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PUREFLOW TechNotes

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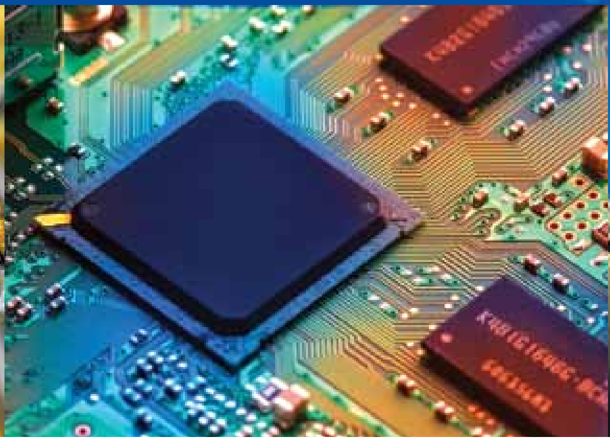


The Future of Ion Exchange

by Stephen Boles,
Pureflow, Inc.

Introduction

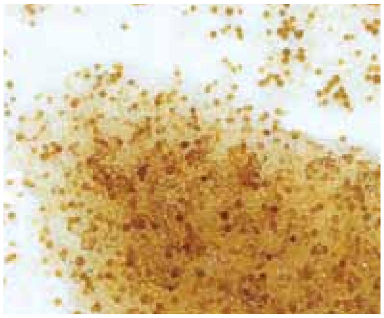
Ion exchange technology for the production of deionized water has been in use for over half a century. Electro-deionization (EDI) technology is an advancement over ion exchange and has been in practical use since the 1980s. EDI eliminates the need for off-line regeneration, bulk chemicals, and waste neutralization. This note provides a review of ion exchange as it applies to deionization, the operation of EDI, the improvements to EDI, and successful applications of EDI.

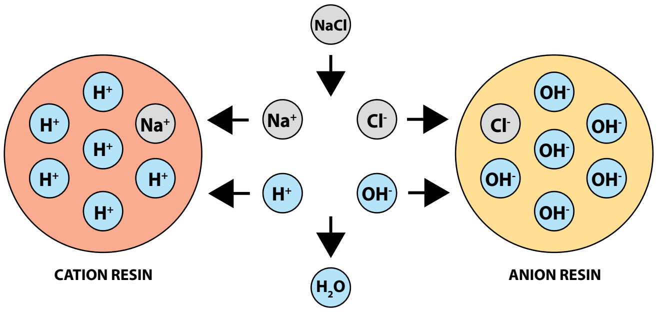
Ion Exchange

From chemistry class we know water to be H_2O, but naturally occurring bodies of water contain much more than just H_2O. These water sources contain both suspended and dissolved solids. Ion exchange focuses on removal of dissolved solids. The most prevalent dissolved solids in naturally occurring fresh water include calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), bicarbonate (HCO_3^-), chloride (Cl^-), Nitrate (NO_3^-), sulfate (SO_4^-), and silica (SiO_2^{2-}).

Dissolved solids are generally referred to as ions. The positively charged ions are cations, and the negatively charged ions are anions. This inherent charge of an ion is the mechanism used in any ion exchange process. Ion exchange is the process of swapping undesirable ions for desirable ions. In the deionization of water, the undesirable ions include anything but the hydrogen (H^+) and hydroxyl (OH^-) ions that together make up water.

The material or media commonly used to provide exchange sites is called ion exchange resin. Resin beads, less than a millimeter in diameter, have either cation or anion exchange sites. These exchange sites are loaded with desirable ions through the regeneration process. During regeneration, a strong acid solution (typically hydrochloric or sulfuric acid) is used to load the cation resin with H^+ ions, and a strong caustic solution (typically sodium hydroxide) is used to load the anion resin with OH^- ions.





For polishing deionization, cation and anion resin beads are loaded in a pressure vessel, mixed, and then put in service. During service, the influent water containing undesirable ions passes through the resin bed. The undesirable cations in the water exchange for H^+ on the cation resin beads, and the undesirable anions in the water exchange for OH- on the anion resin beads. The H^+ and OH^- are released into the water and quickly combine to form H_2O; the undesirable ions are being exchanged for water.

Ion exchange resin has a limited exchange capacity. When the exchange capacity is exhausted, regeneration of the ion exchange resin with strong chemicals must be repeated. Regeneration is an interruption in service that requires water, strong chemicals, waste neutralization, and time.

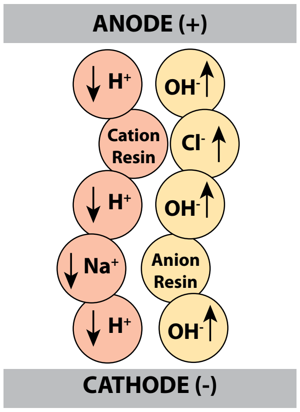
Traditionally, there are two approaches to regeneration. For on-site regeneration the user owns and operates the entire process. This includes vessels full of resin, bulk chemical storage, chemical dilution equipment, waste neutralization equipment, and trained staff. The benefit of on-site regeneration is complete control of the regeneration process. The downside of on-site regeneration is capital cost, operations staffing, space requirements, and hazardous chemical storage and handling.

For off-site regeneration (mobile DI or service exchange DI) the user contracts a service provider to deliver vessels of regenerated resin. When the resin is exhausted, the service provider exchanges the vessels of exhausted resin for vessels of freshly regenerated resin. The resin regeneration process is owned and operated by the service provider at their facility. The benefits of off-site regeneration are lower capital costs and smaller space requirements. The downside of off-site regeneration is higher operating cost and loss of control of the regeneration process.

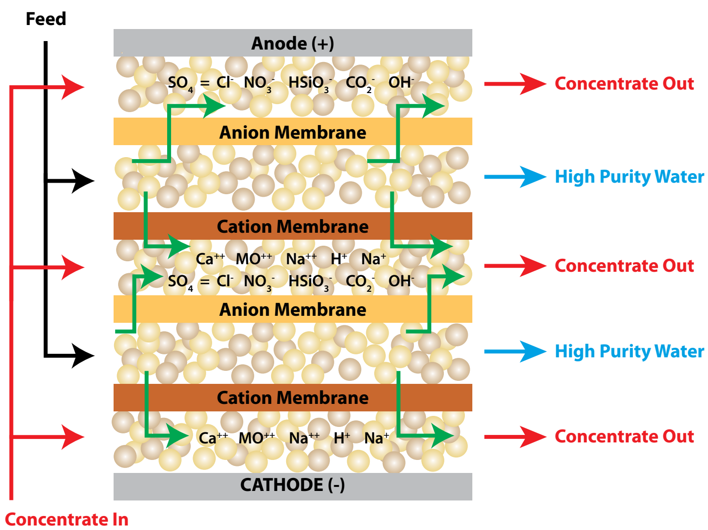
Electrodeionization

EDI takes a different approach to regeneration of the ion exchange resin. It uses electricity to regenerate the ion exchange resin continuously during service. The components of an EDI stack include mixed cation and anion resin to remove undesirable ions, electrodes to provide continuous regeneration, and ion selective membranes to segregate undesirable ions from the product water. An overview of how these components work together as an EDI stack begins with the ion exchange resin. The resin exchanges undesirable ions for H^+ and OH^- as described for traditional ion exchange.

The electrodes provide an electric charge voltage potential across the ion exchange resin. At the cathode, a negative charge attracts cations, and at the anode, a positive charge attracts anions. The DC voltage potential between the electrodes causes two things to take place. First, the voltage potential causes water to split into H^+ and OH^- ions that regenerate the ion exchange resin continuously. Second, the voltage potential causes ions to migrate from ion exchange site to ion exchange site as the ions travel toward the corresponding electrode. This ion migration is what allows the undesirable ions to be segregated from the product water.



Ion selective membranes complete the segregation process. The membranes are either cation selective or anion selective. They are installed within the ion exchange resin in an alternating pattern. This alternating pattern is used to create a set of product chambers and concentrate chambers. These chambers are thin and full of ion exchange resin. The influent water enters the product chambers where undesirable ions are exchanged for desirable ions. Then the undesirable ions begin migrating toward their corresponding electrode. For example, an undesirable cation, such as Na^+, will migrate toward the cathode. It will pass through a cation selective membrane into the concentrate chamber and will continue migrating toward the cathode. However, it will become trapped in the concentrate chamber because the next membrane it reaches is anion selective. The result is the continuous production of deionized water from the product chambers and a bleed flow of undesirable ions from the concentrate chambers.



Improvements

EDI technology has evolved over time. Many early installations included drip pans under the EDI stacks due to leaks between chamber plates. Today it is rare to find a leak. Some systems required a concentrate recycle pump and brine injection to maintain high "conductance" in the concentrate chambers. Today a specialty ion exchange resin fills the concentrate chambers; the recycle pump and brine injection equipment are no longer needed. Early designs were also susceptible to heat damage if flow was lost. Today it is rare to find a stack that is damaged by heat. The latest designs use less power and produce higher quality water. These improvements have not only made EDI a better technology but have opened doors to more challenging and demanding applications.

Applications

Successful EDI installations include reverse osmosis (RO) units as pretreatment. The RO permeate water is free of suspended solids, is free of chlorine (or chloramine), has very low hardness, and typically has a conductivity less than 10µS/cm. Most EDI stacks can polish water with a conductivity up to 40µS/cm and some up to 100µS/cm.

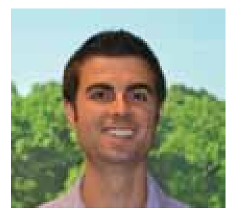
Pharmaceutical companies choose RO and EDI systems because they are easily validated and maintained under their quality control system. These systems are hot water sanitizable, and the sanitization process can be fully automated. EDI also removes the ammonia that passes through RO membranes from chloraminated municipal water.

Power generation, micro-electronics, and general industrial companies have found opportunities to replace on-site regeneration systems with RO and EDI alone or may add polishing service exchange mixed bed DI vessels for insurance. The service exchange vessels in this application would typically be exchanged once per year. This allows companies to eliminate bulk chemical storage, chemical dilution systems, and waste neutralization systems. They are also able to operate continuously with consistent product quality.

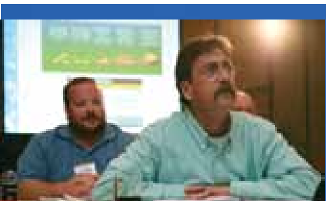
Conclusion

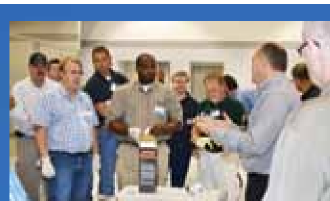
EDI has demonstrated itself to be a viable option for high purity deionization applications. It can either replace or supplement traditional ion exchange methods in order to extend run times and improve product quality. EDI allows users to regain ownership of their equipment, their quality, and their documentation. This technology will find itself in more challenging and advanced applications.

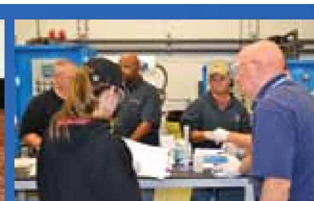
The Author: Stephen Boles



Stephen Boles has over seven years of experience in the High Purity Water Industry. His areas of expertise include the design, build, installation, start-up, and troubleshooting of high purity water systems. He graduated from Cedarville University with a BS in Mechanical Engineering. Stephen Boles has given several presentations on "EDI—An Introduction" at Pureflow, Inc.'s annual training seminar.







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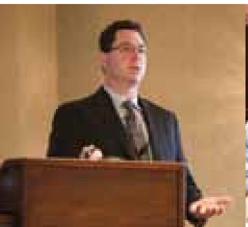

Giving

To give without any reward, or any notice, has a special quality of its own.

- Ann Lindbergh

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