EWP Test Report

By one of the largest water equipment manufacturers in the world

Phase I - Project 9023 AZ

Date: January 3, 2003

Project name: Electronic Water Purifier

1. Objective

To evaluate the performance of a new Electronic Water Purifier marketed by Sabrex, TX. This Purifier is based on the Flow Through Capacitor Technology.

2. Technology Overview

The Flow Through Capacitor (FTC) uses capacitance to remove charged ions from water and other solutions. The flow through capacitor 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.

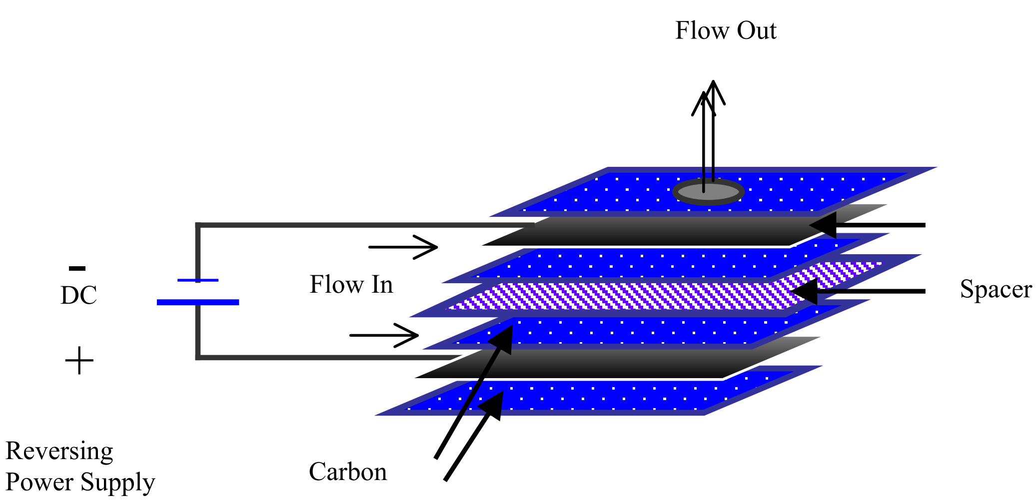


Figure 1: Stack Construction Diagram

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 (90 seconds), 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

Sabrex, TX has adapted the FTC technology for use in the design of their "Electronic Water Purifier". The device tested at Headquarters operates under the following parameters:

1) % removal (rejection) ~91-98%
2) recovery rate ~70% (water chemistry dependent)
3) flow rate ~ 1 gpm
4) maximum conductivity level in the influent – 1000 ppm
5) pH range 4-9
6) pressure drop 25-28 psig

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 potential of ~ -1.2 V DC is applied at the electrodes to each cell. The length of the purification step is 90 seconds. Based on the influent characteristics an appropriate rejection rate is obtained (91% on 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 90 seconds (30 seconds without flow and 60 seconds with flow).

4. Background

The Electronic Water Purifier was tested in February 2002, at Headquarters. The unit was operated at 2 Liter/min. Test data showed that the removal rate decreased from 70-75% to 56% at the end of 2 ½ days of operation. Testing also confirmed a reduction in flow rate indicating an accumulation of scale in the stack. A TDS controller was used to monitor outlet conductivity and control the set-point and length of the service cycle. The lengths of the service and regeneration cycles were 5min and 15 min respectively.

The new Electronic Water Purifier uses shorter cycle times than those used by the unit in February 2002. Furthermore, the current unit does not use a conductivity monitor to control the rejection rate. Hence the rejection set point is not adjustable. As a result the rejection rate is based on influent chemistry and flow rate. The purification and service cycle lengths are equal (each cycle is ~90 seconds).

5. Test Parameters

During Phase I the performance of the Electronic Water Purifier was evaluated under various influent characteristics. Influent characteristics are listed in table 1.

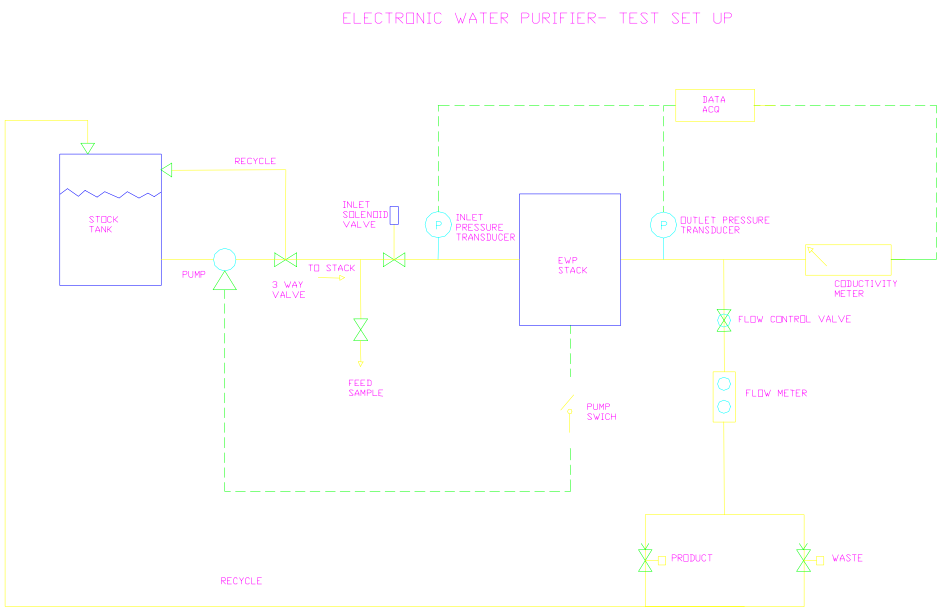
Table 1: Influent Water Characteristics on Day 1 & Day 8 (Lab book 238)

Feed Type	~500 ppm NaCl		~9 gpg iron free hard water		~17 gpg iron free hard water		
Sample Type	Day 1	Day 8	Day 1	Day 8	Day 1	Day 8	
Parameters							Maximum Detection Limit (MDL)
Turbidity (NTU)	0.2	0.1	0.1	0.1	0.1	0.1	
Hardness as $CaCO_3$ (gpg)	0.6	0.1	8.7	5.3	16.8	15.2	
Conductivity (μs/cm)	991	952	458	425	723	680	
Color	0.4	0.0	0.5	1.0	0.6	0.0	
pH	6.1	6.1	8.1	8.1	8.2	8.1	
*Estimated TDS (ppm)	486	466	307	285	492	462	
Cations	**mg/L**						
Calcium	1.6	0.3	43.9	20.2	81.1	68.5	< 0.1
Magnesium	1.6	0.1	9.5	9.8	20.6	21.6	< 0.1
Sodium	178	173	26.6	39.8	35.2	35.7	< 0.1
Potassium	ND	ND	5.9	5.9	12.4	12.5	< 0.1
Strontium	ND	ND	2.92	0.83	5.01	3.80	< 0.05
Barium	ND	ND	0.01	ND	0.02	0.01	< 0.01
Iron	ND	ND	ND	ND	ND	ND	< 0.05
Manganese	ND	ND	ND	ND	ND	ND	< 0.02
Copper	ND	ND	0.006	0.010	0.012	0.011	< 0.003
Zinc	0.11	ND	ND	0.19	0.33	0.27	< 0.05
Anions	**mg/L**						
Chloride	296	289	20.6	56.7	26.8	31.4	< 0.5
Nitrate/Nitrite	ND	ND	0.3	0.2	ND	ND	< 0.5
Sulfate	4	ND	64	21	109	107	< 3
Bicarbonate	0	0	127.8	91.5	237	206.8	
Carbonate	ND	ND	ND	ND	ND	ND	
Fluoride	ND	ND	0.6	0.5	1.3	1.2	< 0.5
Silica	0.21	0.03	4.3	4.31	7.5	7.63	

Flow Rate: ~1 gpm
Influent Dynamic Pressure: 45±5 psig

6. **Test Set-up & Procedure**

Figure 2: Test Set-up



During phase I a stock tank provided the prepared influent water to the stack. The product and waste from the EWP were combined and recycled back into the stock tank. A small diaphragm pump was used to maintain an inlet dynamic pressure of 40-50 psig and a flowrate of ~1 gpm through the stack. A switch on the EWP, controlled the power to the pump during specific flow cycles. Three trials (each with a duration of 8 days) were performed with varying influent conditions (See Table 1). During each of the trials flow rate and dynamic pressure were maintained at ~1 gpm & ~40-50 psig respectively. A Labview National Instruments data acquisition system was utilized to record pressure (via pressure transducers), voltage and outlet conductivity. Influent samples were collected intially (day 1) and at the end (day 8) of each trial.

7. **Results & Discussion**

- Performance on ~472 ppm NaCl

  The unit was initially put to tested on ~472 ppm NaCl solution at 3.7 Lpm and ~40-45 psig dynamic pressure. The average removal rate in this test was ~ 97%. The pressure drop was ~24-29 psig and the % recovery was ~70%. These values remained stable throughout the 8-day test period. Figures 3 and 4 compares the operation of the EWP on day 0 and day 8.

Figure 3: Effluent conductivity & % removal on day 0 with 486 ppm NaCl stock feedwater

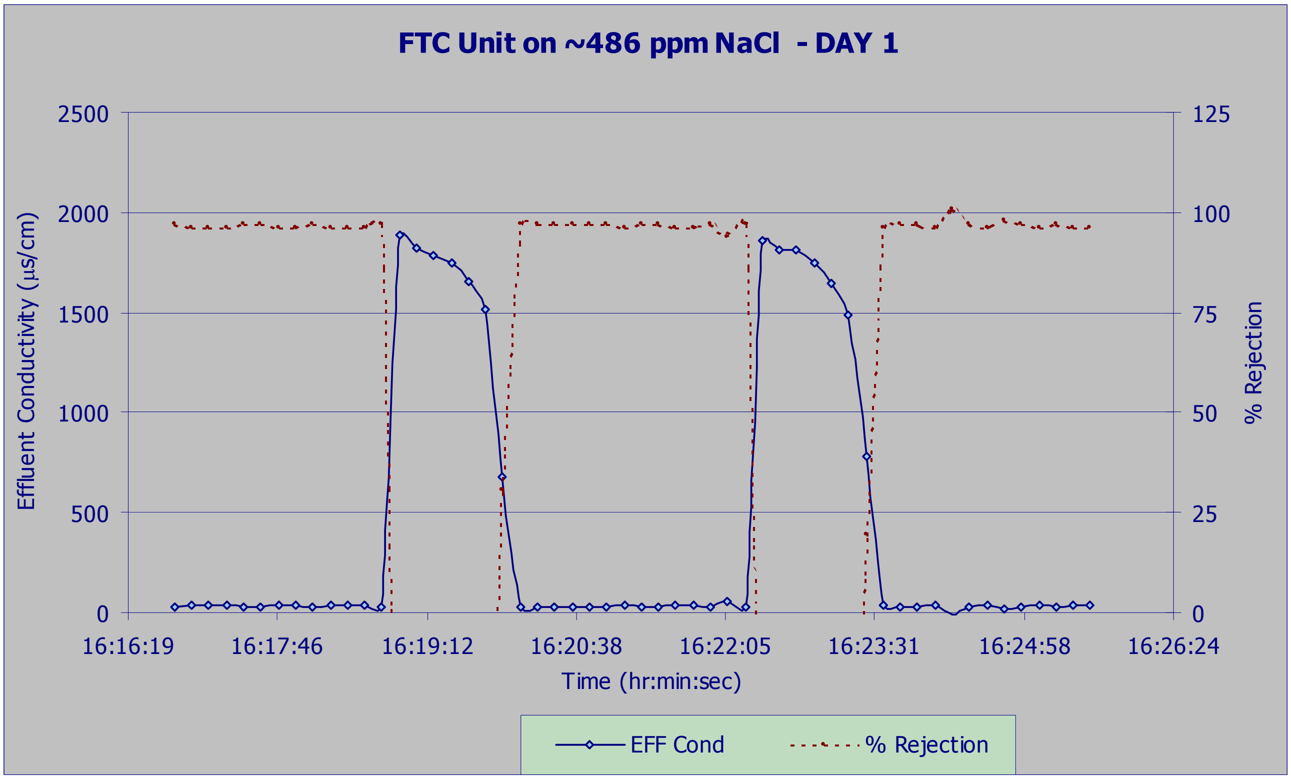
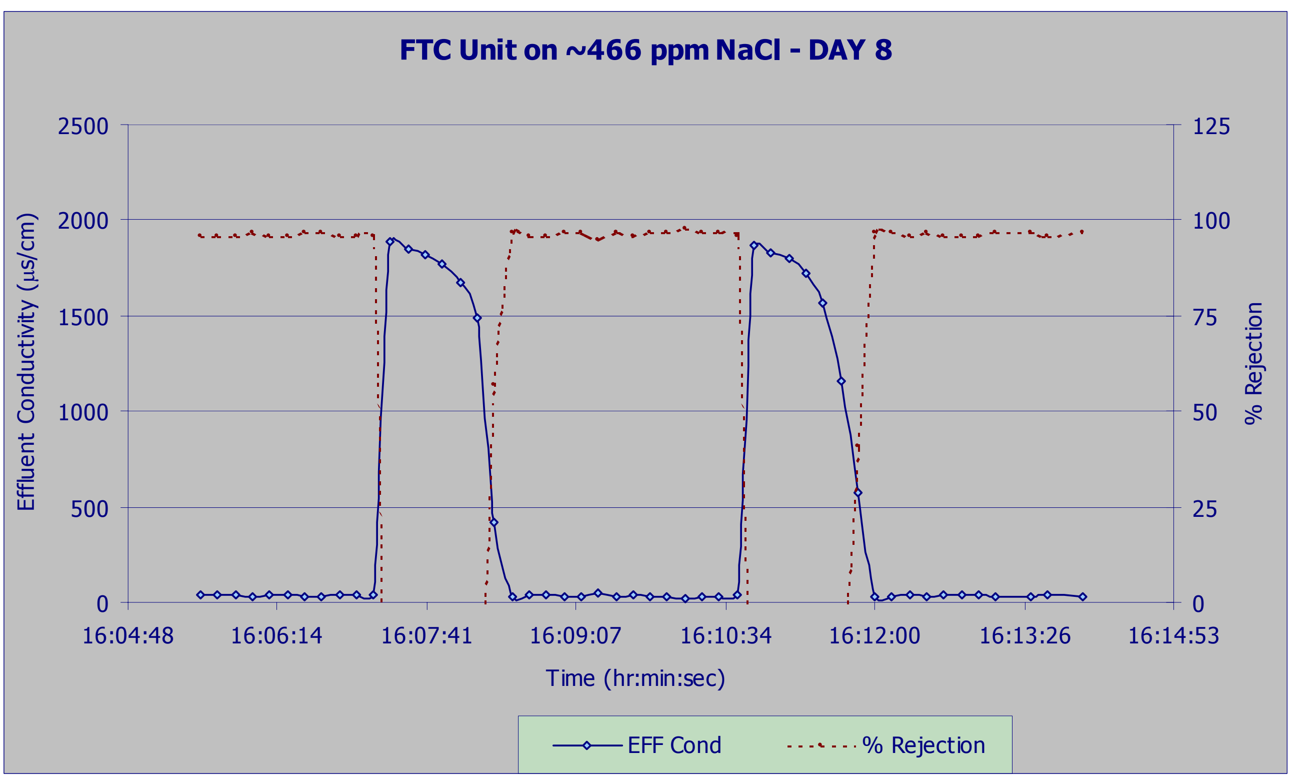


Figure 4: Effluent conductivity & % Removal on Day 8 with 466 ppm NaCl stock feedwater



- Performance on ~9gpg (TDS = 296 ppm) Hard Water

  Next the unit was tested test on ~9 gpg (TDS = 296 ppm) hard water at 3.7 Lpm and ~40-45 psig dynamic pressure. The average removal rate in this test was ~ 92-95%. The pressure drop was ~24-29 psig and % recovery was ~60%. These values remained stable throughout the 8-day test period. Figures 5 and 6 compares the operation of the EWP on day 0 and day 8. However influent water analysis (See Table 1) show a loss of of 23.7 ppm Calcium and 2.08 ppm of Strontium from the stock tank during the 8 days of testing. Water analysis results also show a loss of anions (SO_4 = 43 ppm; HCO_4 = 2 ppm) from the stock tank. This indicates potential scaling in the EWP cell.

Figure 5: Effluent conductivity & % Removal on Day 0 with 9 gpg iron free hard water

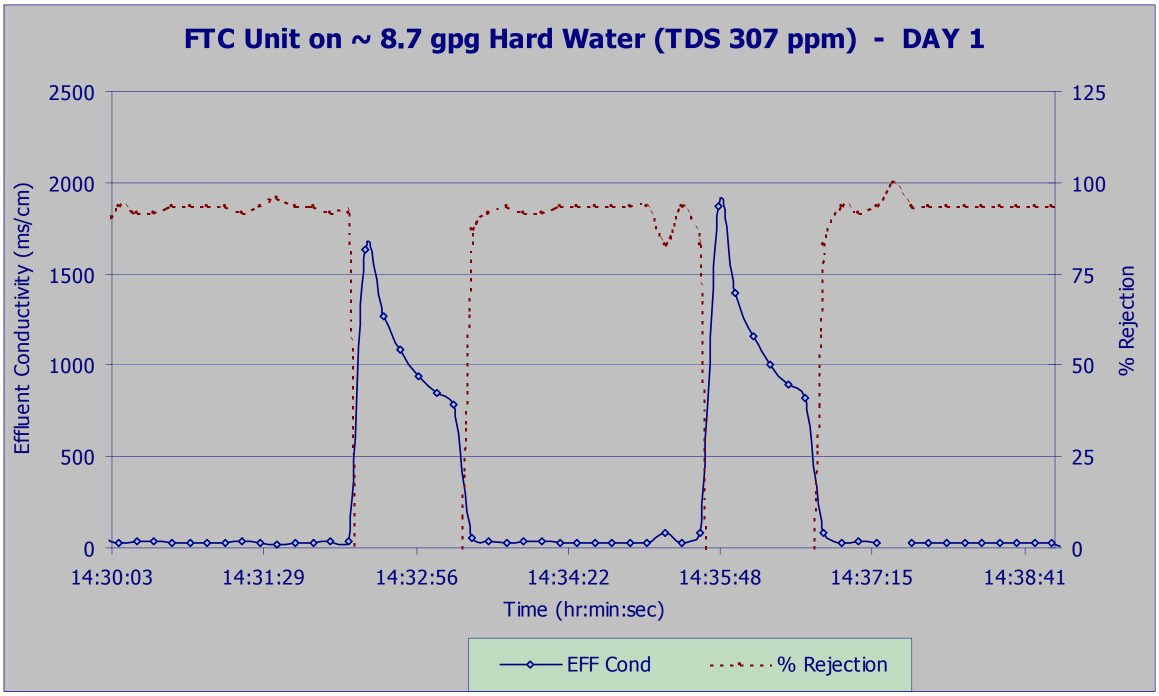
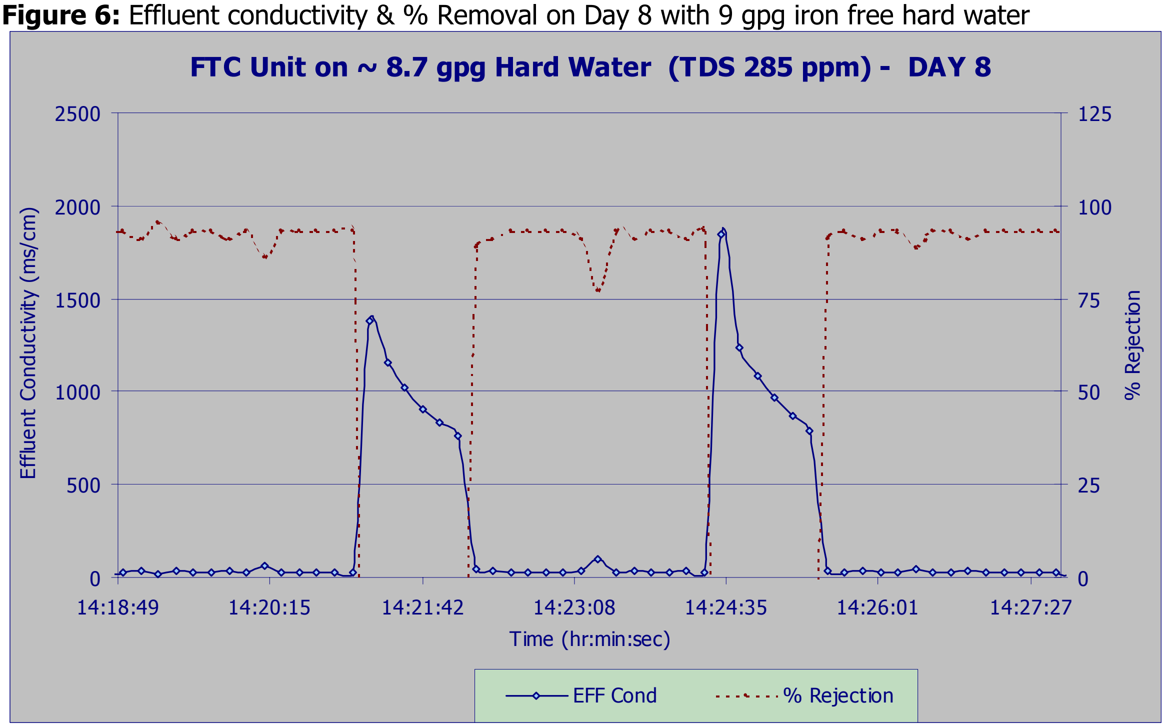


Figure 6: Effluent conductivity & % Removal on Day 8 with 9 gpg iron free hard water



- Performance on ~18gpg (TDS = 477 ppm) Hard Water

Finally, the unit was tested on ~18 gpg (TDS = 477 ppm) hard water at 3.7 Lpm and ~40-45 psig dynamic pressure. The average removal rate in this test was ~ 95%. The pressure drop was ~24-29 psig and % recovery was ~70%. These values remained stable throughout the 8-day test period. Figures 7 and 8 compares the operation of the EWP on day 0 and day 8. This indicates potential scaling in the EWP cell.

Figure 7: Effluent conductivity & % Removal on Day 0 with 18 gpg iron free hard water

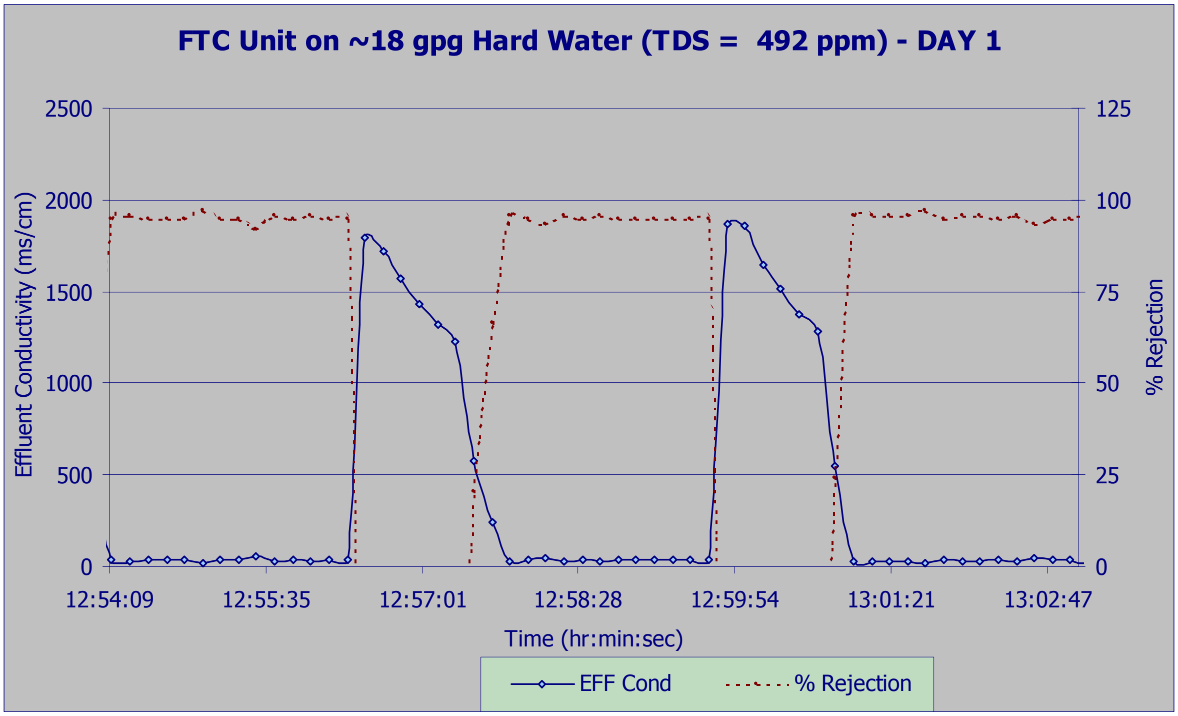
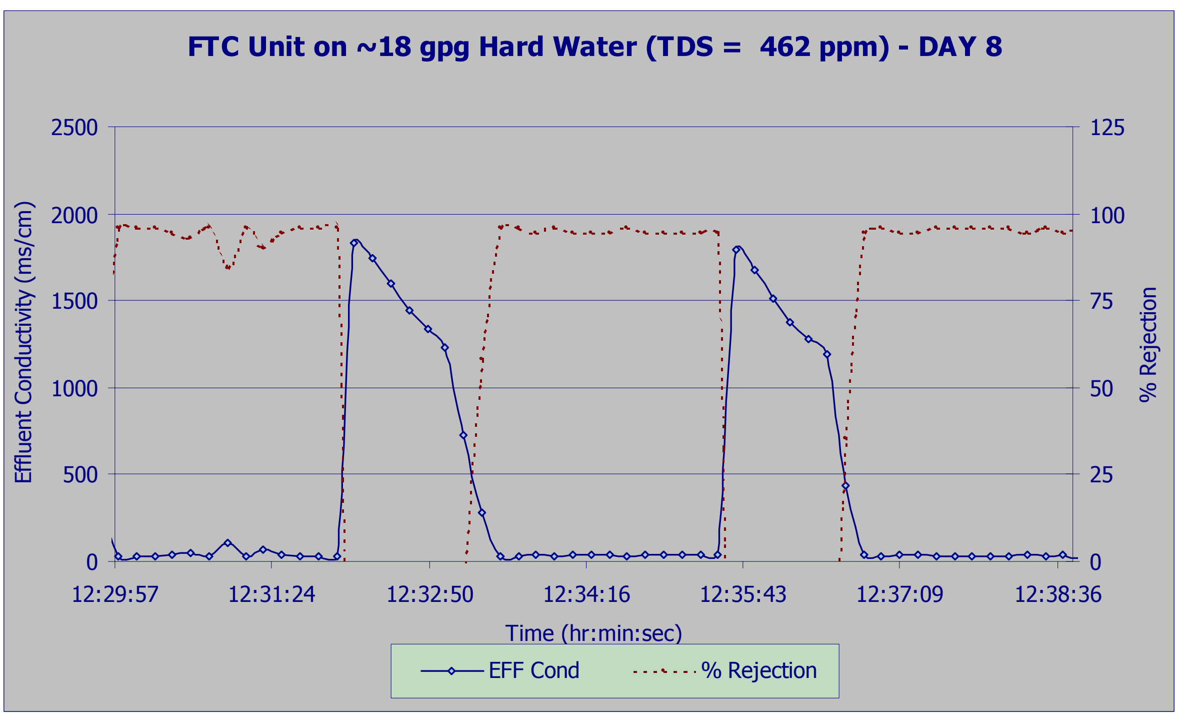


Figure 8: Effluent conductivity & % Removal on Day 8 with 18 gpg iron free hard water



Influent water analysis (See Table 1) shows a net loss of 12.6 ppm Calcium and 1.21 ppm Strontium, during this trial. Hence approximately 16% Ca and 24% Strontium were lost from the stock tank during 8 days of testing. Similarly, an analysis of the anions show a net loss of 36.3 ppm SO_4 (28%) and 30.2 ppm (13%) HCO_3. Interestingly, the stack shows a preference for Ca and Sr ions over Mg, Na, Ba & K. Similarly, SO_4 and HCO_3 are preferred over Cl, NO_2/NO_3 and Fl. Figure 9 shows the total ions adsorbed and discharged during a cycle and % removal during 8 days of testing.
Testing in February 2002, also showed losses. However the level was much higher during the trial in 2002. Percent removal was also lower in the previous trial. Figure 10 shows the total ions removed and discharged during a cycle and % removal during the trial in February 2002. The cycles shown in this trial are during the 1st day of the test.

Figure 9: Ions removed and discharged – on 18 gpg hard water; Also shown % removal (January '03)

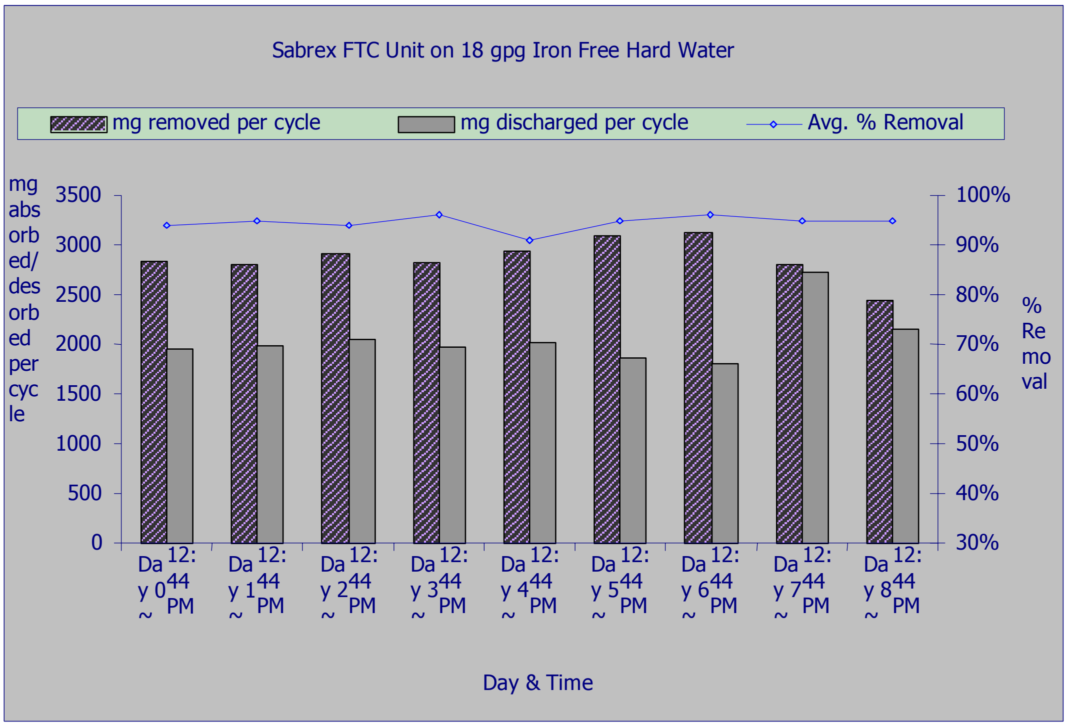
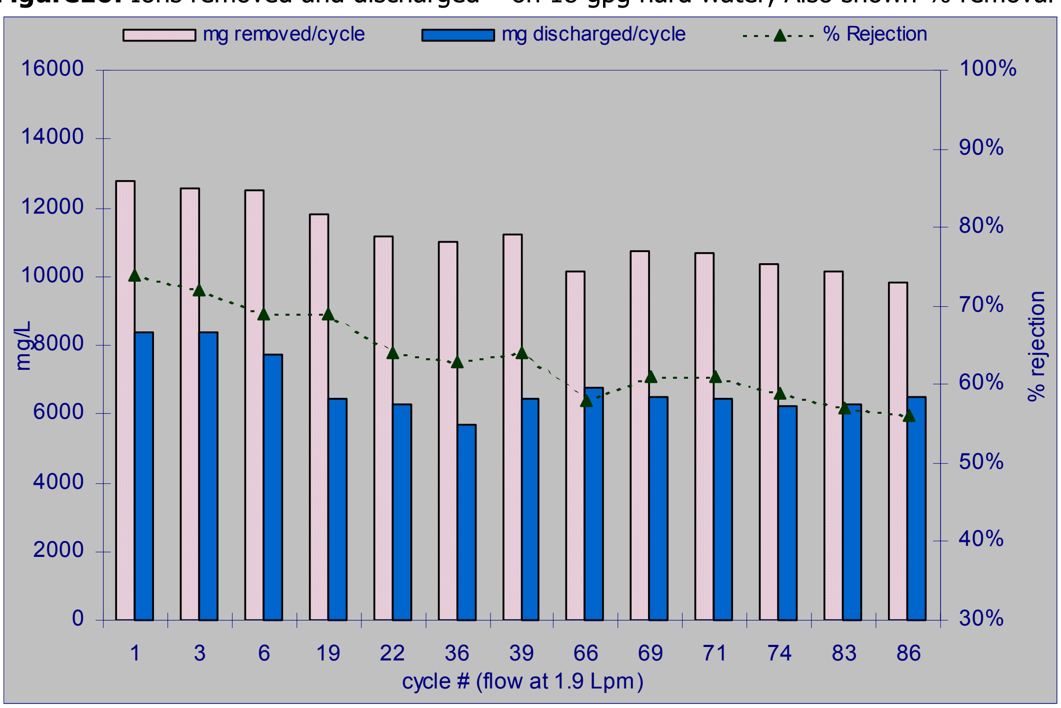


Figure10: Ions removed and discharged – on 18 gpg hard water; Also shown % removal (February '02)



8. Conclusions & Recommendations

- The testing validates the product parameters discussed in section 3.
  1) % removal (rejection) ~92-98%
  2) recovery rate ~60%
  3) flow rate ~ 1 gpm
  4) maximum conductivity level in the influent – 1000 ppm
  5) pH range 4-9
  6) pressure drop 25-28 psig

  These values remained unchanged throughout the test period in each of the three trials. Hence the current EWP unit is a significant improvement over the unit tested in February 2002. The % recovery of the unit is fixed on the current unit. The recovery rate of the EWP is relatively low when compared to that of a conventional softener (~95-99%). The low recovery rate may present a challenge when marketing the product. The recovery rate may be improved by, increasing the feed rate and therefore decreasing the quality of the of the product water. Further testing is recommended to improve the recovery rate.

- Testing showed preferential removal of Ca, Sr, SO_4 and HCO_3 by the stack. However no significant change in the test parameters were observed. Long term testing needs to be conducted to determine the extent of suspected scaling on the unit. Scaling may be avoided if the stack is cleaned after a set period of time. Phase II testing will determine the scaling potential of the EWP unit. During phase II the unit will be directly plumbed into the Culligan well water line. The set-up represents difficult influent conditions.

- Current testing did not determine the current efficiency of the unit. Current efficiency can be determined in the next phase.

- The EWP offers a new method for deionization of water. Unlike conventional softeners it does not require chemicals for regeneration. The recovery rate of the unit is relatively high (~70%) when compared to that of a conventional household reverse osmosis unit (~30%). Based on the influent water quality the operating parameters of the device may be adjusted to produce a preferred product water quality. That is, the final TDS of the product water can be adjusted by altering the operational parameters. This flexibility offers significant benefits to the consumer.

- Current testing has produced favorable results. However further testing needs to be conducted and man-hours need to be allotted to develop this technology into a viable product.