

Prepared Discussion

EDI Performance and Resin Filled Concentrating Compartments

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Electrodeionization has seen remarkable success in application, usage and performance since the commercial introduction of the technology in 1987. The previous limitations have been overcome through electrochemical, mechanical and hydraulic innovations over the past 20 years.

One such improvement is the introduction of resin filled concentrate chambers internal to EDI modules. This was first introduced to modern EDI application for high purity water treatment in US Patent 5,308,466. In this invention, anion removal is reported to improve significantly by utilizing low crosslinked resin for improved ion transport and resin is introduced to the concentrate stream to reduce electrical resistance.

Electrical current is the driving force of EDI. Improved product resistivity and weakly ionized species removal is achieved by higher current through EDI modules. As the authors mention in this paper, the electrical efficiency is improved by reducing the electrical resistance. Without an ion conductive material in the concentrate chambers or "c-chambers", EDI systems require concentrate recirculation and likely brine injection to achieve optimal quality

and electrical efficiency. The paper describes some advantages of resin filled c-chambers, however these advantages are understated to users of EDI systems. There is a significant reduction in electrical consumption, by not only reduced module voltage, which according to Ohm's Law is a function of resistance, but also in the elimination of a concentrate recirculation pump. Typically, a concentrate flow rate of 4.5 to 5.4 gpm per 10 or 15 gpm module is recommended by the EDI manufacture. This results in approximately 0.25 to 0.33 kw-hr/kgal with 80% pump efficiency and 1.3 motor SF. This is a significant savings considering the EDI module presented is typically 0.4 kw-hr/kgal consumption. Additional cost savings can be found in elimination of salt consumption and a smaller system footprint.

Concentrate recirculation continuously feeds high concentration of scaling contaminants. With a 90% system recovery, the concentrate feed water will have 10 times the hardness of the RO permeate. The inlet concentration of hardness and other contaminants with a once through concentrate flow will be equal to the levels of the RO permeate.

A further benefit to eliminating brine injection is the electrical arcing that can occur if the salt builds up externally on a system with multiple EDI modules. Additionally, by continuously recirculating a high concentration of sodium chloride over the electrodes, chlorine gas is generated, the volume dependant on the current according to Faraday's law. Chlorine is a strong oxidizer and attacks EDI resin and membranes, resulting in shortened module life.

The authors present more options than have been previously reported. While lacking in certain areas, the test results of the three different resin configurations were of significant interest and further the research and development of electrodeionization. The scaling potential of pure cation resin in the c-chamber is high. The cation migration path, along with the attraction to the cathode, and high pH carbonate migration through the anion membrane can lead to hardness scaling. Therefore this configuration requires very low hardness feed water.

The performance of the MBIX concentrate chamber design was acceptable with sodium chloride contaminants, but was reduced when the feed water contaminants were changed to sodium bicarbonate. The authors used sufficient experimental testing to rule out mechanical structure design as the cause of reduced product resistivity. The various chemicals injected to increase concentrate conductivity produced varying results, with the sodium bicarbonate proving the worst. The authors did not provide sufficient data to support the conclusion that CO₂ back diffusion was the cause of reduced performance.

One possible cause of the varying results is some sort of internal electrical resistance

change. If voltage data was provided and consistent with the theory, it may have shown the EDI module resistance varied with conductivity. Another item of interest is the pH and CO₂ concentrations of the concentrate inlet and outlets with each test. If the cause in product resistivity is by back diffusion, more testing can prove so.

Another possible cause of the product quality decrease with the different chemicals is the conductivity variance of anion exchange resin in chloride, hydroxide and carbonate forms.

Patent 5,308,466 for resin filled concentrate chambers also shows that concentrate velocity has an impact on performance where higher concentrate velocities improve performance. The concentrate flow rate data would be beneficial.

The results of the layered C-MBIX design showed the best results, but again the data provided is not sufficient to show this is due to the authors' theory of back diffusion. The information provided is enough to show the hardness scaling is less than that of the pure cation arrangement.

If the data is shown to prove the authors' conclusion that the layer of cation resin protects the cation membrane from carbonic acid migration into the dilute chamber, then it seems to reason that a layer of anion resin could protect the anion membrane from hardness scaling. I would be interested to see the test data of a cation-MB-anion multilayer c-chamber compared to a cation-anion dual layer c-chamber.

Questions I would like to pose to the authors are:

1. What were the feed conductivities, E-Factors, concentrate in & out pH levels, and operating voltage for each of the experiments in Table 2?
2. What CO₂ was tested to confirm your back diffusion theory?
3. What were the concentrate velocities used during testing? What are concentrate chamber thicknesses? What were the recoveries? Was the impact of any of these factors studied?
4. Were the various concentrate chemicals injected for the layered concentrate resin bed to prove the theory of CO₂ back diffusion?
5. Was any accelerated hardness testing done on the MB or layered bed design? If so, what were the results?
6. Was silica removal tested? The previous work showed silica loaded anion resin was the least conductive.
7. The paper states hardness scaling can be reduced by four times if the module is operated in countercurrent mode. What data do you have to support this statement?
8. The inlet pressure required for counter current operation would need to be very high in order to maintain a higher dilute outlet pressure than concentrate inlet. What would be the pressure required? Would this offset the electrical consumption saved by eliminating the concentrate recirculation?

References

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