Electro-Deionization: A Small System Case Study

Introduction

Electro-Deionization (EDI) is increasing in acceptance in ultrapure water applications. EDI found initial acceptance in the large industrial semi-conductor and pharmaceutical manufacturers. However, these types of applications are often beyond the reach of the typical water treatment equipment dealer. This case study illustrates that as the acceptance of EDI increases, the access to EDI projects for the water treatment dealer will improve, especially when small capacity equipment is appropriate.

This case study is based on the ultrapure water requirements of a domestic medical device manufacturer. The user required approximately 1,440 gallons per day (GPD) of water with purity in excess of 2 meg-ohm (MW) resistivity in support of the manufacturing process for the medical devices produced at their facility. Feed water to the water purification plant is municipal water of less than 500 mg/L of total dissolved solids (TDS).

Overview of 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 1.

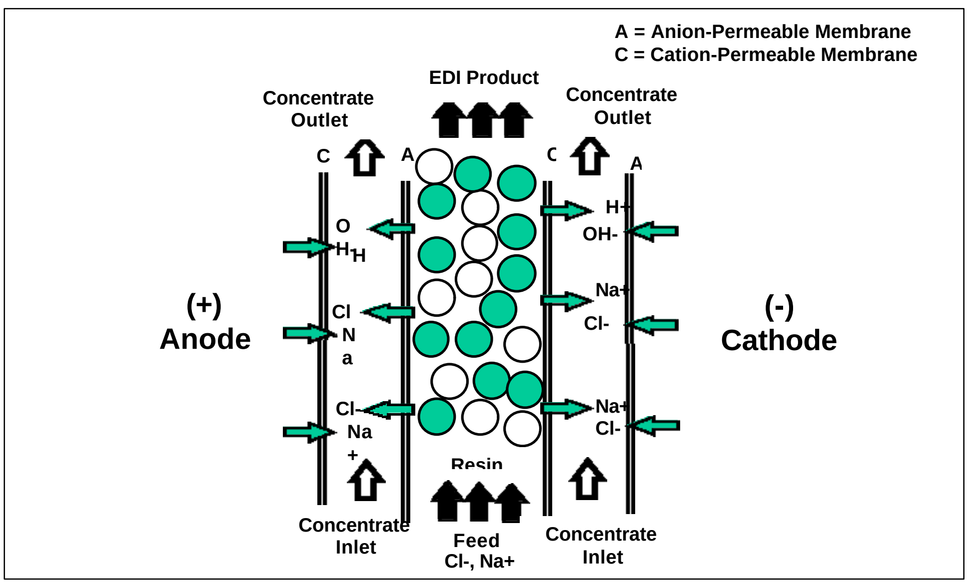

Figure 1 – The EDI Process

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 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 85-95% is typical, leaving 5-15% 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.

<u>Process Flow</u>

The focus of this case study is on the equipment supplied for TDS reduction and microbial protection. Due to the requirement for product resistivity in excess of 2 MW, it was determined that the water purification plant should be based on a single-pass reverse osmosis system with an electro-deionization system for polishing. The process flow for this water purification plant is typical of high-purity applications featuring reverse osmosis and EDI. The complete treatment process is described below and illustrated in Figure 2.

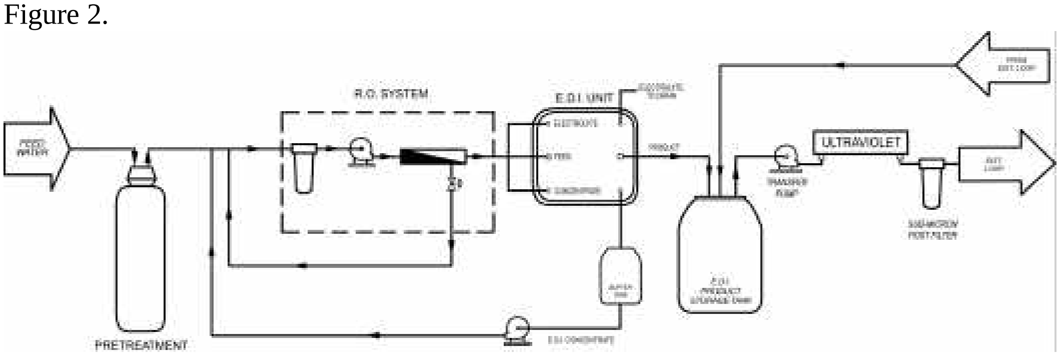

Figure 2 – Process Flow Diagram

<u>Pre-treatment:</u> Conventional media filtration equipment was recommended and supplied by the water treatment dealer to remove hardness and chlorine from the feed water. Protection of the reverse osmosis membrane element from scale and/or oxidation was the primary objective of the pre-treatment.

<u>R.O. System</u>: The reverse osmosis (RO) system was designed to produce 1.15 GPM (1,656 GPD) of permeate water using a single 4" x 40 " brackish water membrane element. A high surface area RO membrane element was selected to provide the required rejection and flow rate while maintaining system flux within the guidelines recommended by the membrane manufacturer. A permeate flow rate of 1.15 GPM was required to account for 87% recovery rate of the EDI unit. Even when using the optional concentrate recycling to improve the RO system recovery, the RO permeate was expected to be less than 10 mg/L TDS; well below the requirements for the EDI module feed.

EDI System: The EDI system was sized to produce the required 1.0 GPM under the expected feed water conditions. A single Electropure XL-200 EDI module with a rated production of 0.5 to 1.5 GPM was selected. Using this EDI module, the RO permeate flow of 1.15 GPM is split into three streams; 1.0 GPM to the EDI feed, 0.05 GPM to the electrolyte inlet, and 0.1 GPM to the concentrate inlet. With an EDI feed of less than 10 mg/L TDS, the EDI system was expected to provide product water in excess of 15 MΩ resistivity.

Storage Tank: The EDI product water is collected in a 500 gallon storage tank. From this storage tank, the product water is continuously recirculated through the facility distribution loop and back to the storage tank. Non-intrusive level switches were installed on the storage tank provide for automatic start/stop of the RO/EDI system and low-level protection for the transfer pump. The tank is sealed and vented with a sub-micron filter to maintain a microbe-free atmosphere in the tank.

Transfer Pump: A stainless steel centrifugal pump is provided to deliver the EDI product water from the storage tank to the distibution loop. The pump is sized to provide up to 30 GPM of flow at a discharge pressure of 60-80 psi.

Ultraviolet Sterlizer (UV): A stainless steel UV system is installed in the distribution loop to provide final and continuous disinfection of the EDI product water.

Sub-Micron Post-Filter: Dual sub-micron filters are installed as the final process step before use of the EDI product water. Absolute rated cartridges in natural polypropylene housings provide the necessary filtration and sanitary conditions.

System Design Features

Although the water purification system described is typical of many high-purity applications, there are some design and installation considerations that make this case study interesting:

RO/EDI Operating as a single unit: The reverse osmosis system and the EDI system were constructed in manner in which both systems operated as a single unit. Since the RO permeate was of insufficient quality to be used and the feed water was too high in TDS to be fed to the EDI unit, there was no occasion when the RO or EDI system could be operated independently of the other.

Concentrate recycling on the RO: A concentrate recycle valve was installed on the RO system to permit operation of the RO system at up to 50% recovery.

Concentrate recycling on the EDI: The RO/EDI system was designed to permit recycling of the concentrate stream of the EDI module back into the RO feed stream. Even with the EDI module operating at 87% recovery, the TDS of the EDI concentrate stream is expected to be only 20% of the RO feed TDS. Since the EDI concentrate stream is so low (only 0.1 GPM), the system is equipped with a divert valve to permit the user to dump the concentrate to drain or to allow the concentrate to be collected in a skid-mounted atmospheric tank for subsequent recycling to the RO inlet.

Sanitary connections: The EDI module and essentially all piping connections from the EDI product outlet to the distribution loop were sanitary clamp connections using inert polypropylene tubing and fittings. The EDI product storage tank was custom-fitted with sanitary clamp fittings for the transfer pump feed, EDI product inlet, vent, and distribution loop return.

Figure 3 – Sanitary Connections on the EDI Module and UV

Master Control Panel: A programmable logic controller (PLC) based control system was used to provide for automatic control of the RO system, EDI system, transfer pump, UV sterilizer, and tank level switches. Key features of the control system included:

Pre-treatment equipment lockout: The RO/EDI control panel includes a feature to automatically stop and restart when the pretreatment equipment is in a backwash or regeneration mode.

Low-pressure Alarm: As protection for the RO system high-pressure pump, the RO system will stop automatically when a low-inlet pressure condition is detected.

Low-flow Alarms: To protect the EDI module, the EDI system includes low-flow switches for the RO permeate inlet stream to the EDI system and for the electrolyte inlet stream. Should flow be interrupted to either stream, both the EDI and RO system are stopped.

High Feed Conductivity: The EDI module provides the best performance when the feed conductivity is below 15-20 mg/L TDS. A conductivity meter installed on the RO permeate line will provide an alarm output when the feed water to the EDI module exceeds 20 mg/L TDS. The system will not stop when this alarm is detected, a warning light on the control panel is illuminated.

Figure 4 – Flow Controls, Instruments, Sample Valves

Sample ports: Sample valves are mounted on the front panel of the RO/EDI system to permit monitoring of the performance of the system. Sample valves are provided for the critical sampling points such as the RO permeate, EDI permeate, and EDI concentrate outlet

Concentrate and Electrolyte flow control: It is essential that the concentrate and electrolyte streams of the EDI system maintain sufficient flow into the EDI module. The RO/EDI system has been equipped with individual flow regulating valves to permit precise adjustment of the flows to the electrolyte and concentrate streams while maintaining the output flow of the EDI product.

Summary

The initial test results from the equipment indicated the equipment as designed will meet the performance requirements. Operating the RO at 50% recovery, the RO permeate water 6.1 mg/L TDS, with the EDI product ranging in resistivity from 16.5 to 17.2 MW

This case study is representative of the type of high-purity application that can be pursued and successfully executed by a water treatment dealer. The small capacity of 1 GPM of EDI product output keeps the project within the financial and technical realm of most dealers. The pre-treatment, reverse osmosis, and post-treatment equipment are familiar to most dealers, and utilizing EDI equipment as described here, the water treatment dealer can consider a high-purity project using Electro-deionization.

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