Continuous Deionization For Electrocoating Applications

By Michael R. Pacek, P.E.

A continuous deionization system can be a cost-effective tool to bring about process control improvements and increased product yields.

Deionized water is used in the electrocoating industry to provide make-up water for electrocoating baths and for rinsing critical parts prior to electrocoating. The use of deionized water helps avoid the accumulation of salts, minerals and other contaminants that can cause quality problems such as spotting in spray rinsing applications and chipping of finishes. Therefore, a consistent megohm-quality water is needed to eliminate any potential problems and to increase product yields.

Achieving Deionization

The traditional method of deionization is resin-based ion exchange (Figure 1). In this process, water is passed through beds of chemically treated resin beads. Ions (charged particles) in the resin beads trade places with ions in the water stream, some resins hold and swap only cations (positively charged), while others hold and swap only anions (negatively charged). The first are called *cation exchange resins* and the latter are called *anion exchange resins.*

Ion exchange is a multi-step process. Water is first passed through resins saturated with hydrogen (H+) cations. The hydrogen cations replace the cations in the water, such as sodium (Na^+) and calcium (Ca^{2+}), which adhere to the resin beads (Fig. 1).

In the second step, anions are removed as the water is passed through abed of resins saturated with hydroxyl (OH-) ions. The hydroxyl anions change places with the anions in the water stream. The result of this two-step process is the removal of dissolved ions from the feed water and the introduction of hydrogen cations and hydroxyl anions. Once together, these two ions combine to form pure H_2O.

Resins retain only a fixed amount of ionic impurities. When all active sites within a resin bed are used, the resins are said to be exhausted. To restore the resins, regeneration is necessary. The cation resins are flushed with hydrochloric and sulfuric acid to replace the retained cations on the resins with hydrogen ions (H^+) from the acid. Anion resins are flushed with hydroxyl ions (OH-).

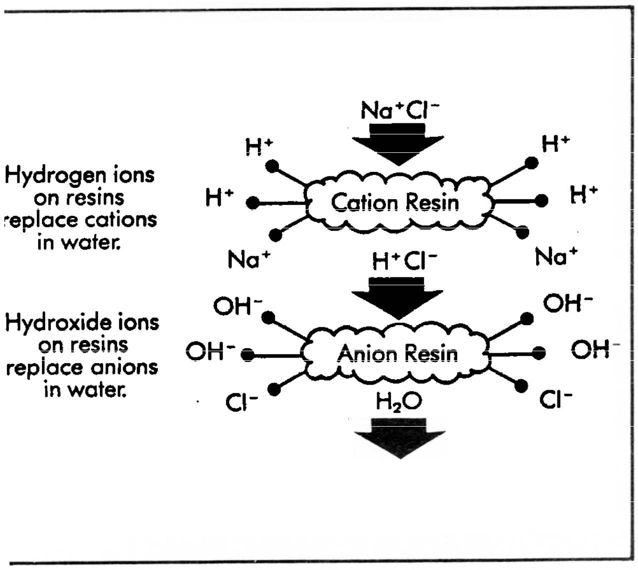

Fig. 1—Traditional resin-based ion exchange.

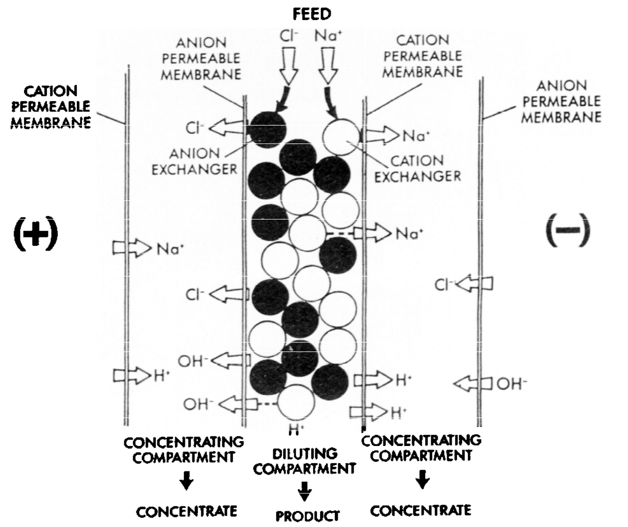

Fig. 2—Continuous deionization process modules consist of many flow compartments formed by alternating ion exchange membranes and spacers.

Continuous deionization (CDI) is a water purification technology that uses ion exchange resin, ion exchange membranes and electricity to deionize water. Process modules consist of many flow compartments formed by alternating ion exchange membranes and spacers (Fig. 2).

CDI differs from electrodialysis (EDR) in many ways, but the most obvious is the use of mixed bed exchange resin to facilitate the transport of ions through the flow compartments.

The basic CDI repeating element is called a *cell pair* (Fig. 2). The element consists of an ion-diluting compartment made up of a mixed-bed ion exchange resin, bordered on one side by a cation-permeable membrane, and on the other by an anion permeable membrane. On either side of the ion diluting compartment is an ion concentrating compartment. Ions in the resin-filled diluting compartment are transferred into the adjacent concentrating compartments by the use of direct current. As the water in the diluting compartment becomes free of ions, the DC voltage splits water into hydrogen and hydroxyl ions, which in turn regenerate the ion exchange resin.

In this way, ion exchange takes place continuously without the need for chemical regeneration of the ion exchange resins. The electric current is all that is needed to continuously drive the retained ions off the resins.

Table 1 details the power consumption of the CDI process, varying the feed water conductivity in micromho against varying flow rates from 5-20 ga/min. The VDC and amp requirements per cell pair do not change as the flow rate increases. However, as the feed conductivity increases, more power per cell pair is needed to achieve efficient ion removal.

Table 1
CDI Power Consumption

Conductivity, μmho	Feed, gal/min	Total, V	Potential CP, V	Current, A
50	5	108	3.6	.75
300	(30 cell pairs)	123	4.1	2.98
600		125	4.17	5.30
50	10	217	3.6	.75
300	(60 cell pairs)	246	4.1	2.98
600		250	4.17	5.30
50	20	433	3.6	.75
300	(120 cell pairs)	491	4.1	2.98
600		500	4.17	5.30

It should be noted that non-ionic species are not removed by electrodeionization. Dissolved carbon dioxide will normally be removed to the extent that it is converted to bicarbonate salts.

Table 2 outlines typical operating and maintenance costs for a CDI system.

System Features

CDI has a number of advantages over traditional deionization in electrocoating applications. Storing, handling and neutralizing the regeneration chemicals is eliminated, and waste disposal and ventilation problems are avoided. In fact, the reject stream from the CDI process does not require waste treatment. Another operational advantage is that unlike traditional regeneration which must occur off-line, CDI regeneration is a continuous function of system operation. The operation requires no additional operator intervention or monitoring. The system also does not normally require cleaning, thereby eliminating the need for on-site hazardous chemical storage.

Inherent in the operation of traditional deionization processes is that as the resin exhausts, the water quality begins to degrade (Fig. 3). When this happens, production may have to shut down while the ion exchange system is regenerated. With continuous de-

Table 2
Typical* Operating and Maintenance Costs, Excluding Capital Amortization

System component	Costs, $/K gal product	Assumptions**
Multimedia filter	.03	5 yr. rebed @ $800 material
Scavenger	.11	1 ppm TOC, reduction, 13 ft³ resin, 15 lb. salt/ft³, 56 g TOC removal capacity/ft³ resin, regeneration @ $.075/lb. salt, 3 yr. rebed @ $270/ft³ resin
Softener	.32	6.0 gpg hardness. 18 ft³ resin, 6 lb. salt/ft³ daily regeneration, 5 yr rebed @ $100/ft³ resin
Prefilter	.18	80, 30" filter/yr. @ $14.50 ea
CDI module		
Electric power	.07	0.7 kwh/Kgal
Component maintenance and replacement	.64	5 yr. component life
Subtotal:		
Operating and maintenance	1.35	
Water and sewer	2.90	3.5 Kga./Da backwash of media filter, softener, scavenger, 75% recovery
Total	4.25	

*30 Kgal/Da, 250 Da/yr. at 25 gpm flowrate, feed of 140 ppm TDS as $CaCO_3$ psig; product at 6 ppm TDS as $CaCO_3$ at 10 psig.
**Water and sewer: $2.00/Kgal; electricity: $.10/kwh.

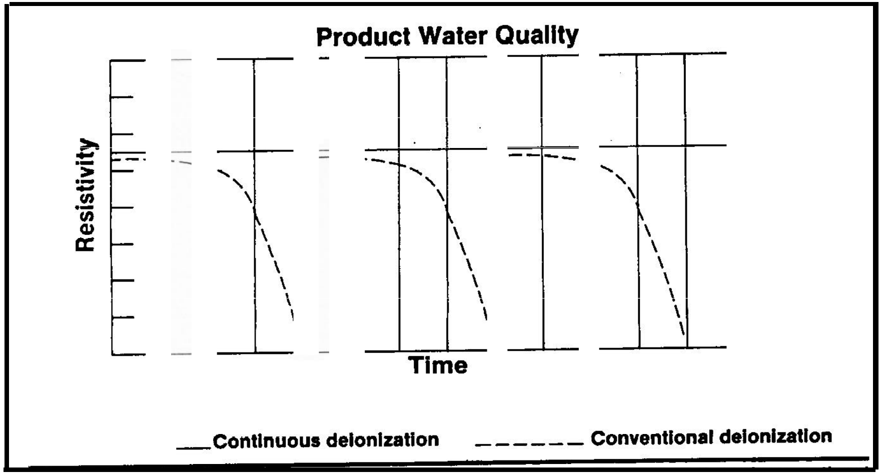

Fig. 3—Continuous deionization performance remains constant, while the performance of conventional In beds begins to deteriorate soon after regeneration.

ionization, water quality remains consistent during operation.

Another feature of continuous regeneration is the use of a much smaller resin bed to treat the same amount of water as a traditional ion exchange system. A typical 10 gpm unit will occupy a 2'x 2' floor space.

Downtime and maintenance expense are reduced with continuous deionization. It typically takes only seven cents to generate 1000 gal of 1.0 megohm water from a pretreated tap feed.

Pre- & Post-Treatment

As with any water purification system, pretreatment is generally required. Pretreatment in CD I units is necessary to prevent scale formation and colloidal and particulate plugging in the compartments. As with any system containing ion exchangers (resin or membrane), treatment is also required to remove high levels of free chlorine and high levels of organic foulants.

If the feedwater is too acidic, base addition to an approximately neutral pH maybe required to achieve carbon dioxide removal. Silica is weakly ionized and is removed only partially by CDI process. Therefore, ion exchange polishers are recommended whenever silica removal is required. ❑

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About the Author

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