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Operation of Hydranautics New ESNA Membrane at St. Lucie West, FL Softening Plant

Introduction

St. Lucie West, Florida Service Distrcit employed the first large scale reverse osmosis (RO) softening plant in the United States to remove high levels of hardness, color, iron, and trihalomethane (THM) precursors from its well water. The plant was originally designed and built by Hydranautics for a permeate capacity of 1 mgd, and operation commenced in April 1988. Initially, the plant utilized Hydranautics PVD1 softening membrane elements, which operated for 8 years without requiring any cleaning. In September 1996, the new ESNA softening membrane elements, introduced by Hydranautics in April 1996, replaced the existing PVD1 membrane elements. This paper will describe the advantages the installation of Hydranautics new ESNA membrane technology has brought to the St. Lucie West Services District in terms of reduced operating costs, superior removal of both inorganic and organic ions, and reliable, stable operation.

Background

Feedwater to the RO plant is pumped from shallow wells (approximately 70 ft deep), which are characterized by high levels of hardness, organics, THM precursors, color, and soluble iron (see table I). Due to the need to reduce the high levels of these constituents and the fact that the raw water is characterized by low salinity, membrane softening was chosen as the process of choice. Hydranautics PVD1 membrane elements are characterized by a very high specific flux (0.24 gfd/psi) which enables operation at a low feed pressure. Combined with a nominal sodium chloride rejection of 80% and a relatively high rejection to hardness and THM precursors, the PVD1 membrane was ideal for this process. Being a fairly clean well water source, pretreatment to the RO plant consisted of sulfuric acid injection to control $CaCO_3$ scale potential, and five micron cartridge filtration.

Table 1: Feedwater Quality and Comparison of Permeate Quality for ESNA and PVD1 Membranes

Constituent	Feed	ESNA Permeate	Acid Feed	PVD1 Permeate*
Ca (ppm)	107	4.7	90	35
Mg (ppm)	6	0.31	7	2.4
Na (ppm)	49.3	11.6	60	34.2
Fe (ppm)	2.6	0.05	3	<0.3
Alkalinity (ppm)	290	25	1.1	1.3
Cl (ppm)	80	12.6	65	78
SO_4 (ppm)	30	0.8	250	5.3
Silica (ppm)	23.4	2.9	23	21.4
TDS (ppm)	588	58.0	501	180
THM Potential (µg/l)	80 - 120	13.6	80-120	9.9
Feed Pressure (psi)	80		80	
Feed pH for each system	7.15		4.0	

* projected for start-up at pH 4

The soluble iron concentration in the raw water ranges from 2 - 4 ppm and potable water limits call for iron levels below 0.3 ppm. The PVD1 membrane, initially exhibited higher passage to iron. It was later learned that iron passage of the PVD1 membranes was a direct function of the sulfate ion concentration. The conversion of alkalinity to sulfate resulted in an increase of iron rejection in the feedwater. Therefore, the feedwater was acidified with sulfuric acid to increase the sulfate ion concentration so that the permeate iron concentration would fall within the allowable potable water standards. To achieve this level, the RO plant required the injection of more than 1500 lb/day of sulfuric acid, which amounted to an excess of $45,000 dollars per year; the addition also reduced the feedwater to a pH of 4. Due to the low permeate and concentrate pH, caustic soda (NaOH) injection was necessary to elevate the pH level to a neutral state. The amount of caustic soda used for both permeate and concentrate was in excess of 1000 lb/day, which amounted to over $80,000 dollars per year.

Membrane Replacement

In May 1996, 8 years after the PVD1 membranes were first installed, St. Lucie West Water District circulated a bid proposal for membrane replacement. The bid was based on a total evaluated cost of the plant s operation. Three membrane manufacturers, Fluid Systems, Filmtec, and Hydranautics, submitted their bids through OEM s. Hydranautics successfully won the bid by demonstrating to have the lowest total operating cost. The advantages and savings that the ESNA membrane provided with respect to the original design and compared to other membrane manufacturers were overwhelming (see Table II for comparison of previous and current plant operating costs). The ESNA design resulted in a substantial reduction in the feed operating pressures; moreover, unlike the bids submitted by competitors, the need for acid addition was eliminated, thus reducing demand for caustic soda and calcium chloride. Even with the decrease in feed pressure, the permeate flow was increased approximately 15%, with only a 5% addition in membrane area.

Table 2 : Chemical Cost Breakdown for ESNA and PVD1

Cost Component (per 1 MG)	ESNA	PVD1

Acid	0	$132.26
Caustic Soda	$0.095	$234.92
Calcium Chloride	$123.95	$104.30
Antiscalant	$39.00	0
Total Chemical Cost per MG	$163.05	$471.48

The Advantages Using ESNA

The ESNA membrane is a new ultra-low pressure softening membrane that is characterized by a higher specific flux and higher rejection than the PVD1 membrane. The ESNA membrane is rated at a specific flux of 0.30 gfd/psi which enables the operation at almost 50% of the Net Driving Pressure (NDP) of the PVD1. This translates to significant cost savings with respect to energy consumption and installation cost. Also, the overall sodium chloride rejection of the ESNA has been improved to 90%, as compared to 80% nominal with the PVD1, which provides an overall better permeate quality.

In St. Lucie West, the ESNA membranes currently produce an overall permeate quality that is 68% (from table I) lower as compared to the operation with the PVD1 membrane. Table I outlines actual permeate quality parameters of both the PVD1 and ESNA membranes in the St. Lucie West Plant. The ESNA membrane is also used for the removal of low molecular weight organics, viruses and bacteria. In the St. Lucie West plant, there is a high concentration of TOC, color and THM precursors. The ESNA, like the PVD1, has provided excellent rejection to these constituents. Overall, the rejection of the ESNA membrane for TOC and THM precursors is better than expected. Since the District is required to comply with potable water quality guidelines, the fact the ESNA exhibited superior field performance was a definite attribute.

Process Description

The softening plant, as it is designed today, utilizes (252) 8540-UHY-ESNA membrane elements arranged in a 24:12 array using 7 element long pressure vessels. (See figure 3 for a flow diagram). The plant operates at 85% recovery with a rated permeate flow of 694 gpm and a design flux rate of 8.9 gfd. The 8540-UHY-ESNA membrane elements are rated for a permeate flow rate of 9000 gpd at 75 psi of feed pressure. Due to the increased membrane area (445 ft^2 with the ESNA, as compared to 425 ft^2 with the PVD1), the overall flux rate of the system was reduced by 5%. In addition, Hydranautics provided the St. Lucie West Water District with the option to increase the overall permeate flow rate by 15% to 800 gpm. So far, the District has not taken advantage of this option due to permitting considerations, but the option remains a viable one.

INSERT: Drawing

Pretreatment to the plant consist of antiscalant injection (to compensate for the acid removal) and one micron cartridge filtration. The need for acid addition, as described earlier, was eliminated. Permeate from the trains is discharged into a degasifier for hydrogen sulfide (H_2S) removal and carbon dioxide (CO_2) stripping. The pH is then adjusted by caustic addition to a pH of 9.0, while total hardness is brought up to the desired level by adding calcium chloride. The concentrate pH is also increased with the addition of caustic soda to a pH of 8.0, and then combined into the irrigation distribution system. St. Lucie West can be viewed as a zero discharge plant because both the permeate and concentrate are consumed for a specific purpose.

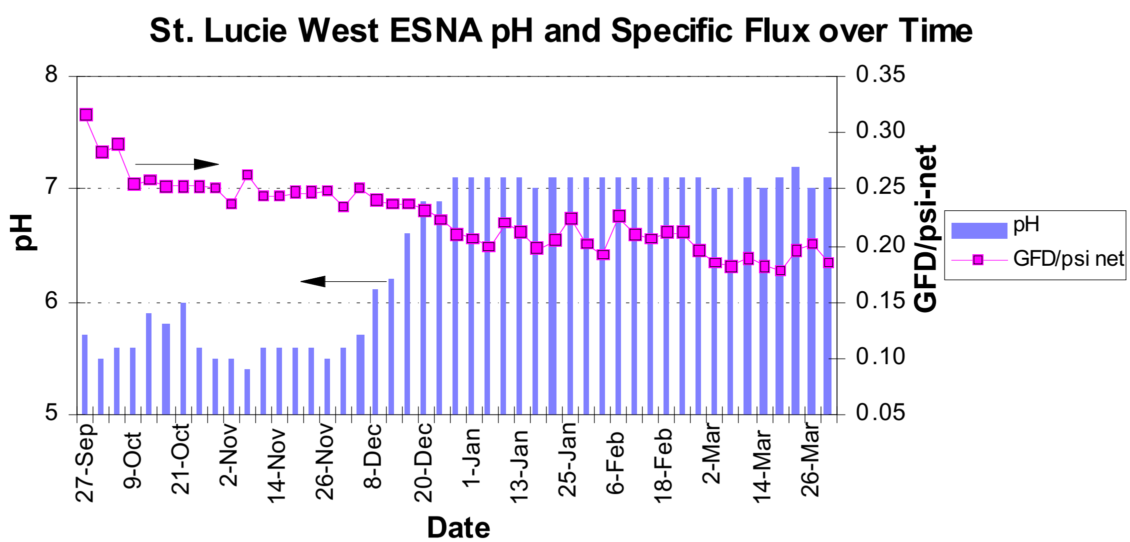
Operating Conditions

The plant with the ESNA membranes commenced operation on September 27, 1996. The feed pressure and salt passage at start-up were both as projected. The initial specific flux rate was 0.30 gfd/psi and salt passage was approximately 6%. Initially, a conservative approach was chosen, and the decision was made to acidify to a pH of 5.8 before gradually adding scale inhibitor and reducing acid concentration. The decision was based on the need to verify that the scale inhibitor would indeed work at elevated feed iron levels. Addition of acid to this pH will control $CaCO_3$ and/or $FeCO_3$ scaling while a gradual replacement of the acid with an organic scale inhibitor takes place.

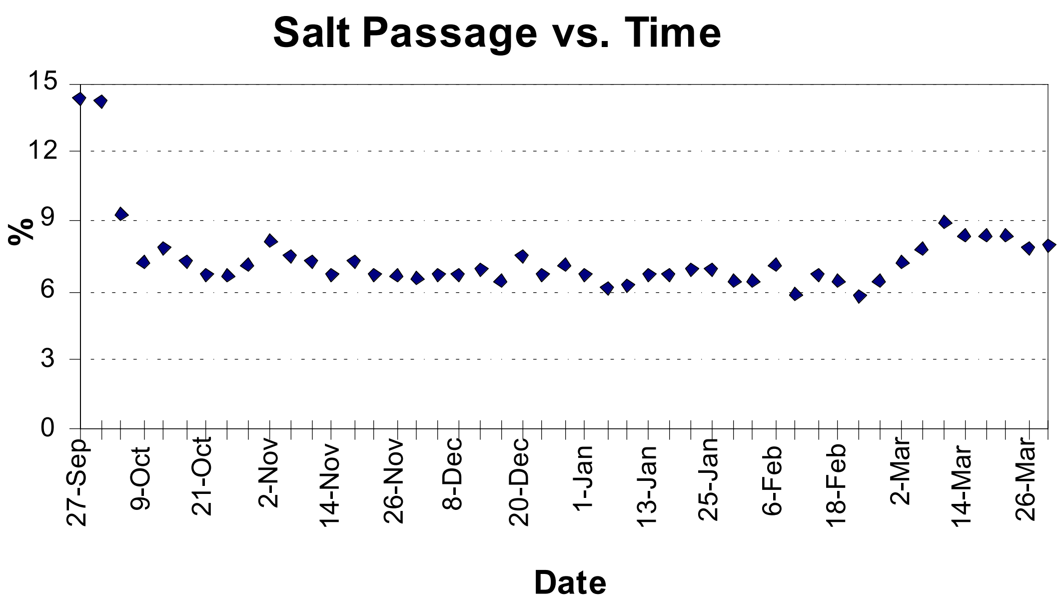
Using the new ESNA membranes, the plant began operation with only 1350 lb/day of acid addition (to pH 5.8) as opposed the previous acid addition of greater than 1500 lb/day (pH 4.0) using the PVD1 membranes. During January 1997, acid addition was removed completely, subsequently increasing the feed water pH from 5.8 to 7.1. Antiscalant addition was set at a rate of 2.0 ppm.

Operational Analysis

The St. Lucie West plant provides an interesting case study for the effects and dependence of membrane flux and rejection on pH and antiscalants in highly fouling feed waters containing a large concentration of organic constituents. The feedwater to the St. Lucie West RO plant contains excessive levels of TOC (23-30 mg/l), which contributes to high levels of THM precursors and color formation (see table 1). As described previously, the only pretreatment that is currently used is antiscalant addition and one micron cartridge filtration. The high levels of organic constituents have had a direct impact on the flux decline that the ESNA membranes have experienced. Observing Figure 1, we can see a membrane flux decline ten days after start-up and also in January 1997 corresponding to the discontinuation of acid addition and the institution of antiscalant addition. Ten days after start-up, the specific flux of the membranes was reduced to 0.25 gfd/psi, a 15% decline. The flux remained at this level for four months until the beginning of January, when it was reduced to 0.20 gfd/psi, an additional 20% decline. Since January 1997, the flux rate of the membrane elements has remained constant.



In addition, the salt passage has remained constant since the start-up in September 1996 (see Figure 2). The salt passage of individual ions and overall conductivity was lower than the projected performance based on nominal values of the ESNA membrane. From the operating data, it is apparent that a certain degree of fouling has occurred on the membrane surface, therefore forming a thicker layer on the membrane surface subsequently reducing the membrane flux.



To try and evaluate the reason for the flux decline, one has to examine all the possible contributing factors. One hypothesis is the dependence of the membrane performance on the pH value under these conditions. From Figure 1 one can see that there is a certain relationship between increasing the pH level and the flux reduction. The pH level, to a certain degree, could have slightly affected either the charge on the membrane surface or the dissociation rate of the organic constituents. This could have caused the organic constituents to have a higher affinity to the membrane surface, therefore increasing the barrier layer and subsequently reducing the flux.

Another possibility is the effect of the antiscalant on the membrane surface. The antiscalant, combined with the high organic levels, could have changed the morphology of the membrane surface, therefore causing it to be more prone to the adherence of organic matter. The data supports the theory of membrane flux decline due to high concentration of organic constituents, however it is unknown whether these factors alone or as a combination could be attributed to the membrane flux decrease. Also, the City of St.

Lucie has yet to perform a membrane cleaning, which in fact could restore, to a certain degree, the initial performance. Therefore, is has yet to be confirmed whether this condition is reversible or not. Further study is required to reach a definite conclusion.

Plant Cost Savings

Currently, both the flux rate and salt passage have remained stable at a level of 0.20 gfd/psi and 6%, respectively. Even though an overall flux decline was experienced, the cost savings with respect to feed pressure and chemical addition previously required were significant. Using the PVD1 membrane elements, the feed pressure required was 105 psi and in excess of 3100 pounds of various pretreatment and post-treatment chemicals were used per day. The total chemical operating cost with the PVD1 was approximately $500 per day. Using the ESNA membrane the City of St. Lucie West has been able to remove sulfuric acid addition, reduce caustic soda consumption by more than 92%, and reduce calcium chloride addition to 575 lb/day as opposed to 685 lb/day. Overall, the District has realized more than 65% reduction in the operating costs, which amounts to a savings in excess of $110,000 per year. Evaluating the savings with respect to the initial element purchase price and membrane life, the pay back would be less than 2 years. In other words, by changing over to the ESNA membrane elements, the St. Lucie West Service District will recover its initial membrane purchase price after less than two years of operation. Assuming the ESNA membranes will last approximately 8 years at the projected operating conditions, the District will save an excess of $600,000 dollars over the life of the installed membrane elements (90% plant factor and an element price of $695.00 was used in monetary calculations).

Summary

St. Lucie West, FL is the first large scale membrane softening plant that is successfully utilizing Hydranautics ESNA membrane elements since its introduction to the market place in April 1995. The recent evolution of composite membranes in the last couple of years has brought forth a new generation of low and ultra-low pressure membranes that are characterized by a high specific flux and comparable rejection characteristics to existing composite membranes. Membrane manufacturers have contributed greatly to reducing installation and operating costs of RO systems by developing a new generation of low pressure membranes. Combined with its high specific flux and the excellent rejection characteristics, specifically to hardness, TOC, color, iron and THM precursors, the ESNA membrane has produced both potable water quality within the required guidelines, as well as immense monetary savings with respect to lowering the overall operating cost of the St Lucie West softening plant. The major advantages the St. Lucie, West plant has realized in using the ESNA membrane are the complete removal of sulfuric acid as a form of pretreatment, over 93% reduction in caustic soda consumption, more than 15% reduction in calcium chloride consumption and 13% drop in plant energy consumption. St. Lucie West softening plant is a typical representation of other softening plants, with similar feed water characteristics, that exist primarily in the Southeastern part of the United States. Most of the Floridian acquifers contain high level of organics, color and THM precursors, and are characterized with very low salinity. Membrane softening has already become the process of choice for many of these current installations. However, now, using the new membrane technology, end-users will reap the benefits of substantially lower installation and operating costs.

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