OpreX™ Analyzers

Liquid Analyzer Measurements for Reverse Osmosis

Application Note

Industry: Refining, Food & Beverage, Power, Oil & Gas, Pulp & Paper, Chemical, Water
Products: pH/ORP and Conductivity Process Liquid Analyzer

Background

Processes requiring pure water must continually replace the water as it is consumed. Replacement water sources are usually nearby rivers or lakes. The water requires pre-treatment and purification before it can be used in the process.

Preliminary water purification includes filtration, clarification, and softening. The water then flows into a two-pass, reverse osmosis (RO) system and a demineralization operation for further purification.

Osmosis is the natural tendency of a fluid such as water to pass through a semipermeable membrane from a less concentrated solution into a more concentrated one, thus equalizing the concentrations on each side of the membrane.

In RO, pressure must be exerted on the side with the concentrated solution to force the water molecules across the semi-permeable membrane to the fresh (pure) water side.

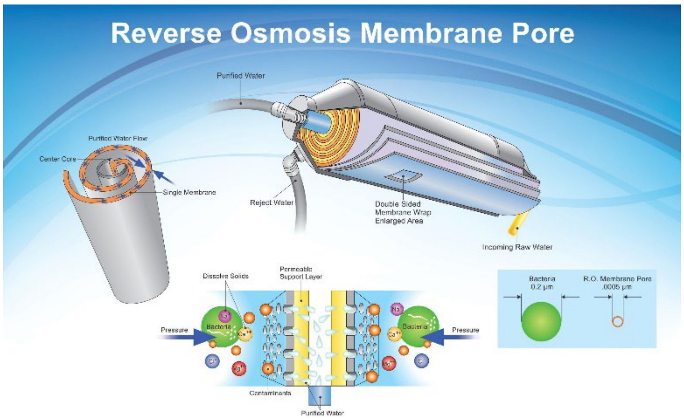
This semi-permeable membrane inhibits the majority of dissolved impurities from passing through to the pure water side. The amount of impurities carried over depends on the type and condition of the membrane (i.e. age, cleanliness) and the amount of pressure applied (energy) to the process.

Not all the feedwater passes through the membrane. Some is diverted to flow over them to clean away the rejected impurities in a cross-flow filtration mode.

The RO system produces one purified water stream called permeate and a second stream referred to as concentrate, brine, or reject.

Feedwater enters the machine at fairly low pressure and flows through pre-filters to remove suspended particles such as silt. A pre-filter is typically a replaceable cartridge type which provides a cost-effective method for keeping the membrane clean. Typical life expectancy for these membranes is approximately three years.

RO systems are designed for automatic operation; they require routine preventative and corrective maintenance. Common problems include improper flow rates and membrane fouling. Those result in reduced throughput capacity and shortened runs.



Membranes can also fail altogether. That results in excessive demand on the downstream purification systems and poor water quality.

Both pH and conductivity measurements are used to safeguard the successful operation of an RO system.

Some types of RO membranes are sensitive to feedwater pH and can become damaged if the pH is outside the recommended range of 5 to 8 pH. A pH sensor upstream of the membrane can provide a feedback signal to control the dosing of the acidic or basic reagent to maintain the pH within acceptable limits.

Conductivity measurements are used at both the inlet and outlet of the RO unit to determine whether the total dissolved solids are being filtered out effectively.

Application

Reverse osmosis systems can remove up to 100% of suspended solids and approximately 90% of dissolved solids, dissolved silica, alkalinity and hardness.

A common use for RO is for purifying water. It removes salts, minerals, and other impurities. These all help to improve the water's color, taste, and odor.

RO is regularly used for commercial and residential water filtration and is also widely used by boats to desalinate seawater for use onboard.

RO systems are capable of rejecting bacteria, salts, sugars, proteins, particles, dyes, and other constituents that have a molecular weight greater than 150-250 Daltons.

The separation of ions with reverse osmosis is aided by charged particles. This means any dissolved ions that carry a charge, such as salts, are more likely to be rejected by the membrane than those such as organics, which are not charged. The larger the charge and the larger the particle, the more likely it will be rejected.

The majority of RO membranes are negatively charged when operated within the pH levels for water applications.

Challenges

A two-pass RO system (Figure 2) is typically installed upstream of the demineralizer. Its performance is pH dependent with the second-pass section most dramatically affected. While these changes are not significant in the majority of applications, variations become crucial to the success of high-purity water processing.

In addition, the effect of minor feedwater constituents, such as alkalinity and ammonia also plays a role in achieving high-purity permeate.

The overall efficiency of dissolved solids removal is usually determined utilizing a pair of conductivity measurements, one at the inlet (cell 1) and one at the outlet (cell 2). This is referred to as % rejection and is calculated by the formula:

$$\% \text{ rejection} = [1-(\text{cell2})/(\text{cell 1})] \times 100$$

For example, if the inlet water contained 200 ppm of dissolved solids and the outlet water contained 10 ppm, the efficiency would be a 95% rejection rate. A typical range for this type of application is 80%-100% rejection.

A final conductivity measurement after the second stage is used to determine the quality of the outlet water.

Ammonia also affects the production of high purity water and may be present due to municipal chlorination of the feedwater or from organic contamination.

Ammonia will pass through the membrane system in either the molecular (NH_3) or ionic (NH_4+) form.

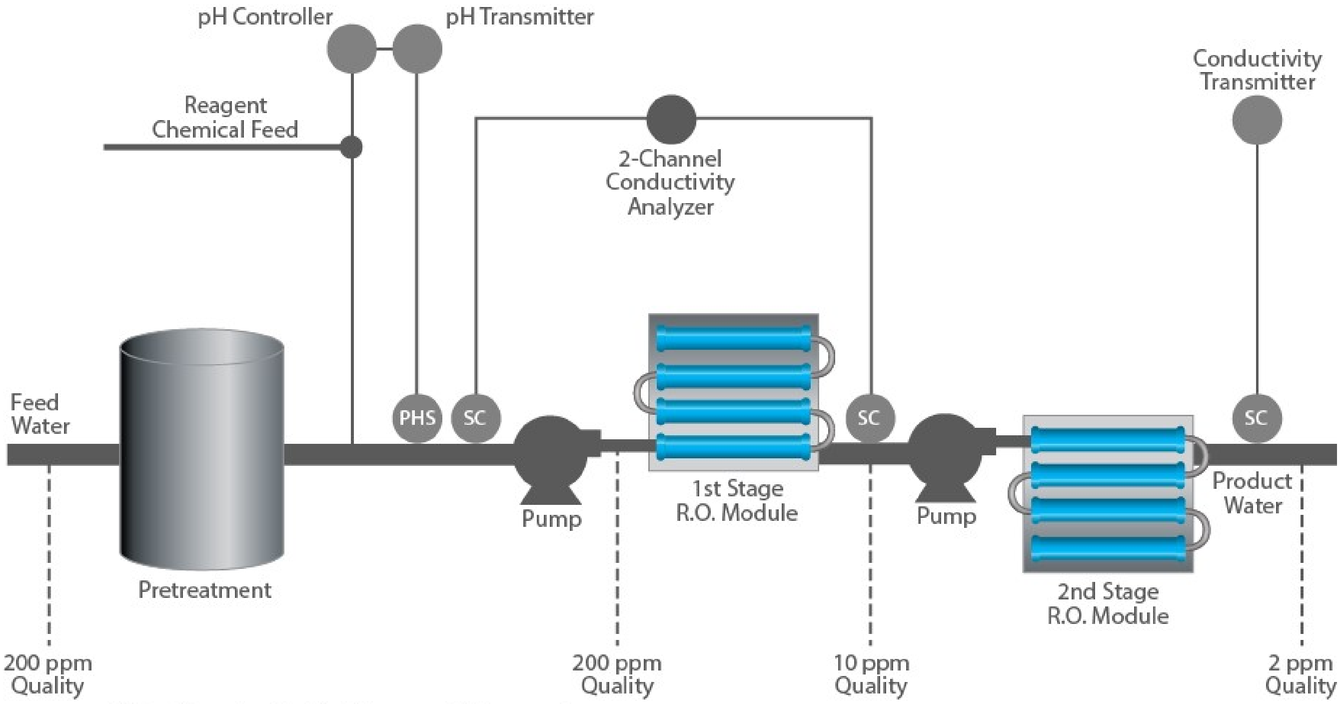


Figure 2. Two Pass Reverse Osmosis Measurement Process

Since ammonium hydroxide (NH_4OH) is less conductive than ammonium carbonate [$(NH_4)_2CO_3$], it is not uncommon to find off-line samples or storage tank water with conductivity higher than that of on-line readings.

The pH values will be lower. This shift in pH is due to the absorption of CO_2 from the air and the formation of carbonic acid in the water. Without the presence of ammonia, this type of contamination of high-purity water with CO_2 would generate higher conductivity and reduce the pH.

Summary

Measurement of pH in high purity water presents many difficulties. In order to achieve a successful measurement, care must be taken to address the unique problems of the application. The low conductivity and limited buffering capacity of low ionic strength pure water causes pH electrodes to drift. Resulting measurements are non-reproducible and inaccurate. In addition to large drift, common problems are unacceptable flow sensitivity and poor temperature compensation.

Electrical noise and interference complicate matters further. Certain properties of pure water adversely affect the ability to obtain a reliable pH measurement. For many years, it was believed these properties could not be satisfactorily overcome in the pursuit of the desired measurement accuracy and reliability. The areas most affected by pure water properties include:

I. Reference electrode stability

II. Glass electrode response

III. Electrical noise

IV. Special T.C. requirements

For more detailed information about the difficulties with pH measurement in pure water, please see our online library.

Selecting the proper electrodes and holder will eliminate problems with reference junction potentials, slow glass electrode response and surface static charges. Selecting the proper transmitter or analyzer will eliminate ground loop problems and allow for accurate temperature compensation for both the Nernst potentials and the dissociation constant of pure water. In addition, sensor diagnostics enable the operator to ensure that the measurement loop is functioning properly.

Yokogawa offers the electrodes (Bellomatic reference and special G-glass measure electrode, or combination style); the sensor holder (model FF20/FS20 stainless steel flow through style); and the transmitter or analyzer (Models PH450G/FLXA21 with sensor diagnostics and "process temperature compensation") to provide accurate pH measurement in high purity water.

Example of Reverse Osmosis System for Drinking Water

Product Recommendations

Process Liquid Analyzer:

2-wire 24 VCD Loop-powered FLXA202 Analyzer
4-wire AC/DC Line powered FLXA402 Analyzer

pH Measurement Sensor Selection:

Option #1:

Holders

- FF20 Flow-thru assembly with individual measure, reference and temperature electrodes
- FS20 Insertion assembly with individual measure, reference and temperature electrodes

Sensors

- Bellowmatic reference electrode (SR20-AC32)
- Shock-proof measuring electrode (SM21-AG4)
- PT1000 temperature electrode (SM60-T1)

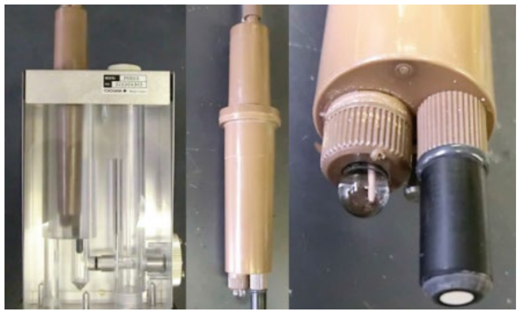
Option #2:

Holder:

PH8HH Flow Thru assembly

Sensor:

PH8EHP Flowing reference pH sensor for high purity water



Conductivity Measurement Sensor Selection:

Holders

- FF40 Flow-thru assembly
- FS40 Insertion assembly

Electrodes

- SC42-SP24
- SC42-SP34

Digital SMART Option:

The re-useable smart adapter, SA11, offers full measurement parameter functionality for analog sensors equipped with a Variopin connector and Yokogawa ID chip. The SA11 automatically recognizes the installed sensor and prepares the appropriate configuration.

YOKOGAWA ELECTRIC CORPORATION
World Headquarters
9-32, Nakacho 2-chome, Musashino-shi, Tokyo 180-8750, JAPAN

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