ORP Sensors in the Production of Potable Water and High Purity Water from Reverse Osmosis Membranes

Application Note

Since its development in the early 1980s, reverse osmosis membranes have been used extensively to produce water of higher purity for drinking water plants, Water-for-Injection, make-up water in power plants, and a host of other applications. Reverse osmosis (RO) is a process which forces water through a porous membrane against its osmotic pressure or salt concentration gradient at high pressures. The pores in the RO membrane are microscopic and make it almost impossible for most contaminants to pass through except for water. The effluent stream from the RO system is known as permeate and is a highly purified water devoid of salts and organisms. However, there is one weakness for these robust RO membranes - they are easily oxidized by free chlorine.

Free chlorine is an oxidizer used pervasively to disinfect water from most types of bacteria. Oftentimes sites have no choice but to use the water supplied from the utility water system, which contains free chlorine. Mild reducing agents such as sodium bisulfite or sodium metabisulfite are mixed with the incoming stream to remove free chlorine before the RO membranes. ORP sensors are heavily employed at this critical step to preclude damage to the RO membranes, which are expensive and costly to repair. Even sites with access to fresh water sources such as aquifers and springs find it necessary to disinfect with free chlorine, although some of these water sources are clean enough to go through micron filtration only.

What is ORP?

ORP stands for oxidation reduction potential. Oxidation involves the loss of electrons from an atom or compound, while reduction is the acceptance of electrons. An ORP sensor is much like a pH sensor in that it contains a measuring electrode and reference electrode. However, the ORP measuring electrode consists of a gold or platinum band around the tip of the sensor instead of pH glass. (See Figure 1) Because platinum has several oxidation states, it can donate and accept electrons from the solution until an equilibrium potential is reached across the platinum band. This equilibrium potential is the ORP potential of the solution. If at equilibrium the platinum band donates electrons to the solution more than it accepts, the ORP of the solution is positive. This occurs when oxidizers are present in the process such as free chlorine, oxygen, and ozone. Likewise, if at equilibrium the platinum band accepts more electrons from the solution than gives, the ORP of the solution is negative. This occurs when there are reducers in the process such as organic compounds or BOD (biological oxygen demand). The more positive the ORP value, the more powerful the oxidant in the process.

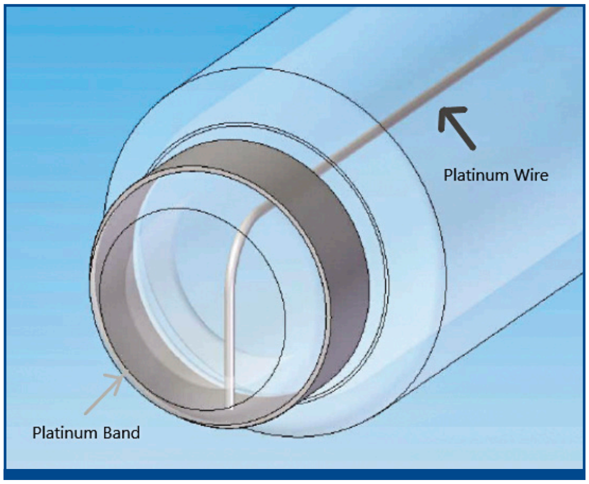

Figure 1 *Platinum Band in ORP Sensor*

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ORP Control in RO Membrane Systems

Figure 2 displays an RO membrane system in a water treatment plant. Most RO membranes are made of polyamides, which have a tolerance of less than 0.1 ppm free chlorine. This concentration is below the detection limit of most commercial free chlorine sensors. Because residual free chlorine is an oxidizer and will register an ORP of around 500–700 mV, its destruction through reaction with reducing agents can also be monitored with ORP. Reducers like sodium bisulfite or sodium metabisulfite are added to react and remove the free chlorine until ORP values are between 50mV to 300mV before entering the RO membrane system. The ratio of sodium metabisulfite to free chlorine will end up at approximately 3:1. It should be mentioned that sodium bisulfite reacts with oxygen also, and thus overfeeding of sodium bisulfite until the ORP goes into the negative values will produce a reducing environment for anaerobic bacteria. Therefore, careful control of the ORP value with addition of sodium bisulfite or sodium metabisulfite is critical. Figure 3 presents a customer installation of an ORP sensor to remove free chlorine before an RO system.

One site in Florida sources water from a wellfield that is drilled 200–300 ft underground. The water is pretreated by a combination of free chlorine and greensand. The greensand is primarily used to capture iron and manganese in the water, while free chlorine is used as both a disinfectant for microbial growth as well as a recharge solution for the greensand. Other salts in the water are removed by the RO membrane system after pretreatment. The Rosemount™ 3900 General Purpose ORP Sensor along with the Rosemount 1056 Transmitter can be used to control free chlorine levels in the pretreatment to 300 mV or less.

Addressing Biofueling

Because RO membranes cannot be disinfected with free chlorine, over time biofouling can occur. Biofouling is the growth of bacteria in and around the pores of the RO membrane. Biofouling decreases the efficacy of the membrane in terms of salt rejection and can also create an increase in the pressure drop across the membrane. Membrane cleaning at one RO system in Florida occurs once a year by a caustic-acid cycle. Individual production trains are taken offline, and each stage of the train can be isolated by proper valving. It must be noted that the intricacies of each step and subsequent steps are not detailed here, but the general cleaning sequence is as follows: the first step is to run caustic soda at a pH level of 12–12.4 for one hour, followed by an hour of soak in the caustic, and then another caustic run for an hour. The process is repeated until the water is clear. The second step is to run phosphoric acid at pH between 1.7–1.9 much the same way that the caustic was handled: one hour of acid run, followed by an hour-long soak in acid, followed by another acid run. The third step is a repeat of the caustic cleanse in the first step.

Figure 2 *RO Membrane System in Utilities Water Production*

Summary

Research to develop anti-oxidation films or coatings against free chlorine is ongoing, however, still in its testing stages. Until then, sites with RO membrane systems must continue to wrestle with the disinfectant free chlorine. Whether through reaction with sodium bisulfite or controlled addition of free chlorine, ORP will continue to be employed as an extremely critical part of the RO loop.

Figure 3 *WFI Generators at Novartis in Singapore. Permission granted for use by customer.*

The Emerson Solution

Accurate ORP measurement requires a reliable ORP sensor and transmitter. The Rosemount™ 389 ORP Sensor features a platinum band as well as a triple junction reference to help prolong sensor life and protect against poisoning from chlorides and other ions.

Rosemount 389 ORP Sensor

The Rosemount 3900 ORP Sensor features a double junction reference that aids in the sensors' resistance to harsh environments and aids in the sensor's resistance to poisoning.

Rosemount 3900 ORP Sensor

The Rosemount™ 1058 Dual-Channel Transmitter supports continuous measurement of liquid analysis inputs from one or two sensors. Each sensor channel is independently configurable to support a wide selection of digital or analog liquid analysis sensors including ORP sensors.

Rosemount 1058 Dual-Channel Transmitter

For more information, visit
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