White Paper

Solve High-Pressure Boiler Water Challenges

Save Time and Money in High-Purity Water pH Measurement

EMERSON

Extend pH Sensor Life and Efficiency in High-Purity Water Applications - A Better Way

Introduction

Water quality monitoring and control are two of the most critical operations manufacturing industries employ to protect critical assets, such as valuable boilers and steam turbines, from corrosion by assuring the correct addition of chemicals. These operations also maintain environmental protection and control. The correct pH measurement is essential to water treatment: pH too high or too low can lead to boiler or steam turbine scaling and corrosion, system failures, and downtime, as well as the costly replacement of equipment.

Figure 1. Boiler Scaling and Corrosion Resulting from Imbalanced Water pH

For many low-pressure boilers, the use of a general-purpose pH instrument is straightforward, but for high-pressure boilers employing high-purity, low-conductivity water, unique challenges arise that can add costs, compromise accuracy, and threaten effective system operation. It is essential for users to understand these challenges when making decisions about the use of pH systems in high-purity water.

At the same time, users need to know that traditional solutions to the high-purity water pH measurement challenges can be extremely effective; however, they tend to add substantial costs, complexity, and maintenance to the process.

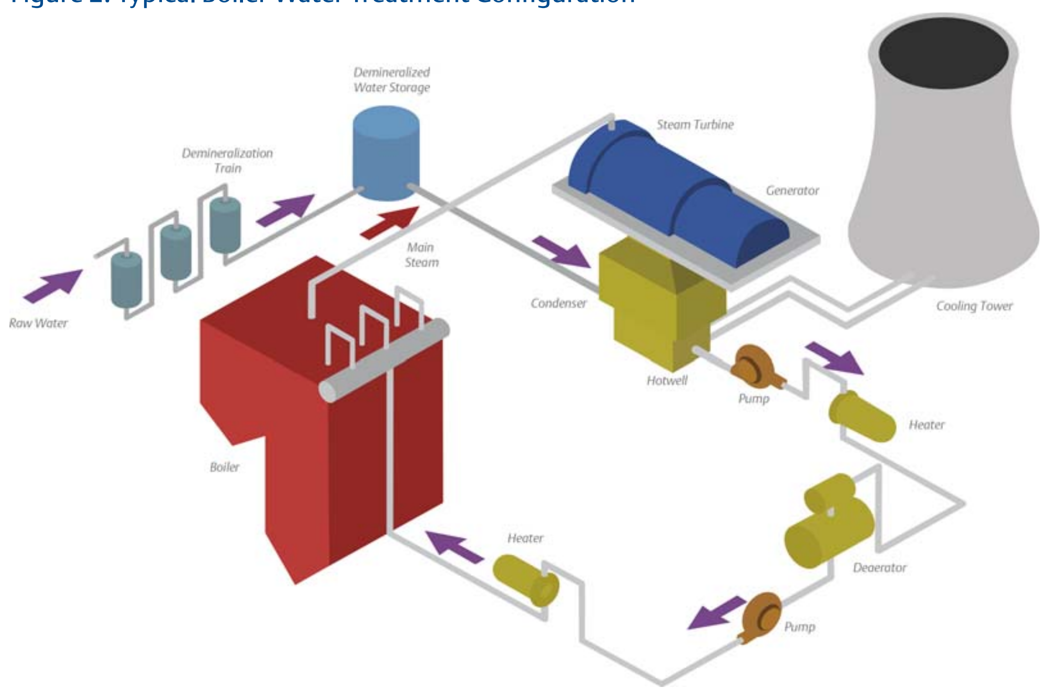
Users need to ask – is there a better way?

This paper is designed to answer that question.

The Boiler Imperative

A major element of boiler water treatment is controlling corrosion by keeping the boiler water slightly alkaline, between 7 and 8.5 on the pH scale. Alkaline pH causes an oxide film to form on the boiler tube surfaces that protects the base metal from further corrosion and allows breaks in the film to heal efficiently. Control of the pH involves feeding sodium hydroxide and sodium phosphate salts in carefully administered quantities. Overfeeding chemicals, a common occurrence in most water treatment operations, can do as much damage as underfeeding, so continuous monitoring of pH is an important part of the boiler chemical control program. No pH sensor on the market can tolerate the temperature and pressures found in even the smallest industrial boiler. Therefore, the pH sensor must always be installed in a cooled and pressure-reduced sidestream sample. To prevent flashing, the sample cooler must be located upstream from the pressure reduction valve.

Figure 2. Typical Boiler Water Treatment Configuration



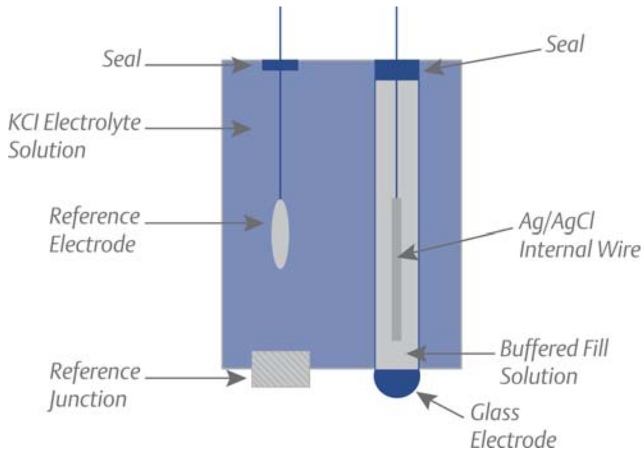
Historically, the choice of a pH sensor for boiler water monitoring has depended primarily on the conductivity of the boiler water. Conductivity can range from 7,000 µS/cm in a low-pressure industrial boiler to under 10 µS/cm in a high-pressure boiler in a steam power plant. A pH sensor that works fine in a low-pressure boiler has generally failed in a high-pressure boiler.

Choosing a sensor to measure the pH of high-conductivity boiler water is fairly straightforward. As long as the conductivity is greater than 50 µS/cm at 25 °C and the suspended solids concentration is low, the use of a general-purpose pH sensor is ideal. The cutoff point between low- and high-conductivity boiler water is 50 µS/cm, which is the lowest conductivity at which conventional pH sensors have reliably been used – historically. Below 50 µS/cm the sensor of choice has traditionally been one designed to measure pH in low-conductivity water.

A Little About pH Systems

To better understand why measuring conductivity in high-purity water is so challenging, it's useful to know a little about pH and pH systems. By definition, pH is the negative logarithm of the hydrogen-ion concentration in an aqueous solution. This means that a solution having a pH value of 4 has 10 times more hydrogen ions than a solution which has a pH of 5.

Figure 3. Complete pH Sensor

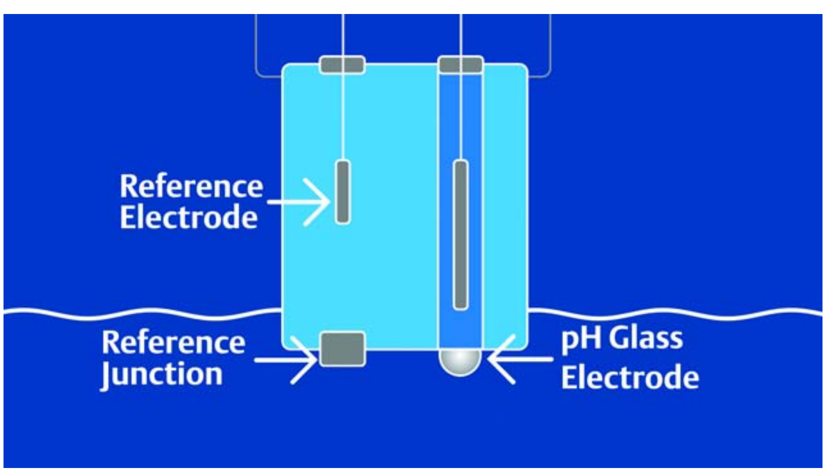


Basically, a pH control system measures the pH of the solution and controls the addition of a neutralizing agent (on demand) to maintain the solution at the pH of neutrality, or within certain acceptable limits. It is, in effect, a continuous titration.

pH measurement is taken by comparing the electrical potential at two points – the reference electrode, which is surrounded by a constant pH electrolyte solution, and the pH glass electrode, which is in direct contact with the solution being tested.

A "reference junction" is used to maintain the electrical connection between the reference electrode and the solution being tested.

Figure 4. pH Measurement Compares the Reference Surrounded by Electrolyte and the Glass Electrode in Contact with the Solution Being Tested

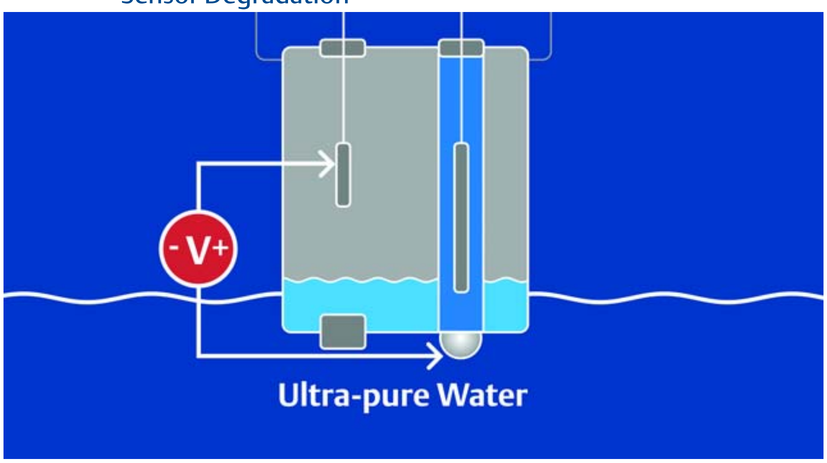


The High-Purity Challenge

The major challenge in measuring the pH of low-conductivity water is minimizing the difference between the liquid junction potentials in the calibration buffers and sample. The junction potential is the charge separation that arises when the reference electrolyte diffuses into the sample and the sample diffuses into the reference electrode. Electrolyte is critical to the proper functioning of the reference system for electrical connection, and ultimately, for the pH measurement, so when it runs out, the electrical connection between the pH electrode is broken and the measurement is impossible. Ultrapure water accelerates diffusion of the electrolyte into the low-conductivity process water. The loss of electrolyte substantially shortens pH sensor life and increases the amount of maintenance required for each measuring point.

Surprisingly, full diffusion can take place in the course of just a few months, requiring replacement of the pH sensor or a recharge of electrolyte fill solution.

Figure 5. In High-Purity Water, Electrolyte is Quickly Diffused, Removing Contact and Causing Rapid Sensor Degradation



An additional problem can arise when a pH sensor is calibrated, because the junction potential that develops in the buffers becomes part of the calibration. If the junction potential in the sample is different, the mismatch will cause an error in the measured pH. The amount of error depends largely on the sample conductivity. Roughly speaking, above 20 µS/cm the error is minor, but at lower conductivity the error can be as much as 0.5 pH. Clearly, such a margin of error is unacceptable when dealing with critical issues such as corrosion control and environmental protection.

Because the mismatch is caused by diffusion of electrolyte into the process, it can be eliminated by using a flowing junction. The outward flow of reference electrolyte from the electrode effectively blocks the sample from entering the junction.

Traditional methods of dealing with high-purity water pH measurement issues have involved using a sensor with an electrolyte reservoir that continuously replaces the electrolyte. This approach, however, requires additional consumables to be ordered regularly, as well as stored, and also adds substantial ongoing maintenance.

Using a Better pH Mousetrap

With a range of advances in technology, this problem of high-purity water pH measurement can now be solved with the combination of a high-performance, general-purpose pH sensor that provides a solution ground to minimize drift and an isolated stable measurement, along with a unique low-flow controller. A general-purpose pH sensor can be used in this application if it offers certain critical characteristics, including:

- Advanced pH glass formulation that resists glass cracking
- A double junction reference, which protects the reference element from poisoning ions in the process
- A solution ground electrode that eliminates sensor drift caused by the mismatch between calibration buffers and low-conductivity fluid in the process, which is often seen in low-conductivity applications

Figure 6. Rosemount™ 3900 General-Purpose pH Sensor from Emerson™

- Smart pH circuitry that stores calibration information and enables auto sensor detection
- A molded polyphenylene sulfide body housing to make the sensor rugged and chemically resistant
- No electrolyte (potassium chloride) replenishment required
- Easy replacement connectors allow for quick cable-to-sensor release, eliminating cable twisting

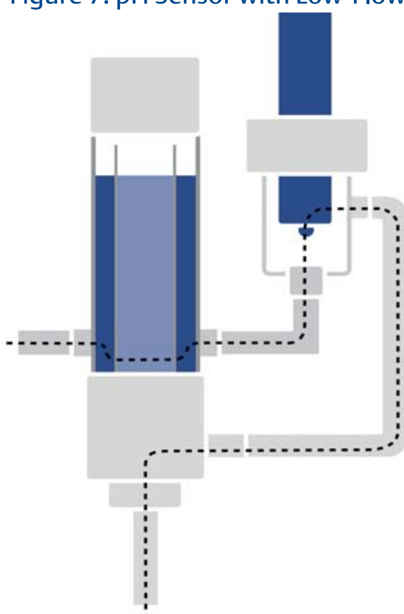
Adding the Flow Controller

A cost- and time-saving new solution enables users to increase sensor life, reduce maintenance time in the field, and decrease water usage by adding a unique low-flow controller to an advanced general-purpose pH sensor. Controlling the flow rate of water across the sensor directly, at a flow rate that's held constant at less than 3 gph, reduces the rate of electrolyte depletion, increasing sensor life and reducing water usage by more than two-thirds versus other sidestream solutions.

Water level must be maintained by an inner drain that keeps the water column and, in turn, the head pressure and flow rate constant. The transparent materials of construction make it easy to verify the continuous flow of sample through the flow path.

When used with the low-flow controller, an advanced general-purpose pH sensor is able to respond to changes in pH at a minimum conductivity of 0.1 µS/cm.

Figure 7. pH Sensor with Low-Flow Controller



A general-purpose pH sensor enhanced with flow controller technology can provide users with:

- Four times the sensor life
- 60 percent less time in the field
- Less maintenance time
- Two-thirds less water usage
- Improved ease of use

A Better "Real World" Way

Why take this approach to measurement of high-purity boiler water? There are certainly viable alternatives. The secret to the success lies in the unique advantages and features that an advanced general-purpose pH sensor offers.

Sensor Life

A general-purpose sensor design that includes an advanced glass formulation that resists cracking, as well as a double junction reference, extends sensor life significantly. With this kind of long-life sensor, users can expect sensor longevity of two years versus the industry average of six months. Users gain four times the sensor life, while also reducing costs of equipment, maintenance, and more.

Standard Sensors

An advanced general-purpose sensor can offer unequaled performance in a variety of applications, so it can be an industry standard sensor that many users may already be employing for other applications. This means plant personnel will already be familiar with its use, further reducing training time.

Low Maintenance and Time in Field

In addition to long-life capabilities, users should also look for sensors that have smart pH circuitry built in to store calibration information and enable auto sensor detection. This kind of circuitry can make a sensor "plug and play" and cuts time in the field by over 60 percent.

Figure 8. Easy-to-Use Rosemount 56 Dual-Channel Transmitter

Ease of Use

Combining the sensor with an advanced transmitter that offers an easy interface allows the user to configure the sensor quickly and provides enhanced process insight. Knowing more about the process allows for predictable service and further reduces time in the field, as well as assures minimal downtime.

Reduced Costs

General-purpose sensors have a lower initial cost than specialized high-purity designs. In addition, their extended sensor life and reduced costs of maintenance and upkeep means the ongoing cost of ownership is also reduced. Finally, further cost reduction is realized when the general-purpose sensor is combined with the low-flow controller because, unlike traditional high-purity sensors, ongoing consumables are not required.

Reduced Water Usage Lowers Costs

A long-life, general-purpose sensor plus low-flow controller requires less than a third of the water usage of other systems.

Conclusion

With today's advances in pH sensor life, using a long-life, general-purpose sensor plus a low-flow controller enables users to tackle their high-purity water applications in a new way, while using an absolutely proven approach. It accomplishes the goals of pH measurement in high-purity water – reduction of corrosion, scaling, boiler failure, and downtime – in a way users will find easy to use and easy to afford.

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