion in Building Water Systems. McGraw-Hill.

NALCO (2009). The Nalco Water Handbook, third edition. McGraw Hill Professional.