REVERSE OSMOSIS AND ELECTRO-DEIONIZATION (EDI)
THE ULTRAPURE SOLUTION

Introduction

One the first and most popular applications of Reverse Osmosis (R.O.) was to use R.O. as pre-treatment for deionization (D.I.). R.O. proved to be a cost-effective method of producing ultrapure water by reducing the frequency of regeneration of the ion exchange resin in the D.I. system.

With the introduction of Electro-Deionization (EDI) as an alternative to conventional D.I., the system configurations available to the ultrapure water system provider have expanded, with many possibilities for combining R.O. and EDI to provide the most reliable, efficient and cost-effective design.

Applications for RO/EDI

EDI can be used anywhere in general industry where deionized water is advantageous. Ultrapure water is used for microelectronic and semiconductor production, for biomedical and laboratory use, by pharmaceutical compounders, as pretreatment for stills, for boiler water during power generation, and in the food and beverage industry.

A typical EDI module will produce permeate water of approximately 15-17 mega-Ohm (MW) resistivity when installed and operated per the manufacturers recommendations. Resistivity in the this range is far better than most pharmaceutical applications, generally adequate for electronics and other traditional D.I. applications, and slightly below the requirements for the 18.2 resistivity required for some semiconductor applications.

The R.O. and D.I. in the Conventional Ultrapure Water Process

As indicated in Figure 1 below, the conventional ultrapure water processes have included reverse osmosis as the primary method to reduce total dissolved solids (TDS) and deionization as the secondary method to remove TDS to "ultrapure" levels. In cases where the feed water TDS is high or a reduction in the frequency of the D.I. regeneration is desired, a double-pass R.O. system can be applied as the primary TDS-reducing component of the overall ultrapure water system. The D.I. technology is often applied in two steps as well, with a primary D.I. system satisfactory for most applications and a polishing system when 18.2 MW water is the requirement.

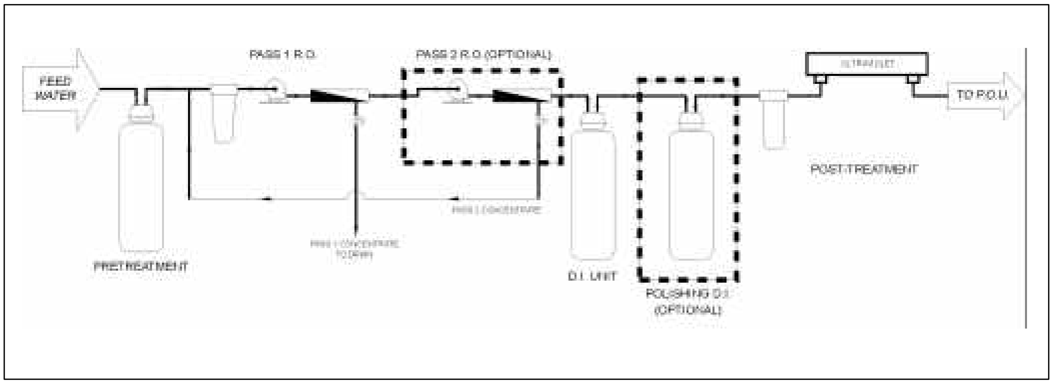

Figure 1: Conventional Ultrapure Water Process

A Brief Introduction to EDI

EDI is a water treatment process that combines two well-established water purification technnologies – electrodialysis and ion-exchange resin deionization, to remove ions from an aqueous stream. EDI equipment consists of alternating cation- and anion-permeable membranes and spacers that form compartments. Alternate compartments are filled with mixed ion-exchange resins. The result is a repeating element called a cell pair, as shown in Figure 2.

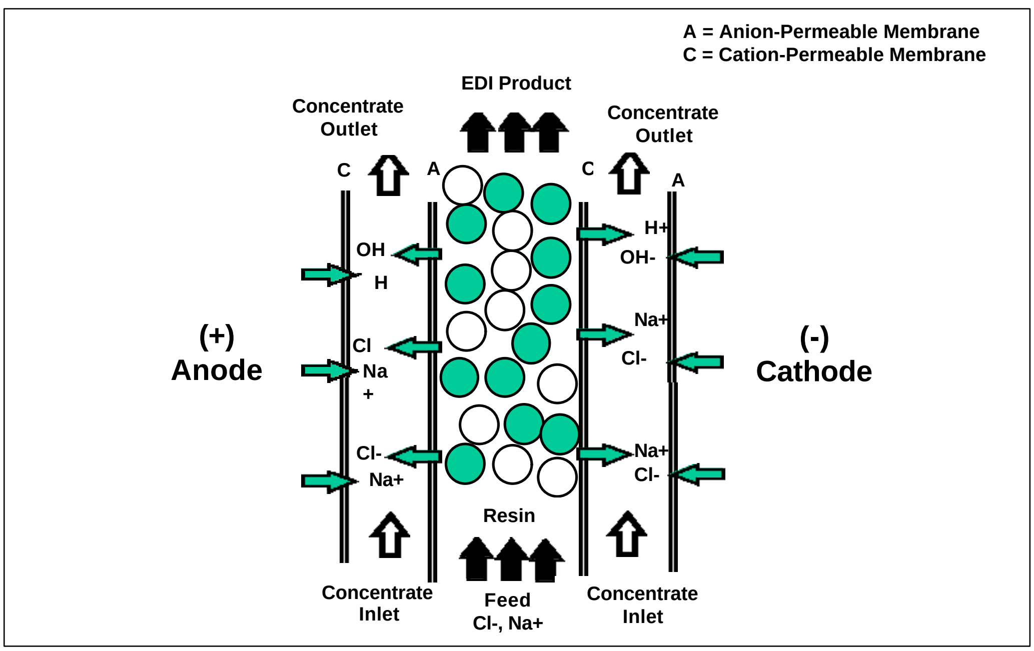

Figure 2: The EDI Technology

Feedwater enters all the compartments in parallel. The imposition of a direct electrical current (DC) serves to motivate ions to move from the compartments containing the resins into the adjoining sections. The charge selective displacement of ions by the transverse DC electric field depletes them from the ion-exchange-containing compartments, which become diluting regions. The transfer of ions across the appropriately charged boundary membranes into neighboring compartments transforms these compartments into concentrating sections. *Water does not flow through the membranes. It is the ions that make this passage, directionally motivated by the direct current.*

The typical EDI module is constructed using three separate streams of water, each for a specific purpose. The feed/product stream provides the entry of feed water to the EDI module and the exit of EDI permeate from the EDI module. Recovery of 90-95% is typical, leaving 5-10% of the feed water to the other two streams. The concentrate stream provides the means to collect the ions which have exited the feed stream, and remove them from the EDI module. The electrolyte stream provides a continuous flow of water across the EDI electrodes to prevent accumulation of ions at the electrodes.

In most applications, the feed water will be split into the three streams. However, in some applications and with some EDI modules, the concentrate stream will be fed with a higher concentration of water than the EDI feed water to improve ion transport efficiency. In these applications, the concentrate solution is derived from a separate brine dosing system and/or by recycling the EDI concentrate back into the EDI concentrate feed.

EDI systems are configured by skid-mounting one or more EDI modules with interconnecting piping, valves, instrumentation, and a DC power supply. The capacity of EDI systems range from less than 1 GPM of product to hundreds of gallons-per-minute, completely scalable as a function of the number of EDI modules installed on the skid.

The R.O. / EDI Ultrapure Water Process

Electro-deionization can be substituted for the primary D.I. system step of the conventional process. EDI is not a viable alternative to reverse osmosis for the primary TDS-reduction step unless the feed water conditions provide feed conductivity of approximately 4 – 30 µs/cm.

As a replacement for DI, an EDI system offers a number of advantages, the most significant being the elimination of chemical regeneration.

- ***No Chemical Regeneration***: EDI does not require chemical regeneration of the resin due to a special feature of this process that causes the water molecules to “split” into hydroxyl(OH-) or hydrogen (H+) atoms. The local production if OH- and H+ within the mixed ion-exchange (IX) resins results in the constant regeneration of the resins without the addition of chemicals. Eliminating the need for chemical regeneration reduces operating costs, simplifies the control process, and makes the system more easily expandable.

- ***Continous Operation:*** In addition to the elimination of the need for hazardous chemicals, and RO/EDI system may be operated continuously because there is no down-time needed for regeneration.

- ***No Resin Fines:*** Mixed beds using large quantities of ion-exchange (IX) resins tend to deteriorate over time and generate resin fines. Resin traps are not required with EDI.

In Figure 3, a single-pass R.O. system is identified as the primary method of TDS removal with EDI as the secondary method. In this configuration, feed waters with TDS of up to 500 mg/L can effectively purified to yield EDI permeate of approximately 15-17 **MW** resistivity. If higher resistivity is required, a polishing system consisting of an additional EDI system or a mixed-bed D.I. system would be included. In most applications, mixed-bed D.I. is the preferred approach for the polishing system, for the following reasons:

- With EDI permeate as the feed water to the polishing D.I. system, the need for regeneration of the polishing D.I. resin is practically eliminated.

- The efficiency of rejection of the EDI module declines when the feed conductivity is outside the specified range of 4 –30 µs/cm. In the polishing application with feed water resistivity of 15 –17 **MW**, there is insufficient conductivity in the EDI feed and concentrate streams to enable efficient ion transport.

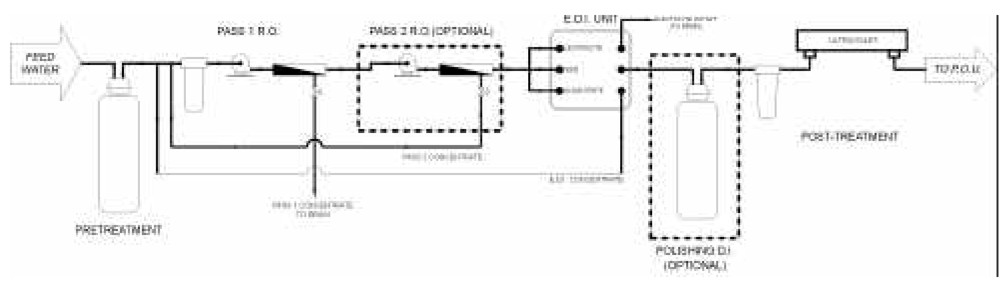

Figure 3: RO/EDI Ultrapure Water Process

Overall system recovery can be increased by recycle of the EDI concentrate to the R.O. feed. Although with typical EDI recovery of 90-95% the TDS of the EDI concentrate can be 10-20 times the EDI feed TDS, the EDI concentrate is still likely to have a diluting effect on the R.O. system feed water.

Use of Double-Pass R.O. with EDI

The decision to use single-pass or double-pass R.O. as pre-treatment for EDI is driven by the need to keep the EDI feed conductivity between 4 – 30 µs/cm. In most applications, double-pass R.O. will yield permeate of less than 4 µs/cm (typically about 1 mg/L TDS), therefore double-pass R.O. may not necessarily be an improvement over single-pass R.O. as a pre-treatment for EDI. There are situations when double-pass R.O. will be the preferred method for primary TDS reduction when EDI is the secondary TDS reducing method:

- ***High Feed TDS:*** If the feed TDS to the R.O. system is in excess of 1,000 mg/L, most single-pass R.O systems will yield permeate with TDS towards the high end or outside the 4 –30 µs/cm range for EDI feed. Although the 4 –30 µs/cm EDI feed range is not an absolute requirement, but a guideline, with feed TDS over 1,000 mg/L, double-pass R.O. should be considered.

- ***High Recovery***: The overall system recovery can often be increased by blending some 1-pass permeate water with some 2-pass R.O. permeate water to yield a blended permeate with TDS higher than the pass-2 permeate, but lower than the pass 1 permeate.

As is the case with the single pass R.O., the EDI concentrate can be recycled to the feed stream of the 1st pass R.O. system to increase overall system recovery.

Summary

An EDI/RO system, when properly designed and maintained, offers many advantages over conventional DI-based ultrapure water treatment systems. Water treatment solution providers who offer EDI/RO systems can provide their clients with the best solution possible for their situation. Table 1 summarizes the water treatment technologies recommended depending on the feed water conditions and the product water requirements.

	PRODUCT WATER REQUIREMENTS			
FEED WATER CONDITIONS	**INDUSTRIAL PROCESS (< 10 ppm TDS)**	**HIGH-PURITY PROCESS (< 1 ppm TDS)**	**ULTRAPURE (1-17 MW)**	**DEIONIZED (18.2 MW)**
< 30 µs/cm	**------**	**1-Pass R.O.**	**EDI**	**1-Pass RO --> EDI --> DI**
15 - 1000 ppm TDS	**1-Pass R.O.**	**2-Pass R.O.**	**1-Pass R.O. --> EDI**	**1-Pass RO --> EDI --> DI**
over 1000 ppm TDS	**2-Pass R.O.**	**2-Pass R.O.**	**2-Pass R.O. --> EDI**	**2-Pass RO --> EDI --> DI**

Table 1: Recommended Water Treatment Technologies

The key points to remember when considering R.O. and EDI are:

R.O and EDI are complementary: EDI performs best when fed with R.O. permeate and in most cases requires R.O. or a similar technology to pre-treat the EDI feed water.

EDI is not a replacement for double-pass R.O.: Single-pass and double-pass R.O. are two alternative methods of pre-treatment for EDI, but it is likely that some type of R.O. system will be needed.

Post-treatment may be required after an R.O./EDI system: EDI will not provide suitable final microbiological protection required for pharmaceutical applications or 18.2 **MW** resistivity needed for some semiconductor applications. In these cases, additional equipment such as a polishing D.I., sub-micron filter, ultraviolet sterilizer, or other similar devices may be required.

Acknowledgements

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Sources

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