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TECHNICAL PAGES

An introduction to spiral wound EDI

The latest generation in EDI technology provides various design benefits.

By Jeff Tate

Electrodeionization (EDI) is typically used in combination with RO systems to produce pure or ultrapure water, continuously and without chemicals. This combination eliminates the need for regeneration chemicals and the inherent cost, safety and inconveniences of storage, handling, treatment and discharge associated with ion exchange systems.

Power plants, electronics manufacturers and pharmaceutical companies are taking advantage of the benefits of EDI.

While the majority of these systems use first generation plate and frame design, the spiral wound version has become the fastest growing technology in the EDI field.

The spiral wound membrane design incorporates a fiberglass pressure vessel more similar to reverse osmosis (RO) membranes. Spiral wound EDI provides some specific advantages in terms of cost competitiveness, leak elimination and better toleration of feed water, particularly hardness.

Electrodeionization process

The core process of EDI is ion exchange resin — as is the core process for conventional mixed bed ion exchange.

Unwanted anions and cations are removed from feed water, yielding high-purity product water.

The conventional ion exchange process requires chemical regeneration and injections of chemicals such as sulfuric acid, hydrochloric acid, and sodium hydroxide are used to refresh the resin with the lower affinity hydrogen (H+) and hydroxyl (OH-) ions.

Water splitting

Instead of applying acid and caustic to the resin, EDI systems continuously split H_2O (or H-OH) molecules into H+ and OH- ions.

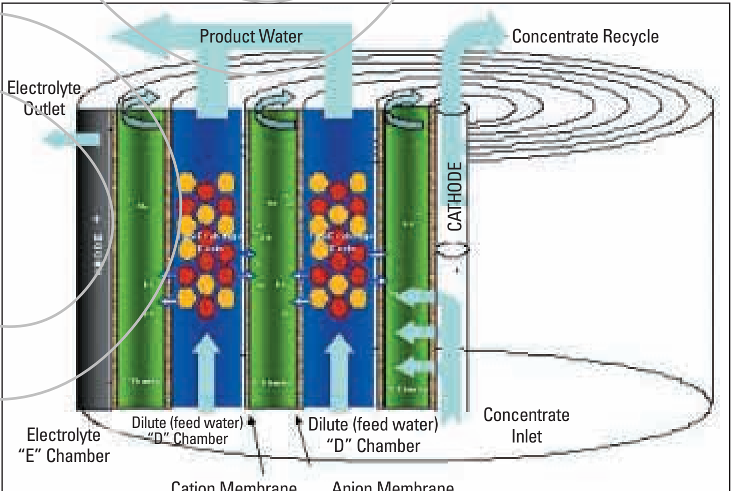

Figure 1

DC current is applied across the EDI modules by electrodes. This process provides continuous resin regeneration.

In addition to ion exchange resins and electrodes, EDI uses ion selective cation and anion membranes to form alternating concentrate and dilute chambers. EDI devices consist of some form of mixed ion exchange resin separated from the concentrate chamber(s) by ion selective cation and anion membranes.

These membranes are constructed of a polystyrene based material, similar to resin. The membranes allow only ions of a positive or negative charge to pass. Figure 1 shows the inside of an EDI module.

Feed water enters the EDI module from below and is diverted into the "D" (dilute) chambers. The dilute stream flows vertically through ion-exchange resins located between two membranes - an anion membrane specifically designed to allow migration of only anions and a cation membrane specifically designed to allow migration of only cations.

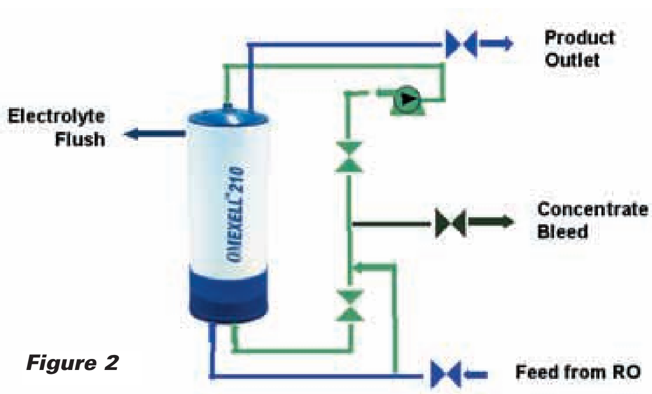

Figure 2

DC current is applied across the cells. The cathode applies negative DC charge and the anode applies positive DC charge.

The DC electrical field splits a small percentage of water molecules (H_2O) into hydrogen and hydroxyl ions. The H+ and OH- ions attach themselves to the cation and anion resin sites, continuously regenerating the resin.

Ion migration

Hydrogen ions have a positive charge and will migrate through the cation resin and then through the cation permeable membranes into the concentrate chamber due to their attraction to the negative charge applied by the cathode.

Likewise, hydroxyl ions have a negative charge and will migrate through the anion resin, then through anion permeable membranes into the concentrate chamber toward the anode.

Cation membranes are permeable only to cations and will not allow anions or water to pass, while anion membranes are permeable only to anions and will not allow cations or water to pass. Some H+ and OH- ions meet in the concentrate chamber to yield water.

Contaminant ions dissolved in the feed water attach to their respective ion-exchange resin displacing H+ and OH- ions, as in a conventional mixed bed. Once within the resin bed however, the ions are attracted to the electrodes and migrate through the resin until they permeate the membrane and enter the "C" (concentrate) chambers.

The contaminant ions are trapped in the C chamber and are swept away in the concentrate stream. The feed water continues to pass through the dilute chambers and is purified. It is collected on the outlet of the D chambers and exits the EDI module.

When multiple EDI modules are present in one system, the feed flow enters the system through a header and is distributed to all modules. The product flow is collected on the outlet of the modules and exits the system through another header.

Recycling concentrate flow

Figure 2 shows a typical EDI process flow diagram. In order to reduce electrical resistance through the EDI modules, most EDI manufacturers recommend recycling the concentrate flow.

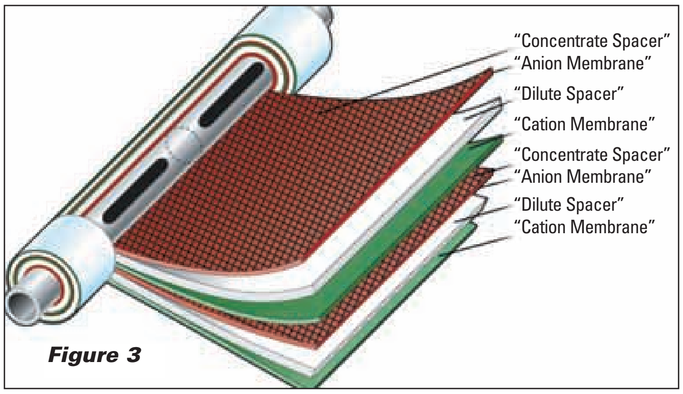

Figure 3

With a spiral wound design, the concentrate flow enters the EDI module through the center pipe from below and is diverted into vertically spiraled cells known as C chambers. Contaminant ions enter the contaminant stream as the flow passes through the C chambers.

The helically flowing concentrate returns to the center pipe in the upper section of the module. The concentrate exits the modules and enters a recirculation pump, where most is sent back into the concentrate inlet.

A small amount of water is continuously bled from the C loop to prevent ion concentration from reaching the point of precipitation (this water may be recycled ahead of the RO unit).

In order to flush trace amounts of gases that form over the electrodes, a fraction of the C-flow is diverted to the electrodes. The electrode flush can be recovered back to the RO inlet if stripped of gases. A small make-up stream from the feed water balances the flow lost through concentrate bleed and electrode flush.

Spiral wound EDI

Spiral wound EDI membranes are similar to that of RO membranes in that the membranes and spacers are rolled to form a cylindrical element (See Figure 3).

The EDI element is manufactured by placing a stainless steel concentrate pipe on a rolling machine and winding the membranes and spacers around the pipe. The element is then placed into a fiberglass pressure vessel and the dilute chamber spacers are filled with resin. The unit is sealed inside the pressure vessel.

The stainless steel pipe acts as both the concentrate distributor/collector and the cathode. A titanium anode lines the inside of the fiberglass pressure vessel and become the anode.

System design and operation

Regardless of the EDI style or manufacturer, it is imperative that the pretreatment be designed and operated properly. Specifically, the RO should be designed to provide the EDI with Total Exchangeable Anions (TEA), CO_2, hardness, silica, pH and temperature as specified by the manufacturer.

Other feed water requirements such as TOC, heavy metals, free chlorine, etc. are well within the guidelines of typical RO production.

EDI costs

Historically, EDI costs have been significantly higher than its mixed bed competitor. During the initial introductory period, an EDI system would typically cost 50 to 200 percent more than a dual mixed bed system.

However, with the introduction of a modular design in 1997, EDI became a cost competitive option based on capital and operating costs of medium to high TDS feed water between 50 and 200 gpm.

Today, the spiral wound design makes EDI cost-competitive at all flow rates, with RO permeate as high as 25 ppm TDS.

The competitive price of EDI broadens the opportunities for system integrators. Many water treatment companies are being pressured by reduced market prices for service exchange DI.

When financed over two to five years, system integrators can profit by leasing a system consisting of pretreatment filters, RO and EDI. Remote monitoring or service visits are options offered to end users.

— *J.T.*

If TEA and/or CO_2 exceed the maximum allowable in EDI feed water, it is unlikely to cause damage to the EDI modules. However the additional load will cause the product water quality to degrade.

Hardness and silica are two parameters that will quickly cause scaling in the EDI unit. Conventional EDI is typically limited to 0.5 ppm as $CaCO_3$, but the spiral wound design can operate with little scaling as high as 2.0 ppm as $CaCO_3$.

It is critical that appropriate system recovery is maintained or scaling can develop rapidly. Silica is typically limited to 0.5 ppm, however, it can be increased without the presence of hardness.

High temperature can cause damage to the EDI resin and/or membranes. As long as freezing does not occur, low temperature will not damage the EDI module; however, low ionic mobility will cause a drop off in product quality.

In a system that is designed for the low temperature, an increase in operating current and/or voltage may be all that is necessary to increase product quality.

Maintenance

EDI systems traditionally require very little maintenance in a properly designed system. It is recommended that data such as flows, pressures, and electrical characteristics are logged several times per week. Over time, that data can indicate when cleaning is necessary due to possible scaling or fouling.

On-site cleaning can restore function if caught in time. In the event of irreversible fouling, conventional EDI requires the replacement of the entire module or cell packs. Either alternative is expensive.

With a spiral wound EDI, resin and/or membranes can be easily replaced, further reducing operating costs. Resin configurations can also be adjusted to allow for changing feed water qualities or a change in product quality requirements. □

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