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Membrane replacement in desalting facilities

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Abstract

As membrane facilities increase in number and age, the need for membrane replacement has continued to be required. Membrane replacement requires careful planning, and should involve computer modeling, membrane probing, membrane profiling and hydraulic evaluations to document modifications in plant performance. Although many existing plants have undergone membrane replacement, little information has been published in the literature on this component of membrane plant operation. The purpose of this paper is to present an overview of membrane replacement, and describe two case studies to document membrane replacement. One case study describes membrane replacement at a hollow fiber membrane facility (Sarasota, Florida), and a second case study describes membrane replacement at a spiral-wound membrane facility (Marco Island, Florida).

Keywords: Reverse osmosis; Treatment plant; Operations

1. Case studies: background and overview

This paper presents the results and findings of two different water utilities that had recently undergone membrane replacement at their reverse osmosis water treatment plants (ROWTPs). The first case study describes membrane replacement activities at a hollow-fiber membrane facility owned and operated by the City of Sarasota, Florida. The second case study summarizes membrane replacement activities at a spiral-wound membrane facility owned and operated by Florida Water Services Corporation (Florida Water) at Marco Island, Florida. This section provides an overview of each of the two facilities.

1.1. The City of Sarasota ROWTP

The City of Sarasota Water Treatment Facility is comprised of two major water treatment plants: a ROWTP component and an ion exchange (IX) component. The 12 million-gal/d (mgd) capacity WTF results from a combination of 4.5 mgd from the ROWTP and 7.5 mgd from an ion-exchange plant, of which 2.3 mgd is a blended bypass water. The City's ROWTP system is supplied by a network of

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eight brackish wells, averaging approximately 2250 mg/L total dissolved solids content. The historical operating pressure of the membrane process has been approximately 390 psi. The ROWTP was placed on-line in 1982 and was originally configured using DuPont® B-9™ polyaramid hollow fiber membrane assemblies. The City's reverse osmosis system is composed of three separate sections or trains (numbered A through C). Each train is designed to produce 1.5 mgd of permeate from 2.0 mgd of raw water at a recovery of 75% and a total plant capacity of 4.5 mgd. All trains have the capability of operating independently from the others, and each train is composed of two stages. Originally, the three process trains were comprised of 10-inch diameter DuPont® B-9™ membranes, where 54 membrane bundles comprised the first stage, and 21 membrane bundles comprised the second stage. The primary objective of the most recent membrane replacement program was to enhance process performance using DuPont's® newest double-cartridge hollow-fiber technology for one of the City's three process trains.

1.2. The Marco Island ROWTP

Florida Water is the largest investor-owned private utility in Florida, and owns and operates a 6 mgd ROWTP that treats 10,500 mg/L brackish ground water, and a 6.67 mgd lime-softening WTP that treats surface water on Marco Island. Marco Island is a popular tourist resort having variable population changes, and is located off the southwest coast of Florida near Naples just west of the Everglades. The original membrane process arrays in trains 1–4 were designed as a 24 : 12 (first pass : second pass) system, with each pressure vessel (PV) containing six 8-inch diameter, 40-inch long membrane elements. Each of the process trains provide 1.0 mgd permeate capacity for a total of 4 mgd. The first two elements in each vessel are FilmTec® SW30-8040's and the remaining four elements are FilmTec® BW30-8040's. The second stage of each train contained 72 FilmTec® BW30-8040 brackish water membrane elements in 12 PVs. The original trains provided a total of 72,000 ft^2 of membrane surface area, and provided a water flux of 13.9 gal/ft^2/d (gsfd). Additional information about the original Marco Island ROWTP and its recent retrofit expansions can be found elsewhere in the literature [1,2].

The ROWTP was recently expanded from 4–6 mgd, with the recently installed membrane skids 5 and 6 designed as a 22 : 12 (first pass : second pass) system. The 1.0 MGD permeate capacity membrane skid contained 132 Fluid Systems thin-film composite (TFC) 8822XR high-rejection brackish membrane elements in 22 PVs in the first stage, and 72 Fluid Systems TFC 8822HR brackish membrane elements in 12 PVs in the second stage. Trains 5 and 6 were designed to provide 67,320 ft^2 of membrane surface area and to produce a water flux (F_w) of 14.8 gsfd. The primary objective of the most recent membrane replacement program at Marco Island was to enhance train 1 process performance using Fluid Systems TFC membranes.

2. Hollow-fiber membrane replacement case study: City of Sarasota

In August 1997, the City initiated studies into membrane fouling and reduced performance of its ROWTP operation. Investigations performed by the City and Boyle resulted in a change in scale inhibitor from polyacrylate-based scale inhibitor to sodium hexametaphosphate, which was found to have improved performance [3,4]. In addition, based on work implemented by DuPont®, the City successfully implemented sodium hypochlorite cleaning (pH 12) to rectify the declining preformance of the new permeators [5]. Train A continued to rely on standard DuPont® B-9™ permeators (Bahrainian version) that had been installed in 1995.

Table 1
DuPont® Hollow-Fiber Double-Cartridge™ technology information

Membrane type	HF technology
Membrane model	BW-L-8540, (double)
Nominal membrane area, ft^2/cartridge	4,475
Nominal permeate flow, gpm/cartridge	13
Minimum concentrate flow, gpm	3
Design feed pressure, psi	100–400
Maximum feed SDI, units	5
Design recovery, %/cartridge	75

Table 2
Summary of permeate water quality before and after replacement

Parameter	Before retrofit membrane replacement	After train A was replaced with Double Cartridges™
Sulfate, mg/L	44	3
TDS, mg/L	450	77
Chloride, mg/L	60	15
Conductivity, μmohs	400–600	150

However, in late 1997, DuPont® announced their new product line of low-pressure 8-inch diameter Cartridges™ [6]. The cartridges are available in double and triple internal staging configurations. As a result, the City initiated an investigation of DuPont's® newest, ultra-low pressure double cartridge configuration that included a side-by-side comparison to the latest spiral-wound and hollow-fiber technologies available in the marketplace [7].

In July 1999, based on the results of the double cartridge evaluation, train A was re-membraned from a 10-inch B-9™ configuration to an 8-inch Double Cartridge™ configuration. Train A had to be retrofitted slightly to make this change possible. The City successfully implemented the required changes to the process train skid assembly to make train A ready for replacement (rework stainless steel piping, recondition connection ports, other miscellaneous skid valve alterations). Table 1 provides data related to the Double Cartridge™ technology.

2.1. Water quality comparison

Table 2 provides a summary of some of the water quality prior to and after membrane replacement for sulfate, total dissolved solids (TDS), chloride and conductivity. The information clearly indicates an improvement in water quality after retrofit membrane replacement had been implemented.

2.2. Hollow-fiber performance results

Train A data represents the results of membrane replacement using the Double Cartridge™ hollow-fiber configuration. Presently, train A operates with a feed pressure of approximately 150 psi, permeate flow of 940 gpm, and recovery of 66%. Fig. 1 presents the results of changes in feed pressure before and after membrane replacement, which shows that the pressure requirements had decreased from about 400 to 150 psi. The permeate flow increased from 850 gpm to about 940 gpm. Differential pressures, historically a problem with the original configuration, was reduced from 125 psi to less than 25 psi, as shown in Fig. 2. Fig. 2 illustrates how successful the City has been at cleaning the Double Cartridge™ hollow-fiber configuration, as indicated by the decrease in differential pressure from 50 to about 15 psi after 4700 h of operation.

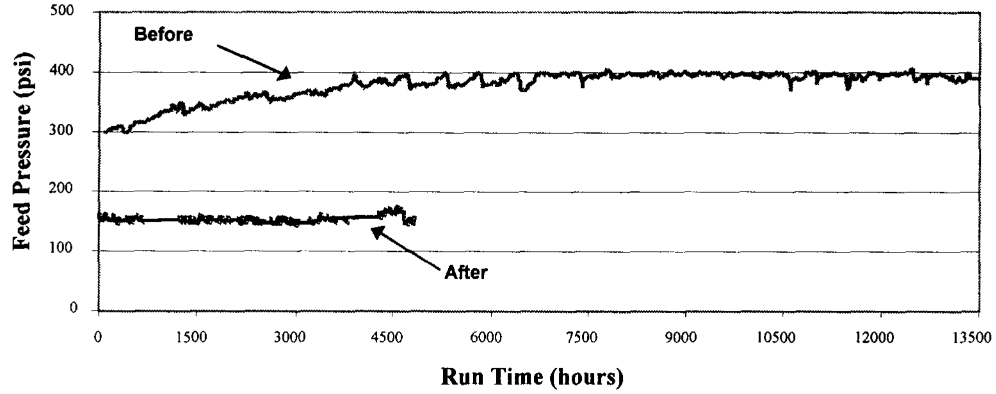

Fig. 1. Process train A feed pressure vs. run time.

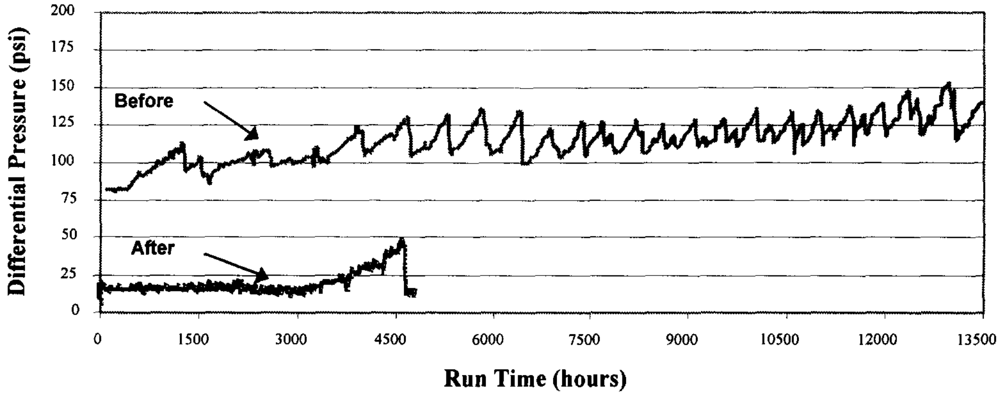

Fig. 2. Process train A differential pressure vs. run time.

3. Spiral wound membrane replacement case study: Marco Island

Based upon evaluation of current ROWTP operating performance and previous "probing" testing, train 1 was scheduled for membrane replacement in August 1999. Overall plant performance of train 1 indicated 34% loss of productivity over 6 years of operation. Computer software packages provided by membrane manufacturers were applied to various treatment scenarios for the ROWTP.

The original membrane trains 1–4 contained a 24:12 array with six elements per pressure vessel. The first two elements of stage one were of seawater construction (Film Tec® Model SW30-80-40). The remaining positions in both stages were loaded with Film Tec® Model BW30-80-40. These membranes in train 1 were replaced with a 22:11 array using Fluid Systems® TFC 8822HR elements in the first two positions of stage one. The remaining positions in both stages were filled with Fluid Systems® TFC 8822XR membrane elements. Membrane inter-connectors, stub-tube adapters and end cap o-rings were also replaced during train 1 membrane replacement. During train 1 membrane replacement, lead elements of the original membranes were noted to have mechanical damage where the outer membrane layers of the elements had unraveled and extended downstream past the remaining layers. This effect is known as telescoping. It may have been caused by surges of high pressure, or higher-than-normal water velocities.

3.1. Spiral-wound performance results

Table 3 presented in the attachment shows that first stage differential pressures averaged approximately 55 psi before the membrane replacement. After membrane replacement on train 1, these pressures were lowered to 14 psi. Table 3 also represents additional information related to membrane replacement at Marco Island, providing comparison data before and after membrane replacement. Membrane productivity was estimated by temperature corrected specific flux (Specific Flux = Flux$_{25^{\circ}c}$/Net Driving Pressure), and the net driving pressure was corrected for osmotic pressure. Historically, train 1 initial productivity level ranged from 0.125–0.100 gsfd/psi at 25°C in 1992 for the first stage of the system. By June 1999, the production level was 0.076 gsfd/psi at 25°C, representing a significant decline in membrane productivity. The production level of train 1 was increased from 0.078–0.086 gfd/psi after membrane replacement. Although the productivity was less than the initial production this was acceptable since an altered configuration and membrane was used. The altered configuration represented a balanced process train design that included interstage turbine control. Additional information on the interstage turbine impacts can be found elsewhere [8].

Table 3
Operating data before and after membrane replacement comparison

Parameter	Spiral-wound train 1	
	Before	After
Feed pressure, psi	344	330
$1^{st}/2^{nd}$ stage pressure drop, psi	56/18	14/8
Total permeate conductivity, umhos/cm	621	448
Overall NaCl rejection, %	92.7	96.6
Water flux $_{@25^{\circ}C}$, gfd	12.68	13.9
Water MTC $_{@25^{\circ}C}$, gfd/psi	0.078	0.086

4. Summary

Although many existing plants have undergone membrane replacement, little information has been published in the literature on this component of membrane plant operation. As a result of rapid advances in membrane element film manufacturing and construction, the membrane elements initially supplied at plant start-up are often no longer available at the time of membrane replacement because either the model was discontinued or formulation improvements had been implemented during manufacturing. Thus the newer or alternative membrane elements have to be used for membrane replacement. These newer generation, or modified membranes, are thus placed into facilities that had been designed for an older model or version, which may require that newer operating conditions be employed to compensate for water transfer performance changes. Consequently, membrane replacement requires careful planning, and should involve computer modeling, membrane probing, membrane profiling and hydraulic evaluations to document modifications in plant performance.

The City of Sarasota successfully implemented membrane replacement on one of its three process trains. Train A was converted from the original DuPont® B-9™ single hollow-fiber bundle configuration to the DuPont® Double Cartridge™ configuration. Results indicated that the retrofit membrane replacement from the older hollow-fiber single bundle configuration (B-9™) to the newer configuration (Double Cartridge™) improved process reliability (less down-time for cleanings), increased productivity (produced equivalent amount of water at a much reduced pressure), and enhanced permeate water quality.

Florida Water successfully implemented membrane replacement at its Marco Island ROWTP. The original membrane trains 1–4 contained a 24:12 array with six elements per pressure vessel. The membranes in train 1 were replaced with a 22:11 array using Fluid Systems® TFC 8822HR elements in the first two positions of stage one. The remaining positions in both stages were filled with Fluid Systems® TFC 8822XR membrane elements. An increase in membrane productivity and stable production at reduced feed pressures was realized by the membrane replacement activity.

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References

[1] C.A. Kiefer, W.J. Conlon, L. Horvath and R. Terrero, Proc., AWWA Membrane Technologies in the Water Industry, Orlando, FL, (1991) 149.

[2] S.J. Duranceau, J. Foster, I. Watson, R. Weis, J. Losch, J.D. Westrick, H.A. Harn and J. Nemeth, Coping with a variable TDS brackish water during the retrofit expansion of a desalting facility. Proc., ADA Biennial Conference Membrane and Desalting Technologies, Monterey, CA, 1996.

[3] S.J. Duranceau, J. Foster, R. Gonzalez, I. Watson, R. Weis, H.J. Losch, J.D. Westrick, J.A. Harn and J. Nemeth, Proc., IDA World Congress on Desalination and Water Reuse, Madrid, Spain, (1997) 455.

[4] Boyle Engineering Corporation, City of Sarasota Hollow Fine-Fiber Reverse Osmosis Water Treatment Plant, Investigation, Pilot Study, and Assessment of Existing Conditions, Public Works Utilities Division, Sarasota, FL, 1998.

[5] R. Myers, Biofouling removal techniques- permasep hollow-fiber membranes. Proc., AWWA Membrane Technologies Conference, Long Beach, CA, 1999.

[6] T.J. Eckman, C.P. Shields, J.W. Strantz and J.M. Wright, The HF Cartridge TM – Development and commercialization of an entirely new RO device/technology. Proc., IDA Madrid Conference, Madrid, Spain, 1997.

[7] S.J. Duranceau, J. Foster, D. Taylor, J. Morton and J. Vargas, Florida Water Resources J., Gainesville, FL, 52 (1) (2000) 24.

[8] S.J. Duranceau, J. Foster, H.J. Losch, R.E. Weis, J.A. Harn and J. Nemeth, Intl. Desalination & Water Reuse Quarterly, 8(4) (1999) 34.