EDR CASE STUDY

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Keywords: Electrodialysis Reversal, EDR, high TDS, Reverse Osmosis concentrate waste water recovery

ABSTRACT

A new and innovative Electrodialysis Reversal (EDR) Technology was recently introduced to treat high Total Dissolved Solids (TDS) waters. The next EDR was developed by the leader of Electrodeionization (EDI) modules, and utilizes a unique membrane and mechanical design.

The first commercial system was recently installed. This paper will review the technology and challenges of the first installation. This includes the application of the technology to recover Reverse Osmosis concentrate waste water, system design and first year performance.

INTRODUCTION

EDR and EDI are both electrochemical devices used to deionize water which evolved from Electrodialysis (ED) research in the 1950's as alternate applications for ED. EDR was developed to reduce cleaning frequency of ED by incorporating an electrode reversal step. EDI added ion exchange resin to reduce the electrical resistance and membrane polarization with the added benefit of being able to produce much higher purity water. EDI, however is limited to treating relatively low conductivity feed waters (typically less than 10 to 40 µS/cm). EDI requires a membrane pretreatment for optimal performance, so it did not become a commercially viable technology until the acceptance of Reverse Osmosis. EDI was commercialized in 1987 with the first "Ionpure" system. The wide spread acceptable of EDI started after Glegg Water Conditioning made the E-Cell technology available to all water system OEMs in 1997. This started the growth stage of the product life cycle as other manufacturers improved their technology and started selling to OEMs. Generally, much more is known by most industry engineers and users today about EDI than EDR, as EDI is more commercially available and utilized.

Historically, EDR had immediate opportunities for installation because it is less prone to fouling and scaling than EDI and could accommodate much higher feed water conductivities. EDR was first commercialized in 1970 with the Ionics "Aquamite" systems, designed for 7-8 gpm. EDR was predominately available from one manufacturer for approximately 47 years, while EDI is used by many manufacturers of ultrapure water.

A new EDR module was developed by a well-know and reliable manufacturer of EDI modules and introduced at 2016 IWC. Although the recent technology was initially targeted for large scale desalination, it has proven to have tremendous opportunities in the industrial water recycle/reuse market. Because of this, the expectation is tremendous growth in the next few years which will likely eclipse that of EDI. This EDR technology is now available to all water system OEMs which should move EDR from introductory stage to growth stage in the product cycle.

EXISTING SYSTEM AND APPLICATION

A medical device manufacturer in the New England area treats well water with a series of chemical injection, greensand filters, activated carbon filters and reverse osmosis. The system was installed in 2006. A diagram of the system is shown in Figure 1. Raw Water originates from two different well sources and is supplemented with city water. These various sources are mixed in the raw water storage tank. Chlorine is injected at 10 ppm for disinfection and iron precipitation, then filtered through three parallel 31" diameter greensand filters for iron removal. After the iron removal, 15 gpm may be diverted to separate processes, and the balance enters a

RO feed storage tank where it mixes with plant Reuse Water. Reuse Water is process RO water used in the plant for rinsing then recovered to the RO feed tank.

RO feed water then is further filtered by 20 and 10 micron cartridge filters, followed by additional greensand filters and activated carbon filters for removal of chlorine. Acid and antiscalant are then injected at the RO prefilter inlet into a single pass RO system. The RO has 12 membranes, 8" dia x 40"L in a 1:1:1 array (4M housings). The RO system operates 16-19 hours per day at approximately 75% recovery (50 gpm permeate and 15-17 gpm RO concentrate).

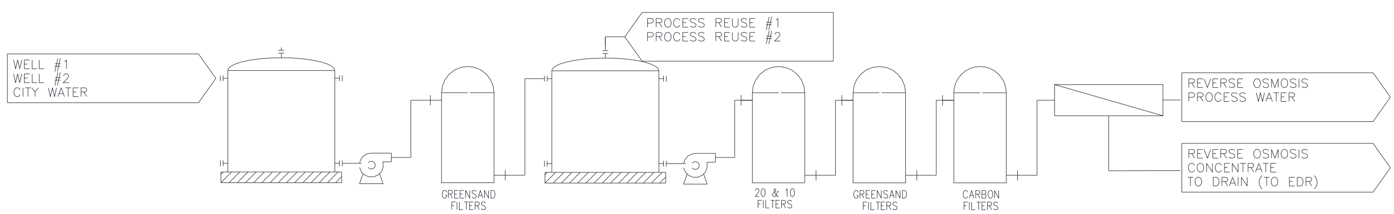


Figure 1

The end user was experiencing frequent RO cleanings and a high volume of waste water. The goal of the system was to reduce 85% of the RO waste water, by treating the RO concentrate with EDR and recovering it back to the Raw Water Storage tank rather than dumping it to drain.

One of the challenges of the EDR installation is the variability of RO waste water quality. The RO feed water varies significantly day to day based on the source of the water and the processes used in the plant between 700-1,600 µS/cm. This means the RO concentrate water was expected to range between 1,400-3,720 µS/cm. The EDR feed water quality variability creates a challenge to EDR operation as excessive amounts of hardness, organics and Silica pose fouling and scaling risks. Higher feedwater TDS requires higher current and high current applied with low TDS will result in polarization of the EDR membranes. Hardness scaling would be certain with concentration polarization in this unsoftened RO concentrate. So, a system that can handle high scaling and fouling potential and high feed variability was investigated.

EDR TECHNOLOGY AND PILOT SYSTEM

EDR is a device which applied a DC voltage to a series of alternating Dilute (D) chambers and Concentrate (C) chambers separated by cation and anion ion exchange membranes. Figure 2 shows a typical ED process. This has been extensively discussed at this conference since 1956, so the technology summary in this paper will be brief. Feed water enters through D-chambers, where water is diluted of ions and exits as desalinated product water. The applied DC current attracts positively charged cations toward the negatively charged cathode and negatively charged anions toward the positively charged anode. Ions may pass through either the cation or the anion exchange membranes, depending on their charge. As cations pass through the cation exchange membranes, the cations are trapped in the concentrate stream since they cannot pass across anion exchange membranes. Likewise, anions pass through anion exchange membranes and are trapped in the concentrate stream as they cannot pass across cation exchange membrane. A portion of the feed water enters the C-chambers and water is concentrated of ions and exits as concentrate outlet water. It is worth noting this ED process differs from EDI as there are no ion exchange resins used in the ED process.

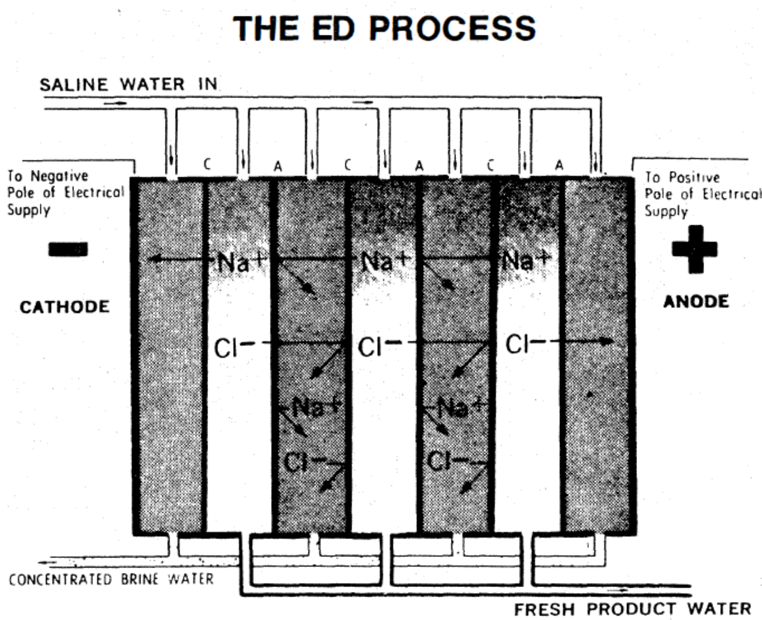
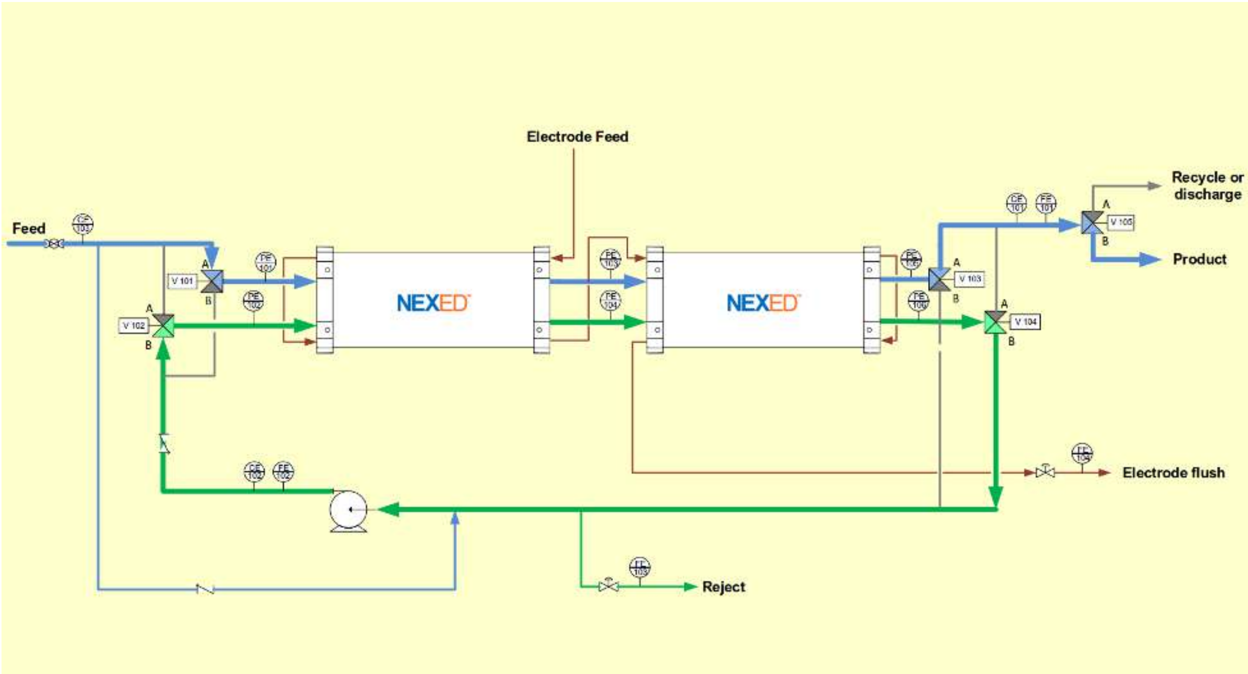


Figure 2 (Katz, IWC-70-28)

EDR is like ED in the electrochemical desalination, however after an adjustable interval, the polarity is reversed. In polarity reversal, the cathode becomes the anode, and the anode becomes cathode, D-chambers become C-Chambers and C-Chambers become D-Chambers. This process is automatically controlled by the programming in the control panel. Figure 3 shows the system process flow design.

Figure 3



The latest EDR module was presented and discussed at last year's conference (IWC-16-52). This latest EDR module design improved on older EDR modules with not only lower cost, but also upgraded membranes, new flow design and low electrical cost. A pilot system was designed by Agape Water Solutions using this module and some performance test data was presented in last year's paper. The end user visited this same pilot system operating on Tewksbury, MA well water, and was impressed. An order was then placed with Northeast Water Services, Inc of Foxborough, MA for the first commercial installation of this latest generation EDR technology.

DESIGN, BUILD AND INSTALLATION OF NEW SYSTEM

The design, build and installation of the new EDR system posed several challenges in physical requirements, process design, electrical design and in automatic controls and programming. We could draw on our experience in designing, building and operating the first pilot plant and many EDI systems, however this installation has its own individual concerns that needed to be addressed in order to ensure successful long-term operation and a satisfied customer.

The location of the new EDR system was extremely limited. The allowable space was roughly 8 ft W x 7 ft D x 7 ft H and tucked into the far corner of the room with only 3 ft walkway to get access to the system. We did not want to trade serviceability for the smaller space, so a 3D design package was used with attention to detail in each component and its dimensions to optimize flow path and mechanical design. During the installation, a garage door was added so that the system could be installed and access granted for service including module replacement if necessary. All the normal service requirements (flows, pressures, valves, controls, and CIP connections) were located on front of skid for easy access and adjustments.

The existing RO Clean In Place system was utilized to act as the EDR feed water storage tank. The RO concentrate was diverted to normally enter the CIP tank, and EDR controls were integrated with the level switches and feed pump. A VFD was added to the CIP/EDI feed pump to prevent water hammer and to better allow for additional water recovery in the future. This CIP system is still utilized for cleaning the RO system, and can also be used to clean the EDR if necessary.

The process design was challenging due to the variability of the feed water. The water source varies frequently day to day depending on whether a particular well is used, city water is used, and/or plant rinse water is used. The primary contaminants of concern are hardness, silica and TDS. The system was designed for worst case feed water, however unlike EDI where low current efficiency helps performance, EDR operates below theoretical current requirements in order to avoid concentration polarization. Concentration polarization results in accumulation of ions on the membrane surfaces in the concentrate chambers, which could result in scaling and lower salt rejection. Extreme polarization could occur when the current exceeds limiting current, water splitting can then occur resulting in pH shifts and increased risk of scaling. A proprietary algorithm was developed and programed in the programmable logic controller (PLC) to allow higher current operation at higher TDS and lower current at lower TDS. The algorithm automatically adjusts current based on flow rates and feed, concentrate and permeate conductivities. The user simply enters a desired permeate conductivity or TDS. The control system automatically increases or decreases current to the first pass EDR and second pass EDR independently. The calculations are developed based on the data from laboratory and pilot test performance.

The PLC is Allen Bradley Micrologix 1400 widely used and accepted in the US with readily available spares. The PLC was programmed using RSLogix 500 and customized to optimize performance of this EDR system. The primary concern for the control system design was that it be user friendly. This included the Human Machine Interface (HMI) display which shows graphic animation and simplifies flow paths and polarity which alternate and reverse operation. Adjustable set points are password protected, but available for customer to change the polarity reversal timer or desired conductivity as well as other set points and to assist in troubleshooting/optimization. It is worth noting that special components were selected in the electrical controls to prevent cell phone interference.

The HMI was provided with remote access availability. The HMI may be displayed on a cell phone, tablet or PC on local network or connected to the internet for remote monitoring at the local service supplier, OEM or EDR module manufacturer's location. All pertinent data including flow rates, conductivities, pressures, currents and voltages are logged and recorded on the USB drive.

The Factory Acceptance Test (FAT) was extensive and involved the service techs, engineers and scientists from the OEM as well as the EDR manufacturer. The end results were impressive, and the extended testing allowed us to improve operation even further. PLC controls were modified, PID loops tuned, and we even found surprises such as the performance and optimization of DC power supplies. We found that while some types of power supplies work well with EDI modules which contains resin, others may work better with EDR module which contains no resin. The manufactures could gather data on the modules and compare performance with expected and theoretical.

RESULTS

The two well sources primarily used for raw water make up to the plant contain between 1,500-1,600µS/cm2 conductivity. It was decided that the initial PLC set point for EDR permeate quality would be roughly half the well feed. A set point of 700µS/cm2 was decided. The system is successfully operating at the less than 700uS/cm2 set point at 72% salt rejection and as high as 85% recovery. After over 8 months of operation there have been no observed degradation of performance and no indication scale formation within the system. No cleanings are planned at this time, but performance will be monitored and chemical cleaning is expected at some point in the future.

Adding EDR has increased the overall recovery to 96.4% overall from 75% for the RO process. Additionally, by recovering the RO reject water, the end user is actually reducing the aggregate TDS feeding all points of use within the building since the higher quality EDR effluent is diluting the well water make up. The client was also able to stop feeding acid pre-RO because the Antiscalant alone can handle the scaling potential.

The performance is graphed in Figure 4. The graph plots feed water conductivity, product water conductivity, and recovery of the EDR system. While the feed water conductivity varies greatly between 1400 to 3200 µS/cm, the product water consistently remains less than 700 µS/cm setpoint. This is due to the automatic current control programed in the PLC which automatically increases and decreases current to achieve the target product conductivity. Also note the achieved recovery is 82 to 84%, exceeding the 80% target.

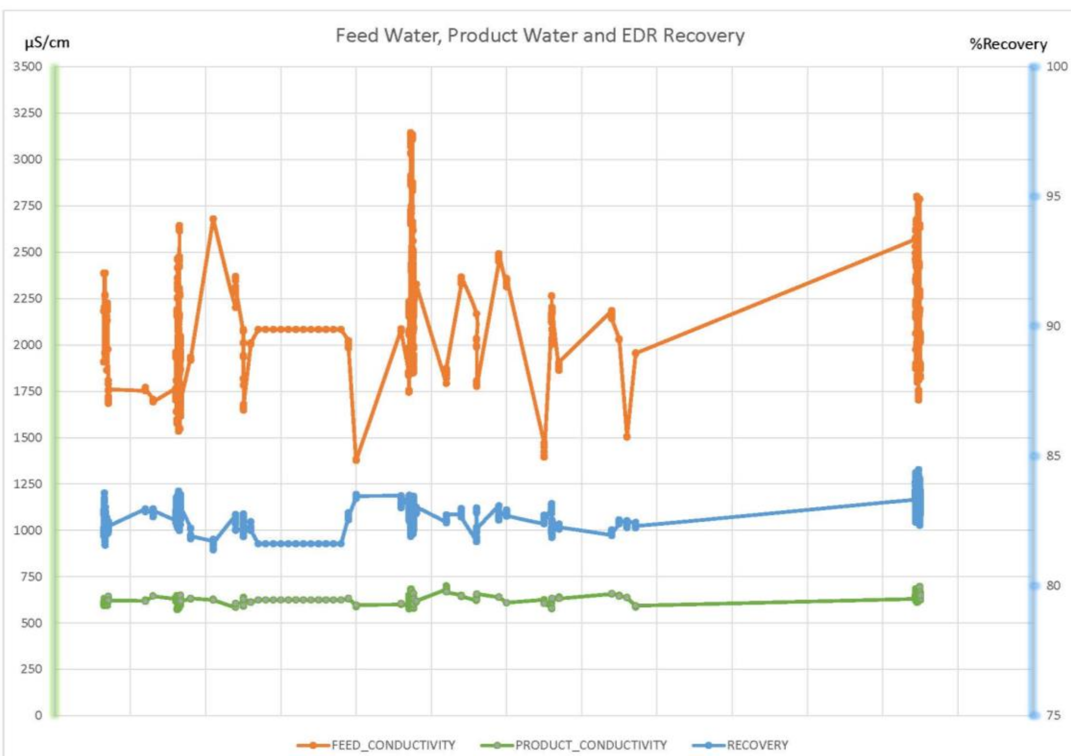


Figure 4

At current operating parameters, the client is on track for an 18 month pay back on the capital investment. However, they are currently monitoring the systems performance to potentially increase the EDR Salt Rejection to achieve lower than 700µS/cm2 and if it's possible to extend the RO cleaning frequency for additional optimization and cost savings.

CONCLUSION

The new EDR membrane technology, power supplies and control algorithms allow for expanded opportunities within the industrial water recycle/reuse markets. These systems can accommodate higher feed water supplies and are nimble enough to handle changes in overall feed water contaminants while still providing better water better than the raw water source.

Many municipal waste treatment facilities are mandating that RO reject water be treated further or used in other plant uses such as cooling tower make up. This technology will allow you to meet these requirements.

A new module configuration has been commercialized since this installation that will allow for even more performance efficiencies and physical system footprint.

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