Improving the outlet water quality of an RO Membrane – Electrodeionization (EDI/CDI)* system using Liqui-Cel Membrane Contactors

RO membranes coupled with EDI/CDI technology are rapidly gaining acceptance in the production of high purity water. Coupling the two technologies offers many advantages to the conventional RO mixed bed system design. The overall performance of a RO-EDI/CDI system can be improved by removing dissolved carbon dioxide between the RO and EDI/CDI units. Membrane contactors are commonly used in conjunction with these technologies to provide a low maintenance, chemical free, high purity water system.

The following information describes the general principles of EDI/CDI and membrane contactors and explains the basic water chemistry involved in this process.

RO-EDI/CDI

EDI is a technology that is rapidly gaining acceptance in the water treatment industry. The technology is a membrane-based device that combines conventional ion exchange resin technology and an electrical current. The electrical current is used to continuously regenerate the resin, eliminating the need for periodic chemical regeneration.

This technology is typically coupled with an RO membrane. This concept offers several advantages to the conventional RO mixed bed design.

A RO-EDI/CDI system continuously produces high quality water. It does not need to be shut down for regeneration. This eliminates the ionic leakage that occurs at the beginning and end of the regeneration cycle in a mixed bed. This continuous process also simplifies operation. The operators and operating procedures associated with recurring regeneration cycles are no longer required.

Another significant advantage realized with EDI/CDI is that no chemicals are required for regeneration. This eliminates storage and disposal costs of hazardous regeneration chemicals and waste streams associated with the regeneration of a conventional ion exchange resin system.

EDI/CDI has evolved from small pilot scale applications to large flow industrial applications over the last 10 years. This concept was traditionally targeted to the production of high purity water in the electronics industry. As environmental issues concerning chemical and waste disposal have become more strictly regulated, this concept has become much more broadly accepted. (1)

Membrane Contactors

A membrane contactor is a hydrophobic membrane device that allows water and a gas to come into direct contact with each other without mixing. Water flows on one side of a membrane and a gas flows on the other. The small pore size and hydrophobic property of the membrane prevent water from passing through the pore. The membrane acts as a support that allows the gas and water to come into contact with each other across the pore. By controlling the pressure and composition of the gas in contact with the water, a driving force can be generated to move dissolved gasses from the water phase into the gas phase.

The membrane contactor works under the same basic principles that a vacuum degasifier or forced draft deareator operate under. However, the membrane-based technology offers a cleaner, smaller and more stable operating system than the conventional degasification tower design.

The membrane contactor brings the gas and liquid phase into direct contact with each other at the pore of a hydrophobic microporous membrane. The pore size of the membrane is on the order of 0.03 microns so airborne contamination will not pass through the pore and contaminate the water stream.

The membrane offers a structured interface between the gas and liquid streams that is not upset by any changes in liquid flow rates. This provides a stable operating system over a wide range of flow rates. The structured interface also offers ten times the contact area per unit volume found in the packing of a conventional degasification tower. This allows the membrane system to be much smaller than a conventional degasification tower. (2)

Carbon Dioxide
Carbon dioxide will freely pass through an RO membrane. As it passes through an RO membrane it will dissociate and raise the conductivity of water. Since the outlet resistivity of the water from an EDI/CDI unit is proportional to the inlet conductivity, any ionic species formed from the carbon dioxide gas will lower the outlet resistivity of the water produced by the EDI/CDI. The added ionic load may also impact the ability of the EDI/CDI to remove weakly charged ionic species such as boron and colloidal silica.

Carbon dioxide is commonly found in water supplies throughout the world. It is produced from the dissolution of MgCO3 and CaCO3 (magnesium and calcium carbonate). These compounds are present in many minerals found in the earth. They are dissolved into the water as the water flows over minerals in the earth's crust. When these carbonates dissolve in water they form magnesium, calcium, carbonate and bicarbonate ions and carbon dioxide gas. The concentration of each depends on the pH of the water source. (3)

An RO membrane will reject the ionic species, however, the carbon dioxide gas will freely pass through the membrane. The dissolved CO2 gas that passes through the membrane will again ionize. (2) This will be a source of ions in the water that will increase the conductivity of the water. The equations below describe the reactions that govern the chemistry of carbon dioxide in water. At low pH the equilibrium is shifted to carbon dioxide gas, when the pH is high the equilibrium shifts to the ionic species.

Carbon Dioxide Management
The management of CO2 in water is typically handled in one of two ways. The pH of the water can be adjusted to allow the RO membrane to reject the ionic species or the carbon dioxide can be removed from the water using a strip gas.

Low pH $CO_2 + H_2O \Leftrightarrow H_2CO_3$ (carbonic acid)

↓ $H_2CO_3 \Leftrightarrow H^+ + HCO_3^-$ (bicarbonate)

High pH $HCO_3^- \Leftrightarrow H^+ + CO_3^{-2}$ (carbonate)

pH Adjustment
The pH of the water into the RO membrane can be raised to shift the equilibrium equations to favor the carbonate side. In this process there is little carbon dioxide gas present in the water. The RO membrane will reject the ionic species and little or no carbon dioxide gas will be present downstream of the RO membrane.

When adjusting the pH of the water, chemicals are added to the water. This adds to the contamination of the reject water that needs to be treated. Water that has high alkalinity may also foul the RO membrane. In order to prevent this fouling, anti-scalants are typically used. This again increases the chemicals added to the water.

Since water quality changes seasonally the control of the chemical addition must be designed to take this into account. This adds to the complexity of the pH control system.

The major drawback of pH control is that the user must add additional chemicals into the water stream. This adds to the chemical, handling, storage and treatment of the waste streams generated from the usage of these chemicals.

Air stripping
A second alternative for CO2 removal from the water is to remove the gas from the water using a strip gas. This has traditionally been accomplished by using a forced draft decarbonation tower. In a decarbonation tower, water flows over a packing material and air is blown into the tower. As the water flows over the packing material it forms a thin film that is in contact with the air. The carbon dioxide preferentially moves from the water into the air stream and it is removed or "stripped" from the water.

In an RO–EDI/CDI system a forced draft decarbonation tower is not practical due to its size and risk of adding contaminates back into the post RO water. Membrane contactors offer a compact, clean, low-cost alternative to the conventional decarbonation tower.

Membrane contactors also offer a simple, low-cost system design. In a conventional forced draft decarbonator, the outlet water must be pumped from a storage tank (clear well) in the tower. In a membrane contactor, the outlet water is under pressure. No storage tank or repressurization pumps are required.

In a properly designed RO–membrane contactor system, the resistivity of the outlet water can be as high as 1-2 mega-ohm/cm. This reduction of conductivity will greatly enhance the performance of an EDI/CDI unit.

CO_2 removal efficiency of a membrane contactor: 4-inch Liqui-Cel® Membrane Contactor with 8 m^3/hr air sweep

Inlet CO_2 gas concentration		Outlet Dissolved CO_2 concentration (ppm)		
	ppm	1 m^3/hr	2 m^3/hr	4 m^3/hr
CO_2	30.0	1.5	4.3	9.5
	50.0	2.0	7.0	15.7
	100.0	3.6	13.4	31.0

Conclusions
RO–EDI/CDI systems are rapidly growing in popularity in the water treatment industry. High inlet conductivity levels into an EDI/CDI device will tend to reduce the resistivity of the outlet water. A common cause of the high conductivity is dissolved carbon dioxide. Membrane contactors provide a clean, maintenance free method to remove carbon dioxide from water without any pH adjustment.

For more information or for help with your specific application, contact your Membrana - Charlotte Representative.

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*Electrodeionization/Continuous Deionization.

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