USF Consumer & Commercial Research and Development

Project # R05 - 1083

Project name: Electronic Water Purifier

1. Objective

To evaluate the performance of a new Electronic Water Purifier. This Purifier is based on CDI Technology.

2. Technology Overview

The Electronic Water Purifier (EWP) uses capacitance to remove charged ions from water and other solutions. The Electronic Water Purifier consists of chargeable plates or layers that work in response to an applied DC potential. Each plate on the capacitor contains a conductive surface such as graphite sandwiched between layers of activated carbon. A non-conductive spacer material separates the plates from each other. These plates are alternately connected to the two sides of a DC power supply via appropriate connecting leads.

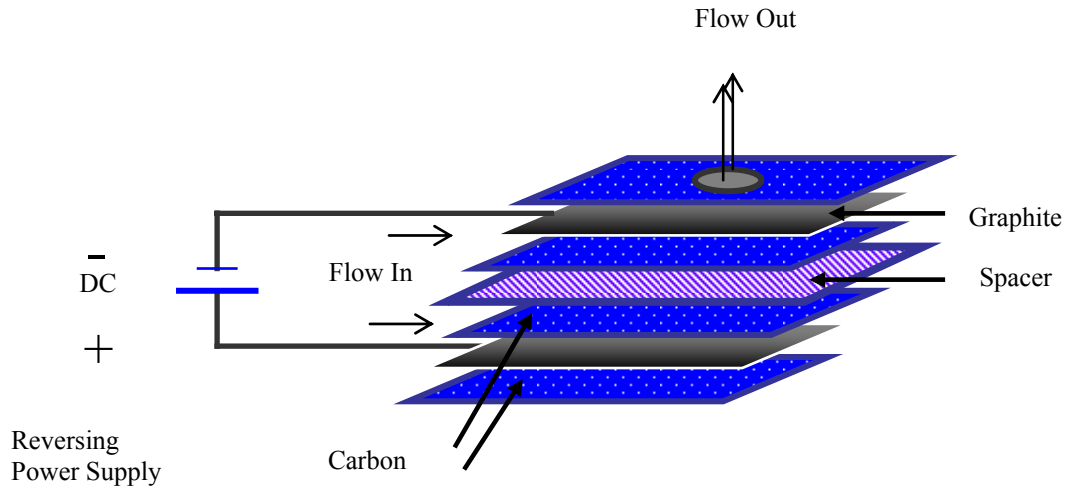


Figure 1: Stack Construction Diagram

The device works on the principles of capacitance to purify water, via application of a low voltage DC potential to attract and discharge ions on the substrate. On applying a DC potential, alternate plates become anodes and cathodes. The high surface area carbon layers in contact with the plates attract and hold ions from a solution, flowing through the device. The positive ions are attracted to the negatively charged plate (cathode), and the negative ions are attracted to the positively charged plate (anode). Eventually, all the charged sites are filled and the device must then be regenerated by discharging the irons from the carbon surfaces. This is achieved by an appropriate combination of flow, shorting of the capacitor and reversing the polarity of the applied DC potential. Once a substantial amount of the new displaced ions are flushed into the waste stream, after a fixed length of time, the unit begins to charge once again by attracting ions from the feed solution under the influence of the reverse potential. This action then begins a service cycle.

3. Product Overview

The device tested at Northbrook operates under the following parameters:

1) % removal (rejection) ~96-98%
2) recovery rate ~62% (water chemistry dependent)
3) flow rate ~ 160 ml/min
4) maximum conductivity level in the influent – 1000 ppm
5) pH range 6-10
6) pressure drop ~52 psig (outlet open to air)

The operation of the EWP is controlled via a Programmable Logic Controller (PLC) and industrial relays. The potential applied across the cell is regulated via a constant voltage DC power supply. The unit operates in a batch mode, delivering either product water or wastewater. The cell is cycled through the various phases of each operation cycle via industrial relays communicating with the PLC.

Each operative cycle consists of two main phases- purification and regeneration. During the purification cycle a DC potential is applied at the electrodes to each cell. The length of the purification step is 1min and 58 seconds. Based on the influent characteristics an appropriate rejection rate is obtained (96% on Culligan Iron Free well water). The regeneration phase consists of several steps. These steps include shorting the capacitor (no flow), 0 Applied Voltage (waste flow) and reverse polarity (waste flow). The length of the regeneration cycle is ~1 min & 53 seconds.

4. Test Parameters

During Phase I the performance of the Electronic Water Purifier was evaluated using an iron free hard water influent (~18 gpg). Influent characteristics are listed in table 1.

Table 1: Influent Water Characterisitcs

Feed Type	Iron free Culligan well water			
Sample Type	Day 3	Day 23	Day 27	
Parameters				Maximum Detection Limit (MDL)
Turbidity (NTU)	0.1	0.1	0.1	
Hardness as $CaCO_3$ (gpg)	16.1	16.0	14.8	
Conductivity (μs/cm)	716	693	672	
Color	0.0	0.0	0.0	
pH	7.7	8	8	
*Estimated TDS (ppm)	436	423	410	
Cations	**mg/L as element**			
Calcium	79.1	77.2	70.4	< 0.1
Magnesium	19	19.4	18.9	< 0.1
Sodium	37.7	37.2	36.8	< 0.1
Potassium	13.9	13.6	13.3	< 0.1
Strontium	6.04	5.92	5.83	< 0.05
Barium	0.028	0.026	0.025	< 0.01
Iron	ND	ND	ND	< 0.05
Manganese	ND	ND	ND	< 0.02
Copper	ND	ND	ND	< 0.003
Zinc	ND	ND	ND	< 0.05
Anions	**mg/L as element**			
Chloride	14.4	13.7	13.9	< 0.5
Nitrate as N	2.5	ND	ND	< 0.5
Nitritie as N	1.4	ND	ND	<0.1
Sulfate	129	134	135	< 3
Bicarbonate	271.5	266.9	250.2	
Carbonate	NM	NM	NM	
Fluoride	2.6	1.1	1	< 0.5
Silica	6.82	6.7	6.43	

Flow Rate: ~163 ml/min
Influent Dynamic Pressure: 50±5 psig

5. Test Set-up & Procedure

The EWP was plumbed directly into the hard water line. An iron filter was used before the stack to obtain iron free well water. The outlet flow control valve was left wide open during this trial. The flow rate through the stack was ~163 ml/min at 50 psig dynamic pressure. A Labview National Instruments data acquisition system was utilized to record pressure (via pressure transducers) and outlet conductivity. Influent, product and waste samples were also collected during the test.

6. Results & Discussion

The average removal rate in this test was ~ 96%. The pressure drop was ~52 psig (outlet valve fully open) and % recovery was ~62%. These values remained stable throughout the 30-day test period. Figures 2 and 3 compares the operation of the EWP on day 1 and day 34.

Figure 2: Effluent conductivity & % Removal on Day 0 (cycles 2&3)

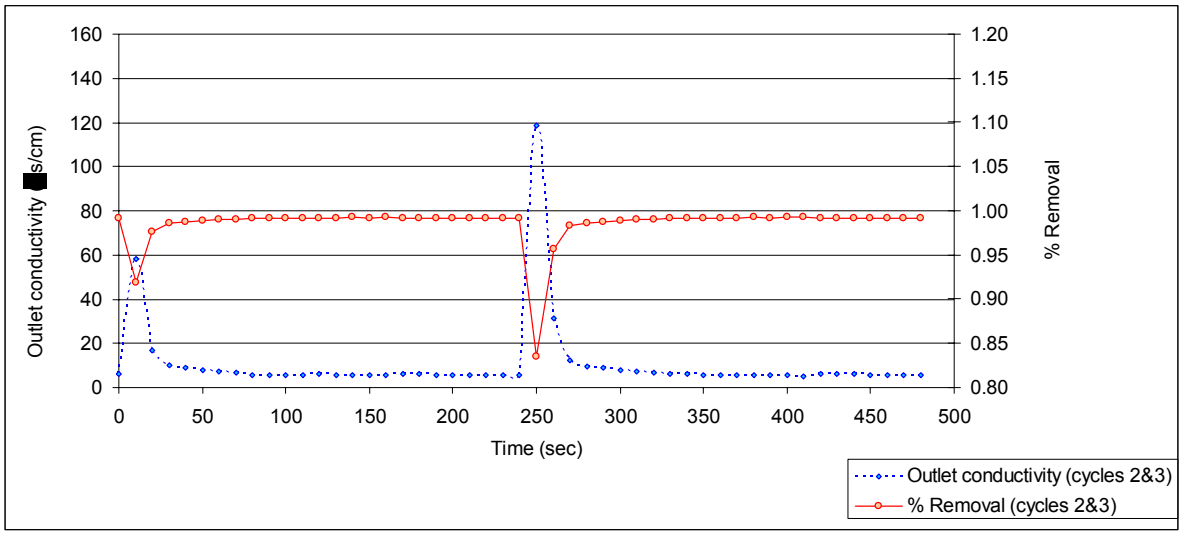
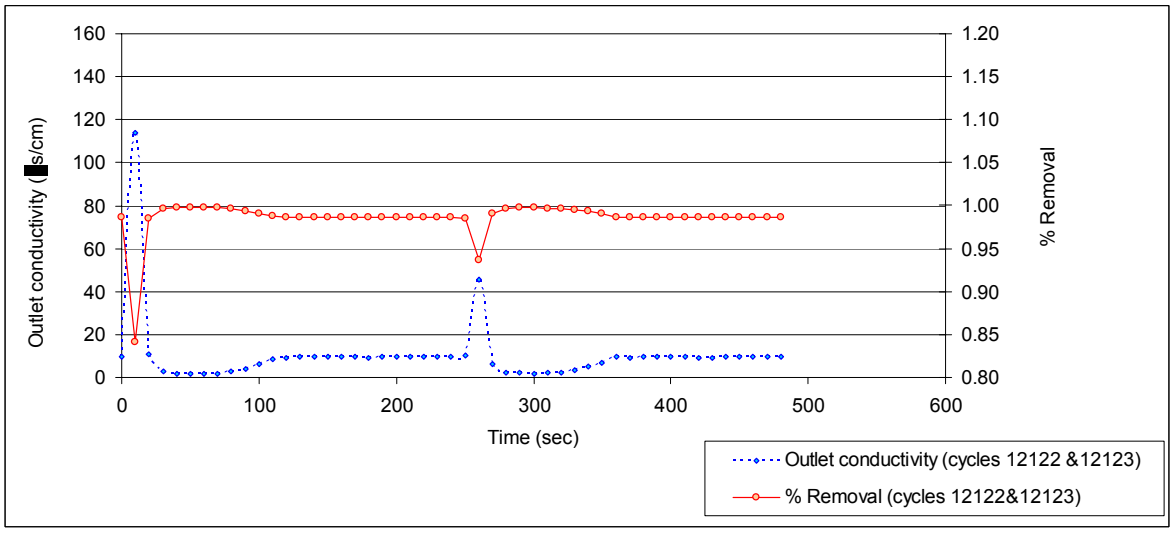


Figure 3: Effluent conductivity & % Removal on Day 34 (cycles 21122 & 21123)



Furthermore, outlet conductivity and product flow rates throughout the test are given in figure 4 & 5. The graphs display that these variables remained relatively stable. Interestingly, the product flow rate did not degrade drastically, as seen with previous EWP units tested.

Figure 4: Outlet conductivity for cycles throughout test (Days 1 – 34)

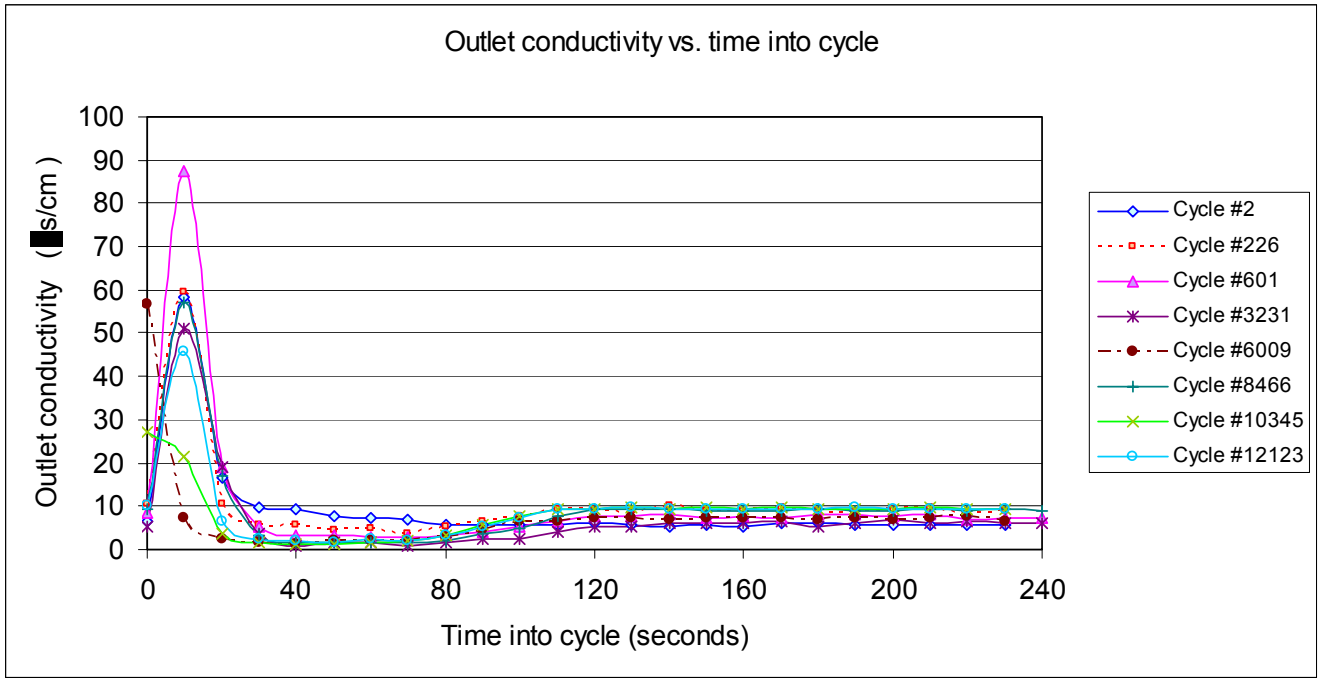
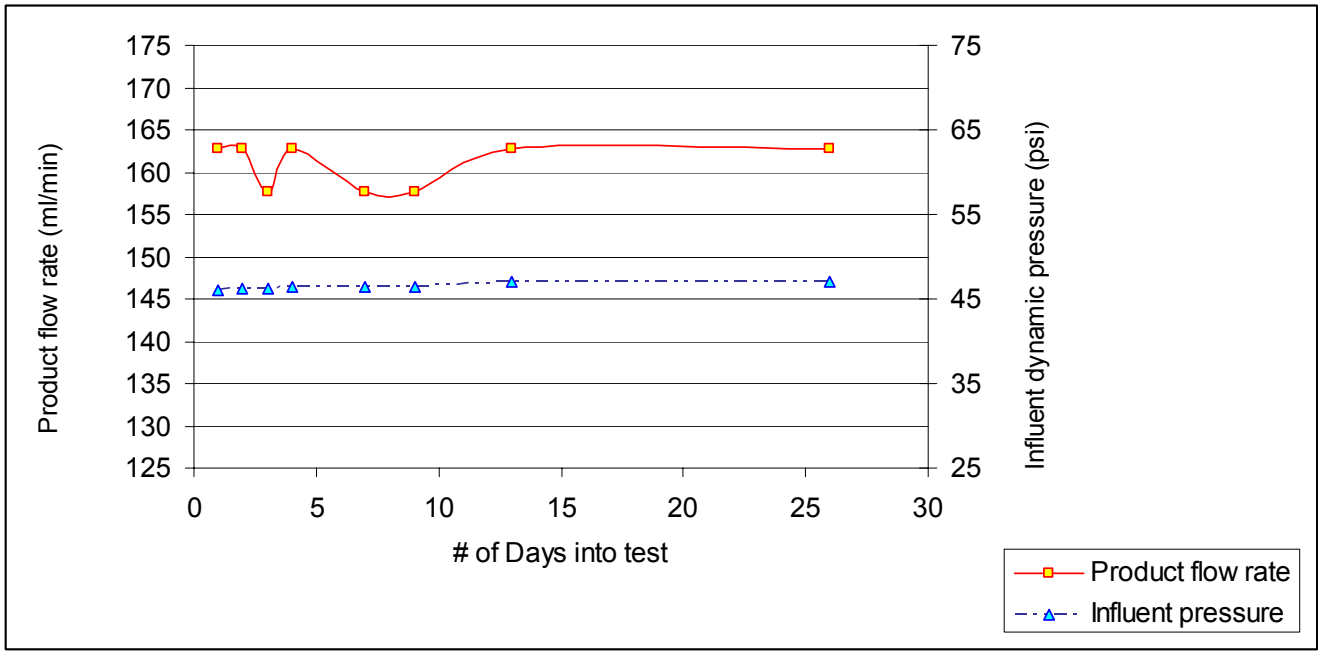


Figure 5: Product flow rate and influent pressure for cycles throughout test (Days 1 – 23)



Influent, product and waste water samples analyses are listed in table 2. These data show that there is some loss of Calcium, which indicates scaling. However, significant degradation in the flow rate was not observed.

Table 2: Water sample analyses

Day	Day 3			Day 27			
Sample Type	Influet	Product	Waste	Influet	Product	Waste	
Parameters							Maximum Detection Limit (MDL)
Turbidity (NTU)	0.1	0.1	0.1	0.1	0.1	0.1	
Hardness as $CaCO_3$ (gpg)	16.1	0.3	21.8	14.8	0.4	20.9	
Conductivity (μs/cm)	716	26	1410	672	24	1180	
Color	0.0	0.0	0.0	0.0	0.0	0.0	
pH	7.7	7.1	8.2	8	7.3	8.3	
*Estimated TDS (ppm)	436	22	853	410	21	715	
Cations	**mg/L as element**						
Calcium	79.1	1.7	68.5	70.4	2.3	59.2	< 0.1
Magnesium	19	0.3	48.9	18.9	0.3	51	< 0.1
Sodium	37.7	2.4	158	36.8	1.5	101	< 0.1
Potassium	13.9	0.4	38.9	13.3	0.4	38.8	< 0.1
Strontium	6.04	0.11	12.12	5.83	0.13	13.06	< 0.05
Barium	0.028	ND	ND	0.025	ND	0.039	< 0.01
Iron	ND	ND	ND	ND	ND	ND	< 0.05
Manganese	ND	ND	ND	ND	ND	ND	< 0.02
Copper	ND	ND	ND	ND	ND	ND	< 0.003
Zinc	ND	ND	ND	ND	ND	ND	< 0.05
Anions	**mg/L as element**						
Chloride	14.4	0.5	32.7	13.9	ND	34.4	< 0.5
Nitrate as N	2.5	ND	0.7	ND	ND	0.6	< 0.5
Nitritie as N	1.4	ND	ND	ND	ND	ND	<0.1
Sulfate	129	ND	575	135	ND	366	< 3
Bicarbonate	271.5	12	231.2	250.2	11.2	236.6	
Carbonate	NM	NM	NM	NM	NM	NM	
Fluoride	2.6	0.1	1.4	1	0.1	2	< 0.5
Silica	6.82	6.76	6.91	6.43	6.24	7.05	