QUALICHEM

DISSOLVED OXYGEN CONTROL IN COMMERCIAL AND INDUSTRIAL BOILER WATER SYSTEMS

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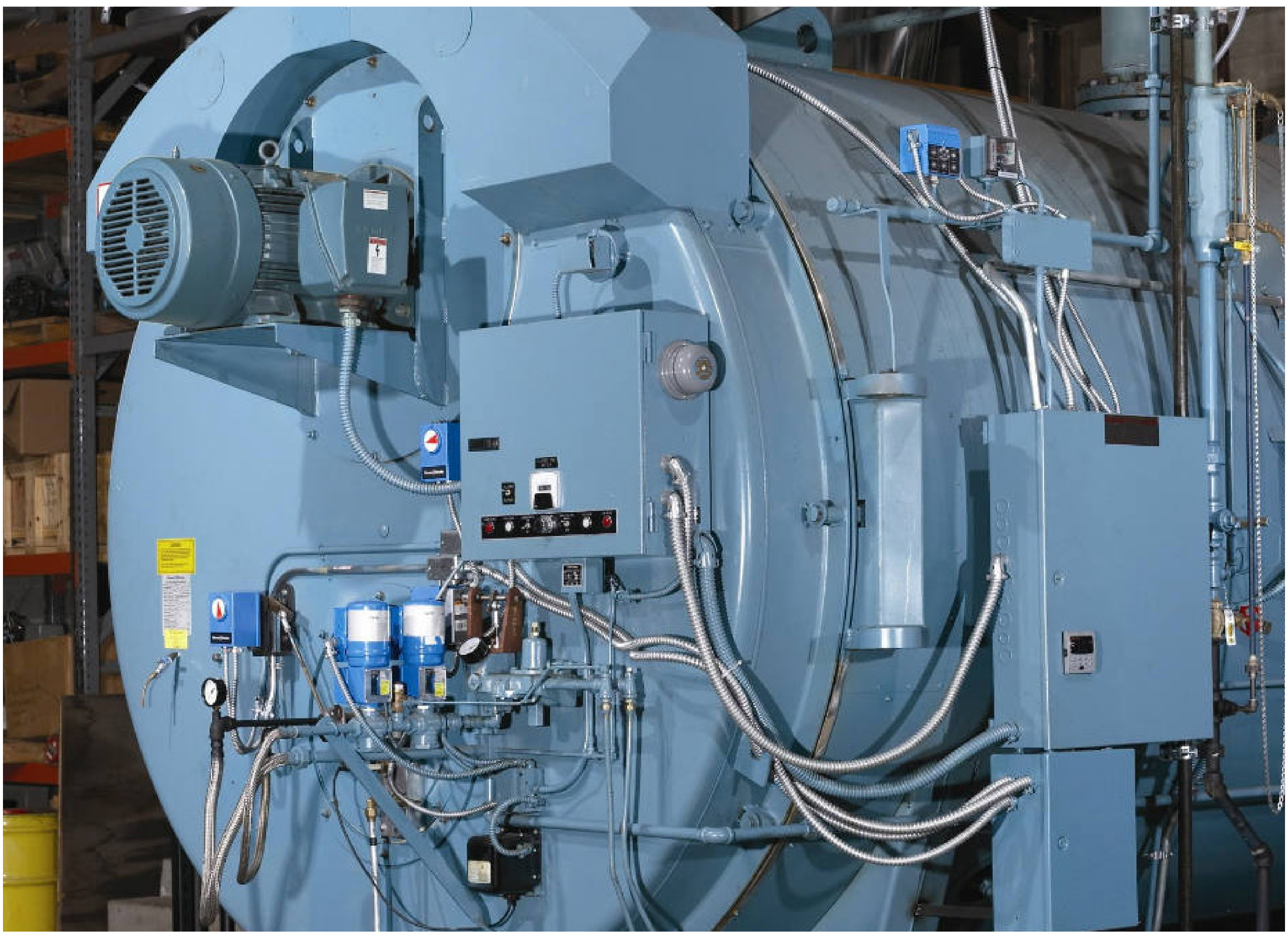
Introduction

When treating a boiler, it's important to understand how dissolved oxygen affects the efficiency and reliability of the boiler. The dissolved gases present in water, specifically oxygen, cause problems in boiler water systems if left untreated. The presence of dissolved oxygen will result in corrosion if left untreated. Dissolved oxygen causes pitting which is a very severe and localized form of corrosion

Commercial and Institutional boiler water systems offer unique challenges to those attempting to treat or prevent dissolved oxygen corrosion. Unlike Industrial boiler systems, which often make use of deaerators and have different system requirements, Commercial and Institutional boiler systems typically make use of less intricate pre-boiler feedwater systems but still require careful monitoring for proper operation.

The following provides an overview of the factors that can affect boiler water system dissolved oxygen control in Commercial and Institutional boiler water systems.



Dissolved Gases and Dissolved Oxygen Corrosion Control

Problems associated with dissolved oxygen

Dissolved oxygen is very corrosive in small concentrations and can cause serious problems. Dissolved oxygen pitting is localized in nature and can span a large area. These pits can often result in rapid failure of the system piping. The corrosion process also generates corrosion by-products which can deposit on pre-boiler and boiler heat transfer surfaces. This deposition can reduce the overall efficiency and reliability of the boiler water system.

Sources of dissolved oxygen

There are several major sources of oxygen in an operating system. For example, a few potential sources are: low temperature feedwater, in-leakage of air on the suction side of pumps, the breathing action of receiving tanks, and leakage of undeaerated water used for pump seals.

Acceptable levels of dissolved oxygen: The acceptable dissolved oxygen level will depend on many factors, from water temperature, pH, flow rate, and dissolved solids content to the metallurgy and physical condition of the system. There are various guidelines surrounding oxygen limits, but the generally accepted American Society of Mechanical Engineer (ASME)'s limit is less than 7 ppb.[1]

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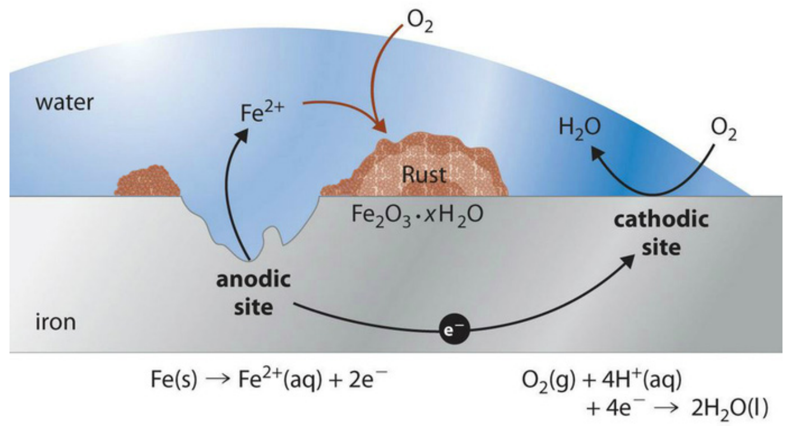
Nearly complete oxygen removal is required to meet industry standards for the allowable oxygen content and metal oxide levels in feedwater. This can be accomplished by efficient mechanical deaeration (using heat, steam atomization, and venting) and an effective and properly controlled chemical oxygen scavenger treatment program.

[1] *Consensus on Operating Practices for the Control of Feedwater and Boiler Water Chemistry in Modern Industrial Boiler Systems, CRTD-Vol. 34, ISBN 0-748-1204-9*

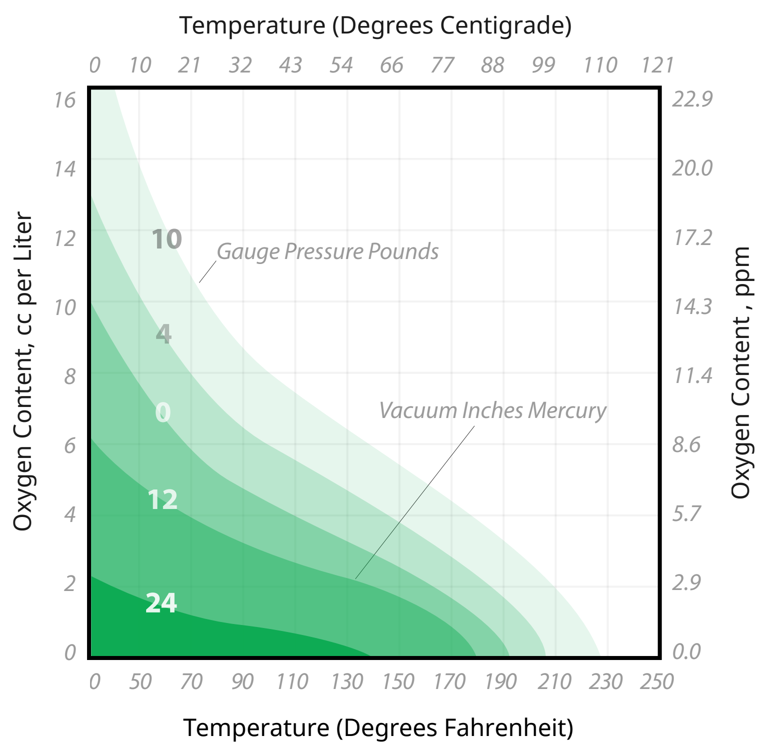
Oxygen corrosion mechanism: The attached illustration is a detailed representation of how oxygen induced pitting occurs. Simplified, the metal loss occurs from the anodic area (anode). Iron, Fe^0, is lost to the water and becomes oxidized to Fe^{+2} ion. Because of the formation of Fe^{+2}, two electrons are released to flow through the steel to the cathodic area (cathode). The dissolved oxygen in the water is reduced at the metal surface (cathode) and completes the electric circuit by using the electrons that flow to the cathode to form hydroxyl ions $(OH)^-$ at the metal surface. Reducing the available dissolved oxygen supply will greatly reduce this corrosion reaction mechanism.

HOW OXYGEN PITTING OCCURS



The role of temperature in reducing dissolved oxygen: Temperature is another important factor for helping to control dissolved oxygen corrosion in pre-boiler and boiler systems. As temperature increases, the solubility of oxygen within that water is decreased. This means that there will be less dissolved oxygen the higher the temperature of the water.

The amount of steam required to heat and deaerate the water depends on the amount of incoming water and its temperature. The graph depicts the amount of oxygen dissolved in water at a given temperature and pressure. This is helpful in determining the amount of dissolved oxygen that needs to be removed.



SOLUBILITY OF OXYGEN

Methods of Dissolved Oxygen Control

Controlling the amount of oxygen within a boiler water system is a vital part of maintaining an efficient and reliable boiler system. There are two ways to control dissolved oxygen: mechanical removal and chemical removal.

Mechanical methods of dissolved oxygen removal alter the physical characteristics of the water to reduce the amount of dissolved oxygen. Chemical methods of dissolved oxygen removal use specific chemicals to scavenge the remaining oxygen out of the boiler system.

It is a best practice to make use of available mechanical methods to reduce dissolved oxygen rather than solely relying on chemical methods. Optimizing the effectiveness of the mechanical options will keep chemical usage to a minimum.

Mechanical removal

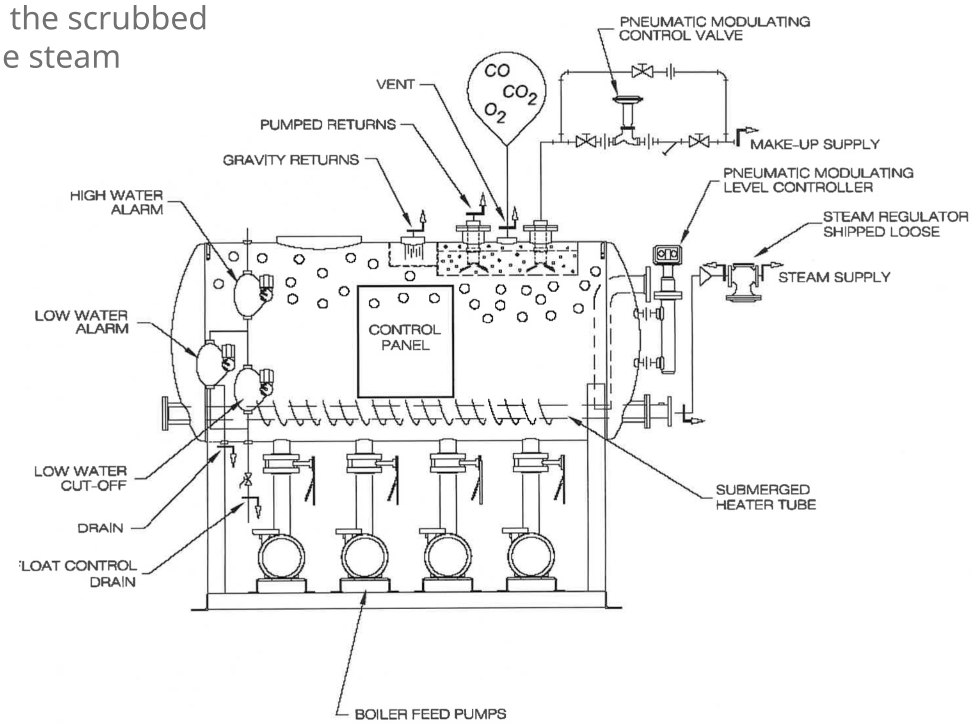
Mechanical removal is the most fundamental method of removing dissolved oxygen from a hot water or feedwater tank in the boiler water system. It involves the manipulation of the incoming water temperature and pressure by utilizing steam injection.

Here's a brief overview of common methods of mechanical oxygen control:

Hot water or "feedwater tanks": Commercial and Institutional systems most often make use of equipment referred to as "feedwater" or hot water tanks. A feedwater tank is the simplest mechanical method used to reduce the amount of dissolved oxygen in a boiler system. This tank is typically a vessel for storing makeup water (city, softened or demineralized) and where the return condensate collects.

These tanks often use steam sparging to increase the water temperature and drive the scrubbed oxygen out through a vent. As the steam

TYPICAL FEEDWATER TANK LAYOUT



enters the vessel it elevates the water temperature and decreases the solubility of oxygen in the water to drive off the oxygen. The lower the amount of dissolved oxygen in the tank, the lower the amount of chemical oxygen scavenger required. Since steam is generally readily available, this is the most fundamental method of mechanical deaeration.

Deaerators: Deaerators are more often used in larger commercial and institutional systems, as well as Industrial boiler systems. Deaerators are vessels that collect makeup water and condensate and direct it over trays or as a spray, countercurrent to a steam flow. The released dissolved gases (oxygen) are removed via a vent on the vessel.

Deaerators reduce dissolved gases, particularly oxygen, to a low level and have the added benefit of improving thermal efficiency by raising the water temperature. Deaerators also provide feedwater storage and proper suction conditions for boiler feedwater pumps. Efficient mechanical deaeration can generally reduce dissolved oxygen to the 5 to 10 ppb range.

For complete protection from oxygen corrosion, a chemical scavenger is required following each form of mechanical deaeration.

Chemical removal

Chemical treatment for dissolved oxygen involves the use of specific chemicals to chemically “scavenge” the remaining trace amounts of dissolved oxygen from the boiler feedwater and provide an excess amount of the oxygen scavenger (residual) to the boiler in order to maintain a level of insurance against dissolved oxygen corrosion.

Many factors can influence the best choice for an oxygen scavenger for a specific application. These include product cost, reaction speed, residence time in the system, temperature and pressure, pH and the end use of the steam. The type of water treatment chemical used to remove oxygen from a boiler water system will depend on the system’s unique conditions.

Different types of chemical oxygen scavengers: By definition, oxygen scavengers are reducing agents. They are used to provide a favorable reducing condition at the metal surface. The term ‘oxygen scavenger’ refers to chemicals that facilitate chemical reactions that consume the dissolved oxygen from a system decreasing the likelihood of oxygen induced corrosion damage.

Oxygen scavengers can be volatile organics or inorganic in nature.

- **Inorganic scavengers:** Inorganic materials are the most basic chemicals with relatively simple chemical structure. The most widely used inorganic scavengers used within this classification are sulfites and bisulfites. Sulfites and bisulfites are variations on the same chemistry and are the most common oxygen scavenger used in commercial and institutional applications. These lower pressure systems favor sulfite products because they have minimal health and environmental impact and are inexpensive and safe to use.

  Plants that require FDA certification must make use of allowed oxygen scavengers and controlled below the maximum allowable levels. Sulfites meet FDA requirements.

  Sulfite easily reacts with dissolved oxygen but the reaction rate is slower in waters below

200 deg F. It is a standard practice to add a catalyst to help accelerate the reaction rate. A commonly used catalyst for sulfite oxygen scavengers is cobalt sulfate.

- **Organic scavengers:** Higher pressure industrial steam systems and power plants make use of organic oxygen scavengers. In these systems sulfites are replaced with organic scavengers such as DEHA, Carbohydrazide, and Erythorbates. The best organic oxygen scavenger for an application will depend on the system's needs.

Use of an oxygen scavenger in a boiler system requires monitoring to ensure there is sufficient residual of the oxygen scavenger.

Monitoring of oxygen scavengers: Use of an oxygen scavenger in a boiler system requires monitoring to ensure there is sufficient residual of the oxygen scavenger. It is necessary to carry an oxygen scavenger residual to help prevent dissolved oxygen corrosion should there be an increase in dissolved oxygen due to system upsets or changes in operation.

There is a specific amount of oxygen scavenger required to consume a specific amount of dissolved oxygen. At stoichiometric levels, the oxygen scavenger and the dissolved oxygen are in balance. However to ensure complete reaction, an excess of oxygen scavenger is routinely fed.

For systems that use sulfite, it is not uncommon to maintain a sulfite residual from 30-60 ppm to establish a buffer of excess sulfite. That way, if the system experiences any variances in temperature or pressure, the excess sulfite will be consumed by the dissolved oxygen in the water.

Summary

To accurately diagnose a boiler water system with respect to dissolved oxygen corrosion, make sure to evaluate all of the possible sources of dissolved oxygen, identify and optimize the most effective oxygen removal method for the system and monitor the oxygen scavenger residual. These actions will help reduce the impact of dissolved oxygen induced corrosion.

Proper maintenance and monitoring of the boiler water system, when active or during downtime and storage, are additional vital steps to ensure the long-term reliability and performance of the commercial and industrial boiler water system.

Have a problem that goes beyond the basics of boiler system chemistry troubleshooting? Contact QualiChem at (540) 375-6700 or visit http://www.qualichem.com/ to find out why The Blender Matters and how we can help you with your blending and water treatment needs. QualiChem provides unparalleled technical support to the customers we blend for.

Established in 1989 with headquarters in Salem, Virginia, QualiChem develops and manufactures water treatment chemical solutions worldwide. The Water Treatment Division formulates and blends for regional sales and service companies. QualiChem is a quality-focused ISO 9001:2008 company.