A COMPARISON OF THREE REVERSE OSMOSIS MEMBRANES AT LA CHIMBA DESALINATION PLANT, ANTOFAGASTA, CHILE

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Summary

To increase plant capacity at the La Chimba Desalination Plant, Antofagasta, Chile, Atacama Water Technologies (AWT) installed three new reverse osmosis skids (provided through Xylem) each producing 1,000 m^3/day (264,172 GPD) and equipped with elements supplied by NanoH_2O, and two other suppliers. These new trains utilized the existing plant intake and pre-treatment system. Each new train consisted of 10 pressure vessels (PVs) with six elements each and used Energy Recovery Inc. (ERI) PX work exchangers.

This paper presents comparison of the three new 1,000 m^3/day (264,172 GPD) trains installed in December 2012. Each of the trains has membrane modules with different performance characteristics from three different seawater reverse osmosis (SWRO) membrane manufacturers. Early data from this parallel comparison demonstrates that in cold, low salinity waters there is a significant energy cost savings to using high flux membranes given the water quality needs for this project.

I. INTRODUCTION

Constructed in four phases, the 52,000 m^3/day (13,736,947 GPD) La Chimba Sector desalination plant, Antofagasta, Chile was the first phase put into operation in 2003. These four phases, each consisting of 13,000 m^3/day (3,434,237 GPD), were delivered by Inima (first three phases) and AWT (final phase). The plant utilizes eight-plus-one intake pumps, delivering seawater from 350 m (1,148 ft.) offshore and a depth of 22 m (72 ft.). Pretreatment consists of 20 sand filters and 8 cartridge filters. The plant has eight racks of 90 pressure vessels with seven elements per vessel. Each rack has one high-pressure pump and a Pelton turbine provides energy recovery. Twenty-four calcite chip filters provide permeate post-treatment.

AWT sells water to its parent company, Aguas Antofagasta (AA), for distribution to the city of Antofagasta in northern Chile. AA supplies both desalted water and treated water from the Andes to the city of Antofagasta and plans to build an 86,000 m^3/day (22,718,797 GPD) plant, Desladora Sur, capable of supplying all of Antofagasta's water needs.

To increase plant capacity, AWT is installing high flux NanoH_2O elements in one train, and another manufacturer's membranes in five other trains and adding three new skids (provided through Xylem). Each skid will produce 1,000 m^3/day (264,172 GPD) and be equipped with elements supplied by NanoH_2O, Supplier B and Supplier C. These new trains will utilize the existing intake and pre-treatment systems. Each new train will consist of 10 pressure vessels with six elements each and use ERI PX devices rather than Pelton turbines.

II. DESIGN ARRAY

Projections were prepared to maximize the performance of each of the respective elements and system array. AWT sought low-pumping pressures at a maximum TDS of 400 mg/L. Figure 1 shows the design array used by each supplier. Suppler B provided projections for 10x6 37.5 m^3/day (9,900 GPD) elements with a salt rejection range of 99.5-99.8%. Supplier C provided projections for 10x6 37.5 m^3/day (9,900 GPD) elements with a salt rejection range of 99.6-99.8%. NanoH$_2$O provided projections using Q+ for a hybrid array of one Qfx SW 400 R 34 m^3/day (9,000 GPD) 99.75-99.85% salt rejection (and five Qfx SW 400 ES 52 m^3/day (13,700 GPD) 99.7-99.8% salt rejection in 10x6 PVs [1]. NanoH$_2$O's design afforded the lowest pressure design across a range of 14° - 21° C (57° - 70° F), while delivering permeate below 400mg/L TDS. Table 1 shows an analysis of the deviation in pressure based on initial projections, prepared prior to installing elements, between NanoH$_2$O's design and the two competitors.

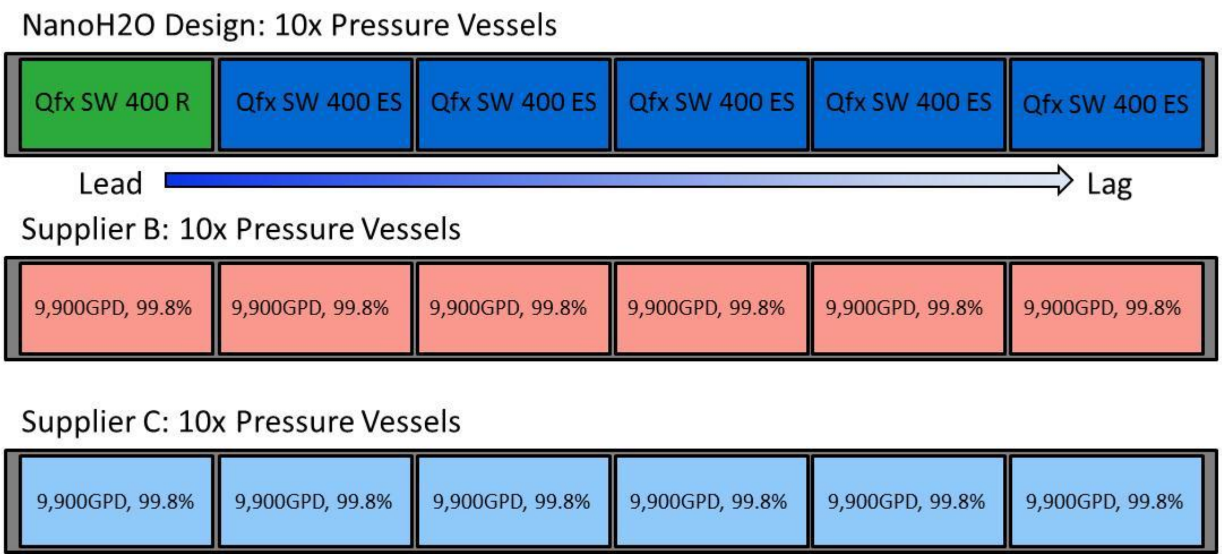

Figure 1. Design array diagrams for each supplier

Table 1: Percent Performance Deviation Based on Pumping Pressure Required

% Deviation		
Temp	Supplier B	Supplier C
14° C (57° F)	9.5%	8.3%
21° C (70° F)	5.2%	7.0%

The design arrays discussed above were installed at the plant in December 2012, and the data will be collected and analyzed over the first quarter of 2013. Section III provides a summary of initial data.

The presentation will show a longer record that demonstrates the value of high flux membranes given these conditions.

III. RESULTS

Initial results based on 20 days of recorded data are provided in Table 2, where system designs, permeate TDS and feed pressures are compared.

Table 2: Projected Performance of Elements from Different Manufacturers

Supplier		NanoH2O	Supplier B	Supplier C
Input				
RO Feed Conductivity	μS/cm	53,000	53,000	53,000
Est. RO Feed TDS	ppm	36,105	36,105	36,105
Temp	°C	20	20	20
pH		7.2	7.2	7.2
Yr of operation		0	0	0
Permeate	gpm	175.4	174.2	160
Concentrate	gpm	229	227.9	225
Recovery based on flows		43.4%	43.3%	41.6%
Design				
		Stage #1	Stage #1	Stage #1
Element Specification		(1) Qfx SW 400 R	37.5 m3/day	37.5 m3/day
Element Specification		(5) Qfx SW 400 ES	99.6-99.8%	99.5-99.8%
# PV per Stage		10	10	10
# Element per PV		6	6	6
Permeate Back Pressure	psi	20	20	20
Output				
Product Conductivity	μS/cm	475.7	261.4	292
Est. Product TDS	ppm	**228**	**125**	**140**
Concentrate Conductivity	uS/cm	82,500	82,900	-
Feed Pressure	Bar (psi)	**46.7 (686)**	**52.3 (769)**	**54.4 (800)**
Concentrate Pressure	Bar (psi)	45.2 (664)	51.2 (752)	53.1 (781)
Pressure Percent Difference			12.1%	16.6%

Regarding the pressures that were measured onsite using NanoH$_2$O's element array, the field data showed greater pressure savings than projected against both suppliers. The NanoH$_2$O design afforded 12.1% better pumping pressure on Competitor B and 16.6% on Competitor C at 20^{o}C. Considering that Table 1 shows a greater pressure saving at the low design temperature of 14^{o}C, the plant may show substantially better savings over a longer test period.

Regarding the differences in projected permeate quality, using elements with higher flux but with similar rejection specification (~99.8); will produce higher permeate TDS due to successively greater brine concentrations with each element within a pressure vessel [2]. That is, because more permeate is recovered from the system than in a standard 37.5 m^3/day (9,000 GPD) element, the feed solution becomes more concentrated and in successive elements in the pressure vessel, a greater salt transport rate is experienced. This is explained by the equations below:

$$Q_s = B \times S \times \Delta C$$

$$\Delta C = C_b - C_p$$

Salt transport rate (Q_s) is equal to the salt transport coefficient or B-value (B), which is specific to each membrane surface multiplied by the surface area of the membrane (S) multiplied by the change in salt concentration (C). This change in salt concentration is equal to the concentration of salt at the surface of the membrane (C_b) minus the salt concentration in the permeate (C_p). This shows that as more water permeates the membrane C_b increases along the pressure vessel.

To minimize this effect, NanoH_2O ensured that the Qfx SW 400 ES had the highest possible element rejection at its given flow (or the lowest possible B value).

Tables 3, 4 and 5 compare performance data from each manufacturer with projected values. Each table shows the variation of the field data as it compares with the projected data for permeate TDS and feed pressure.

Table 3: Field data vs. Projections

NanoH2O		Field Data	Projection
Input			
Est. RO Feed TDS	ppm	36,105	36,105
Temp	°C	20	20
pH		7.2	7.2
Year of operation		0	0
Permeate	gpm	175.4	146.4
Concentrate	gpm	229	229
Recovery		43.4%	39.0%
Design			
		Stage #1	Stage #1
		(1) Qfx SW 400 R	(1) Qfx SW 400 R
		(5) Qfx SW 400 ES	(5) Qfx SW 400 ES
# PV per Stage		10	10
# Element per PV		6	6
Permeate Back Pressure		20	20
Output			
Product TDS	ppm	228	213

NanoH2O		Field Data	Projection
Feed Pressure	Bar (psi)	46.7 (686)	48.2 (708.5)
Concentrate Pressure	Bar (psi)	45.2 (664)	47.0 (691.4)
Permeate Percent Difference		6.9%	0

Table 4: Initial Field Data vs. Projections – Supplier B

Supplier B		Field Data	Projection
Input			
Est. RO Feed TDS	ppm	36,105	36,105
Temp	°C	20	20
pH		7.2	7.2
Year of operation		0	0
Permeate	gpm	174.2	145.7
Concentrate	gpm	227.9	227.9
Recovery		43.3%	39.0%
Design			
# PV per Stage		10	10
# Element per PV		6	6
Permeate Back Pressure		20	20
Output			
Product TDS	ppm	125	167.1
Feed Pressure	Bar (psi)	52.3 (769)	49.6 (729.5)
Concentrate Pressure	Bar (psi)	51.2 (752)	49.0 (719.7)
Permeate Percent Difference		-25.2%	0
Pressure Percent Difference		5.4%	0

Table 5: Initial Field Data vs. Projections – Supplier C

Supplier C		Field Data	Projection
Input			
Est. RO Feed TDS	ppm	36,105	36,105
Temp	°C	20	20
pH		7.2	7.2
Year of operation		0	0
Permeate	gpm	160	144
Concentrate	gpm	225	225
Recovery		41.6%	39.0%
Design			

Supplier C		Field Data	Projection
# PV per Stage		10	10
# Element per PV		6	6
Permeate Back Pressure		20	20
Output			
Est. Product TDS	ppm	140	206
Feed Pressure	Bar (psi)	54.4 (800)	48.6 (713.7)
Concentrate Pressure	Bar (psi)	53.1 (781)	47.5 (697.6)
Permeate Percent Difference		-32.0%	0
Pressure Percent Difference		12.1%	0

NanoH_2O elements showed a 3.2% lower pressure that projected, while elements from Suppliers B and C showed 5.4% and 12.1% higher pressure, respectively, compared to their projections. Flow instrumentation on site gave a recovery of 43.4%. However, samples were taken from the site and water quality analysis was undertaken. Using a mass balance analysis approach based on TDS afforded a recovery of 39%. For this reason, new projections used 39% recovery and compared with the field data at 43.4% recovery.

IV. CONCLUSIONS

Given the differing performance characteristics of the membrane elements selected for the three trains, a direct comparison of the offerings of the different suppliers is not meaningful. However, these data demonstrate the value of using high flux elements to save energy. High flux NanoH_2O elements show acceptable water quality produced at 5.6 to 7.8 bar (83 to 114 psi) lower pressure than the membranes provided by the other suppliers. This translates into a savings of 5.6 to 7.8 bar (83-114 psi) lower pumping pressure or a specific energy of 0.5-0.6kWh/m^3. The known tradeoff between flux and rejection for reverse osmosis elements is also evident in these data. Higher flux elements pass more salt compared to lower flux elements. Consideration of the goals of the project related to either maximizing energy savings or maximizing water quality need to guide element selection. Although other high flux elements are available on the market, NanoH_2O elements have the highest flux of any and hence show cost savings advantages over these competitors. Cost savings demonstrated in the field at La Chimba, Antofagasta, Chile.

V. REFERENCES

1. NanoH_2O, Inc., Q+ Projection Software (version 1.3), 2012
2. Voutckov, N., 2013, Desalination Engineering Planning and Design: McGraw-Hill, 642p.