

Industry: Refining, Food & Beverage, Power, Oil & Gas, Pulp & Paper, Chemical
Products: Contacting Conductivity Process Liquid Analyzer

Background

Ion Exchange is a method for the exchange of ions between two electrolytes or between an electrolyte solution and a complex molecule. In most cases the term is used to denote the processes of purification, separation, and decontamination of aqueous and other ion-containing solutions with solid polymeric or mineralic ion exchangers. Typical ion exchangers pass the solution through porous solid material, usually minerals of the zeolite group or specially prepared synthetic resins (plastics) containing large complex molecules. Zeolites are a large group of minerals composed of hydrated aluminum silicates of alkali metals and alkaline earth metals.

An organic ion exchange resin is composed of high-molecular-weight polyelectrolytes that can exchange their mobile ions for ions of similar charge from the surrounding medium. Each resin has a distinct number of mobile ion sites that set the maximum quantity of exchanges per unit of resin. Ion exchange is a reversible chemical reaction wherein an ion (an atom or molecule that has lost or gained an electron and thus acquired an electrical charge) from solution is exchanged for a similarly charged ion attached to an immobile solid particle.

Ion exchangers can have binding preferences for certain ions or classes of ions, depending on their size, their charge, or their chemical structure. Ion exchangers are either cation (exchange positively charged ions) or anion (exchange negatively charged ions). There are also amphoteric exchangers that are able to simultaneously exchange both cations and anions. However, this simultaneous exchange can be more efficiently performed in mixed beds that contain a mixture of anion and cation exchange resins, or passing the treated solution through several different ion exchange materials.

Introduction

Hardness in water, caused by calcium and magnesium ions, is removed by ion exchange. The water is filtered through an artificial zeolite, and the sodium in the zeolite replaces the undesirable

ions that are in the water. When the zeolite is saturated with these metallic ions, it is washed with a salt solution, which restores the sodium.

Ion exchange resins come from a wide variety of organic and synthetic materials containing positively or negatively charged sites which attract ions of opposite charge from the surrounding solution. The resins commonly consist of a styrene-divinylbenzene copolymer. The electrically charged groups are commonly sulfonic or carboxylic acid salts or quaternary ammonium salts. Polymers containing acid groups are classified as anions or cation exchangers because they exchange positively charged ions, such as hydrogen ions and metal ions.

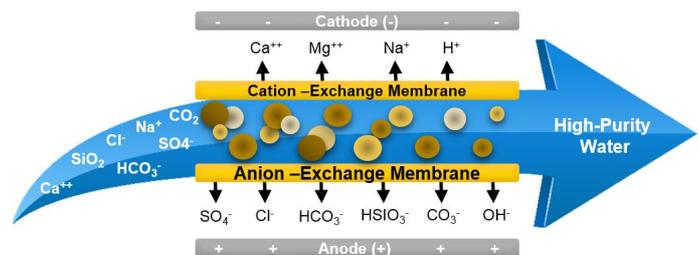


Figure 1. Membrane example

Anion exchange materials are classified as either weak base or strong base depending on the type of exchange group. The weak base resins act as acid absorbers, efficiently removing strong acids such as sulfuric and hydrochloric. They are used in systems where strong acids predominate, where silica reduction is not required, and where carbon dioxide is removed in degasifiers. Preceding strong base units in demineralizing processes, weak base resins give a more economical removal of sulfates and chlorides.

Ion exchange resins are light and porous solids usually prepared in the form of granules, beads, or sheets. When immersed in solution the resins absorb the solution and swell. In industrial and domestic applications, ion exchange resins are used for the removal of calcium, magnesium, iron and manganese salts from water (water softening), for the purification of sugar, as well as for concentrations of valuable elements such as, gold, silver, and uranium.

Cation exchanger materials consist of inorganic zeolites, natural (greensand) or synthetics. Sulfonated coal, styrene-base resins, phenolic resins and acrylic resins are some that have been developed. Weakly acidic cation exchange resins contain carboxylic and phenolic groups. They remove alkalinity by exchanging their hydrogen ions for the cations associated with the bicarbonate ion (calcium, magnesium, and sodium bicarbonates). Being weakly acidic, they will not affect the cations associated with the anions of strong acids.

How it Works

Deionization of demineralization is a process that removes dissolved ionic material from water for purification. Deionization takes place in an ion exchange unit, which usually consists of a cation bed, an anion bed and a mixed bed in series. The mixed bed, also referred to as a polisher, contains both cation and anion resins and provides the highest ion removal efficiency.

The cation bed is used to remove positively charged ions such as calcium, magnesium and sodium, while the anion bed removes negatively ions such as sulfate and chloride. Specific resins are chosen to optimize bed performance, depending upon the water composition to be purified.

Control (regeneration) of the ion exchange unit is accomplished by monitoring the conductivity. Precise control can be achieved in cation and anion beds, by measuring the inlet and outlet conductivity to obtain a ratio. This is referred to as "Across the Bed" monitoring. Comparing the inlet and outlet conductivity identifies when breakthrough occurs (when resins no longer have the capacity to exchange ions) and regeneration is necessary. In a cation exchange bed, cations entering the bed are exchanged with hydrogen ions producing an acidic solution at the outlet. Since the hydrogen ions leaving the bed are more conductive than the cations entering the bed, the conductivity at the outlet will be considerably higher. A high conductivity ratio indicates good mineral ion removal, while a ratio approaching one (1) indicates poor removal. The conductivity (conductance) ratio is expressed as the conductivity of the outlet cell (cell 1) divided by the conductivity of the inlet cell (cell 2). The typical ratio range is 1 - 4.

Measuring the conductivity in the bed and at the outlet, is referred to as "Within the Bed" monitoring and can signal when regeneration is necessary before breakthrough occurs. "Within the Bed" monitoring is difficult because one of the conductivity sensors must be inserted into the bed taking caution

to prevent resin beads from entering the flow path of the sensor and shorting the cells.

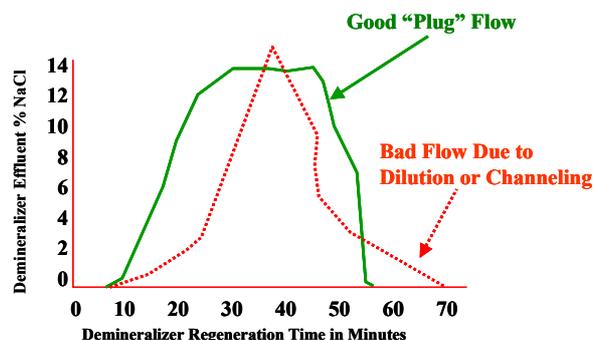
During normal operation of "Within the Bed" monitoring, both conductivity cells will see a high conductivity value as the mineral cations are exchanged for hydrogen ions and the ratio approaches one (1). As the resin is depleted the conductivity value of cell 2 comes in contact with the less conductive mineral cations and will start to decrease as the ratio increases. The typical ratio range is 1 - 1.5. A ratio of 1 indicates good system performance and a ratio approaching 1.5 indicates regeneration is necessary. An alarm can be set to initiate regeneration before mineral breakthrough reaches the outlet.

During purification, the properties of the water vary at different stages of deionization, requiring a number of different temperature compensation algorithms. Raw water typically contains neutral minerals requiring one temperature algorithm, cation exchanged water is acidic requiring another temperature algorithm and deionized water (high purity) is close to neutral and requires yet another temperature algorithm.

Any single ion exchanger or demineralizer experiences changes in capacity from one regeneration run to another, because it is difficult to obtain perfect flow distribution with a flat wave front. Deviations of 5-10% are common.

A steady falloff of capacity however is a serious matter requiring investigation to determine and correct the cause. One of the most common problems is a gradual loss of material (resins) due to regeneration runs. Periodic bed depth measurements check for this loss.

Dirty ion beds resulting from improper backwash is another problem solved by proper cleaning procedures. Incorrect chemical application will also cause poor resin performance. Determining if there are regeneration problems is relatively easy.



Evaluation Regeneration Profile. Optimum concurrent regeneration of Sodium exchanger requires the brine discharge to exceed 8% for about 30 minutes.

Samples are taken from the bottom port of the Demineralizer at regular intervals. The conductivity of the solution is measured or a % concentration is determined also based on a conductivity reading. The conductivity (percent concentration) is plotted against time (see above).

The dotted line shows poor regeneration characteristics, caused by excessive chemical dilution. The resin beads may also have a channel running through the bed (improper backwash) which prevents an even regenerate contact throughout the resin bead.

The solid line shows the regeneration time at the proper concentration levels.

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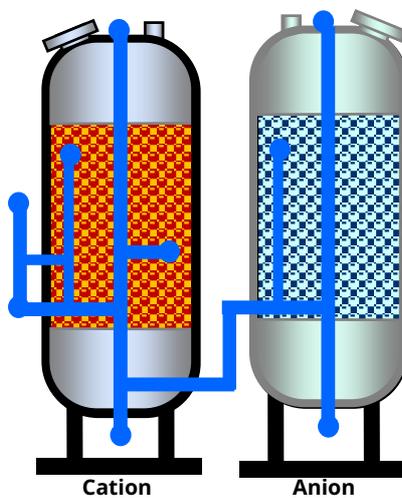


Figure 2. Demineralizer Beds

Summary

"Across the Bed" Monitoring

In a cation exchanger, cations entering the bed are exchanged with hydrogen ions producing an acidic solution at the outlet. Since the hydrogen ions leaving the bed are more conductive than the cations entering the bed, the conductivity at the outlet will be considerably higher. A high conductivity ratio indicates good mineral ion removal, while a ratio approaching one (1) indicates poor removal. The conductivity ratio is expressed as the conductivity of the outlet cell (cell 1) divided by the conductivity of the inlet cell (cell 2). The typical ratio range is 1 - 4.

"Within the Bed" Monitoring

During normal operation of "Within the Bed" monitoring, both conductivity cells will see a high conductivity value as the mineral cations are exchanged for hydrogen ions and the ratio

Product Recommendations

Conductivity Measurement System:

Process Liquid Analyzer:

2-wire FLXA202 Contacting Conductivity Analyzer

4-wire FLXA402 Contacting Conductivity Analyzer



Digital SMART Option:

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

Sensor Selection:

Analog and Digital SMART sensors are available. Analog options allow users to interface with a system that has been used historically. SENCOM™ technology, which allows sensors to transmit and receive data when connected to a transmitter/analyzer or any PC. The SMART digital sensors maintain specific measurement and calibration data on an integrated chip along that is an integral part of the sensor providing easy plug and play solutions. The Data management software to optimize the performance of sensors for enhanced reliability and process safety.

Option #1:

SC42-SP34 Large-Bore Conductivity Sensor (fittings available for Flow-Thru, Insertion, or Immersion installations)

Option #2:

SC4A Conductivity Sensor (fittings available for Insertion, Sanitary, or Retractable installations.)



Tangible Benefit

With the ability of the dual channel process liquid analyzer you have the ability to measure the beds inlets and outlets and calculate the ratio or % passage of the bed.

Note: For additional information on this application contact the local Yokogawa Process Liquid Analyzer Department

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YOKOGAWA ELECTRIC CORPORATION

World Headquarters

9-32, Nakacho 2-chome, Musashino-shi, Tokyo 180-8750, JAPAN

<http://www.yokogawa.com/an/>



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