LARGE DIAMETER SEAWATER REVERSE OSMOSIS ELEMENTS – A YEAR'S OPERATION IN CHILE

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Abstract

This paper discusses the Planta Desalinizadora Muelle, Proyecto Esperanza (Pier Desalination Plant, Esperanza Project). Located in the Antofagasta region of Chile's north coast, Minera Esperanza's copper-gold mine is about 1,500 km north of Chile's capital city of Santiago. Fresh water is a scarce and expensive resource and so the Chilean government has placed constraints on industrial and drinking water supply, requiring companies to provide their own water. Hence, Antofagasta Minerals opted to use a seawater desalination system to produce water for the production facilities at the mine port, which is located about 170 km from the mine. This project is unique, in that it is the first commercial plant to use the world's largest reverse osmosis (RO) elements for seawater desalination. Large diameter elements were selected because the system could provide the required capacity in a small footprint.

Phase 1 was installed first to provide potable water for the early phases of construction and was commissioned in June 2009. Phase 1 supplied drinking water for the mining camp and fresh water for concrete production during the construction period of the Michilla Pier. Phase 2 was completed in April 2010. The mine port will be used for overseas shipment of the copper concentrate. The copper concentrate is sent from the Mine site via a steel pipe 180 km long and from 2600 m above sea level. At the port site, the copper concentrate will be filtered and washed using RO permeate from the Phase 2 system.

The seawater supplied to the desalination plant is drawn from the Pacific Ocean. It is pumped for about 500 m. The seawater is then prefiltered with automatic/self cleaning filters, followed by 1 micron cartridge filters on the RO skids. The feed water is pre-chlorinated and then sodium metabisulfite is used to neutralize any remaining free chlorine before the filters to prevent free chlorine entering the RO. An energy recovery device minimizes the energy consumption of the RO trains. Prior to distribution, the desalinated water is post-chlorinated for disinfection.

The commissioning of both systems went smoothly. The permeate meets design water quality requirements. Phase 1 experienced fouling due to the intake location and pretreatment. Changes in the intake location and pretreatment design enabled Phase 2 to better handle upsets. The performance of this plant shows that, as expected, large diameter elements perform in the same way as typical 8-inch diameter elements, and, just like for 8-inch systems, pretreatment to seawater RO systems is important.

I. INTRODUCTION

Located in the Antofagasta region of Chile's north coast, Minera Esperanza's copper-gold mine is about 1,500 km north of Chile's capital city of Santiago. Fresh water is a scarce and expensive resource and so the Chilean government has placed constraints on industrial and drinking water supply, requiring companies to provide their own water. The plant owner, Antofagasta Minerals, selected a system integrator, Nicolaides S.A. to provide a seawater desalination system to produce water for the production facilities at the mine port, which is located about 170 km from the mine. The Planta Desalinizadora Muelle, Proyecto Esperanza (Pier Desalination Plant, Esperanza Project) includes two phases of seawater RO systems.

This project is unique, in that it is the first commercial plant to use the world's largest RO elements for seawater desalination. Large diameter elements were selected because the system could provide the required capacity in a small footprint.

The mine port initially needed water for potable use and fresh water for concrete production during the construction period of the Michilla Pier. Once the pier was completed, the desalinated water is used to process the copper concentrate.

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II. DESIGN WATER QUALITY

Table 1 shows the design water quality. The water salinity was actually a little lower than design, with Total Dissolved Solids (TDS) of 35,000 to 38,000 mg/L.

Table 1: Design water quality

Parameter	Influent	Effluent
Chloride (mg/L)	22,000 – 24,000	< 250
TDS (mg/L)	39,000 – 43,000	< 500
Sulfate (mg/L)	2,500 – 2,700	< 500
Conductivity (µS/cm)	50,000 - 53,000	
Temperature (°C)	12 - 17	

III. PROCESS

Figure 1 shows a simplified process flow diagram. The seawater is drawn from the Pacific Ocean and is pumped for about 500 m. After pre-filtration, the water is processed in the RO system, and then post-chlorinated for disinfection prior to distribution.

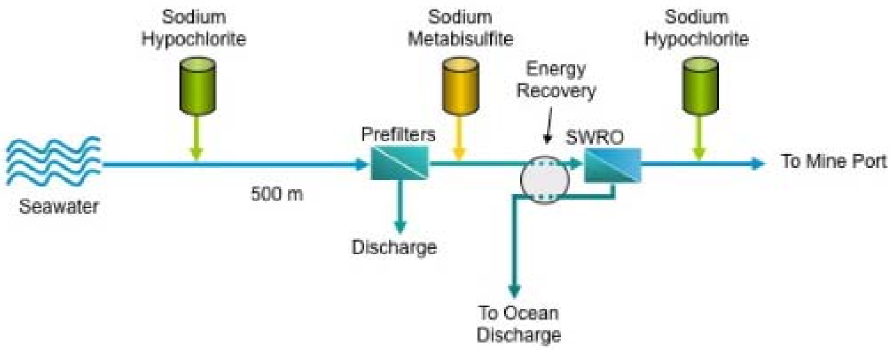

Figure 1: Process flow diagram

3.1 Pretreatment

The pretreatment is prefiltration with automatic/self cleaning AMIAD Filters, first stage 50 microns, second stage to 3 microns followed by 1 micron cartridge filters on the RO skids. The feed water is chlorinated with up to 0.3 ppm free chlorine. Sodium metabisulfite is used to neutralize any remaining free chlorine after the filters to prevent free chlorine entering the RO. Figure 2 shows the prefilters on the Phase 1 system during installation. The red filter on the front right is 50 micron, the white filter on the front left is 3 micron, and the blue vertical filter in the background is the 1 micron filter.

Figure 2: Pretreatment

3.2 RO System

Phase 1 uses a single vessel with five large diameter elements to produce 20.5 m^3/hr (130,000 gpd). Phase 2 includes two trains of two vessels each, each with a capacity of 41 m^3/hr for a total of 82 m^3/hr (520,000 gpd). Figure 3 shows a photograph of the seawater RO vessel and Figure 4 shows a photograph of the Phase 1 seawater RO system. Figure 5 shows one train of the Phase 2 system.

Figure 3: Large Diameter Seawater RO Vessel

Figure 4: Phase 1 Seawater RO System

Figure 5: Phase 2 Seawater RO System

3.3 Energy Recovery

Both Phase 1 and Phase 2 of the project use a pressure exchanger energy recovery device. The pressure exchanger uses a rotor that translates the concentrate pressure to a portion of the feed flow. This allows the high pressure feed pump to be reduced in size. An additional boost pump is required to obtain the feed pressure of the pressure exchanger flow. However, this boost pressure is small compared to the high pressure feed pump boost pressure. The manufacturer of the device is Energy Recovery Inc. The Phase 1 system used a single PX-140S unit whereas the second phase systems used two PX-180 units on each of the RO trains.

3.4 Post-treatment

Prior to distribution, the desalinated water is chlorinated at a dose rate of 0.2 to 2.0 mg/L chlorine for disinfection.

IV LARGE DIAMETER RO ELEMENTS

Over the last several years, increasing the diameter of spiral elements has been studied as a method of lowering the cost of reverse osmosis. Previously presented technical papers have shown that the installed cost of a reverse osmosis plant can be reduced by using larger diameter elements [1]. The Esperanza plant is the first commercial plant to use the world's largest RO elements for seawater desalination. The RO elements used were 18 inches diameter and 61 inches long, with 3,050 square feet of membrane area per element. These features of these elements were described in a previous paper [2].

V OPERATING DATA

5.1 Water Quality

Table 2 shows the quality of the raw feed water, the RO feed after pretreatment, the RO permeate and the RO concentrate. The RO membranes rejected over 99 % of most ions and meet the design effluent quality. The rejection of boron was over 70 %. Boron is only partially ionized at the operating pH, and so as expected, the membranes did not reject all the boron. The feed water salinity has Total Dissolved Solids (TDS) of 35,000 to 38,000 mg/L and the product TDS is less than 500 mg/L. The product water meets Chilean drinking water standards.

Table 2: Water quality

Parameter	**Raw Feed**	**RO Feed**	**RO Permeate**	**RO Concentrate**
Bromide [mg/L]	66.4	67.4	0.63	110
Calcium [mg/L]	398	392	0.55	698
Chloride [mg/L]	19,500	19,500	154	36,600
Magnesium [mg/L]	1,300	1,290	1	2,200
Potassium [mg/L]	429	429	3.76	718
Sodium [mg/L]	10,900	10,900	97	8,600
Sulfate [mg/L]	2,820	2,820	2	4,890

Alkalinity [mg/L as $CaCO_3$]	121	121	3	203
TDS [mg/L]	36,400	36,900	344	62,900
Turbidity [NTU]	0.63	0.15	0.15	0.2
pH	7.9	7.84	6.6	7.78
Conductivity [µS/cm]	54,000	54,000	521	85,800
TOC [mg/L]	4.72	3.8	<0,1	7.08
Boron [B mg/L]	4.64	4.45	1.31	7.18

5.2 Phase 1 RO Operation

Over the first three months of operation, the Phase 1 system produced water of the required quality. The system was operated at the design flux of 14.5 lmh (8.5 gfd). Salt passage was relatively stable, as demonstrated by the chloride rejection in Figure 6. However, the membrane permeability declined, as shown by the relative A-value in Figure 7, and the vessel pressure drop increased as shown in Figure 8. This data indicated fouling of the elements. The Phase 1 system utilized a temporary intake structure, and there were some initial pretreatment issues. The RO feed SDI was frequently in the range of 4-6, which is quite high for a seawater RO system, and similar fouling issues would have been expected with 8-inch RO elements.

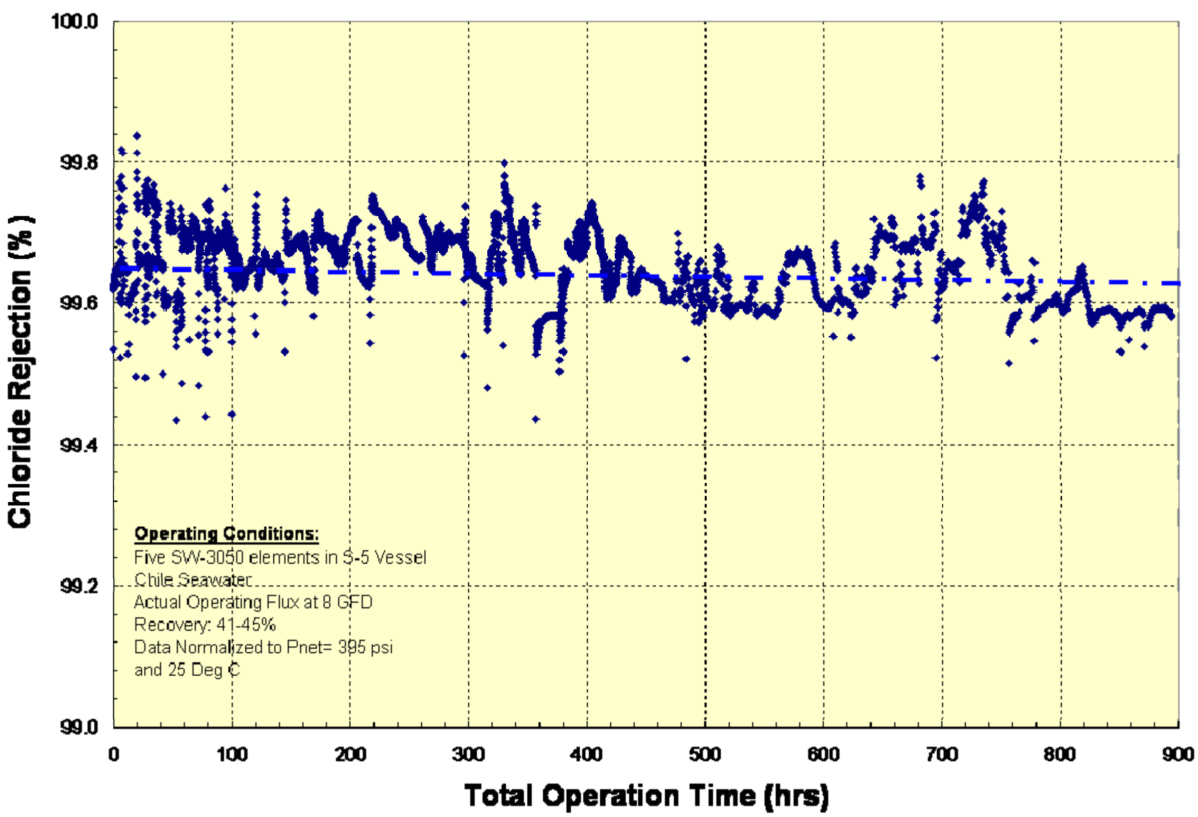

Figure 6: Chloride Rejection versus Time

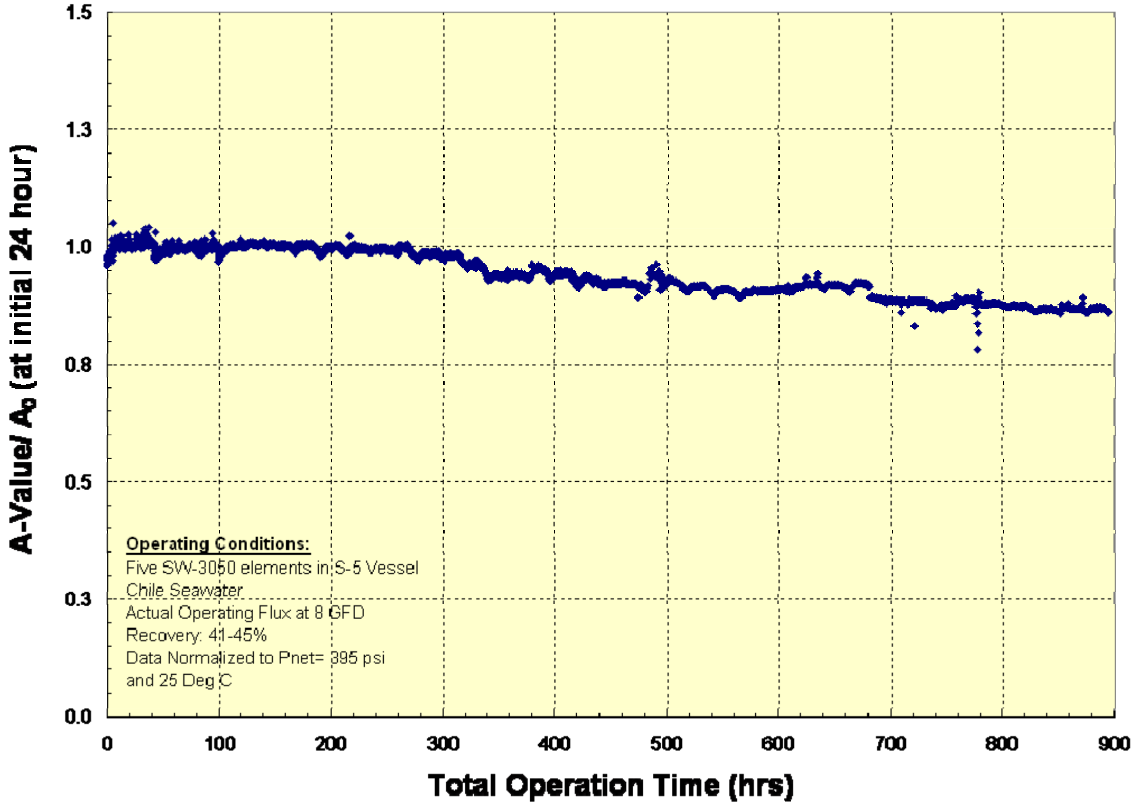

Figure 7: Relative A Value versus Time

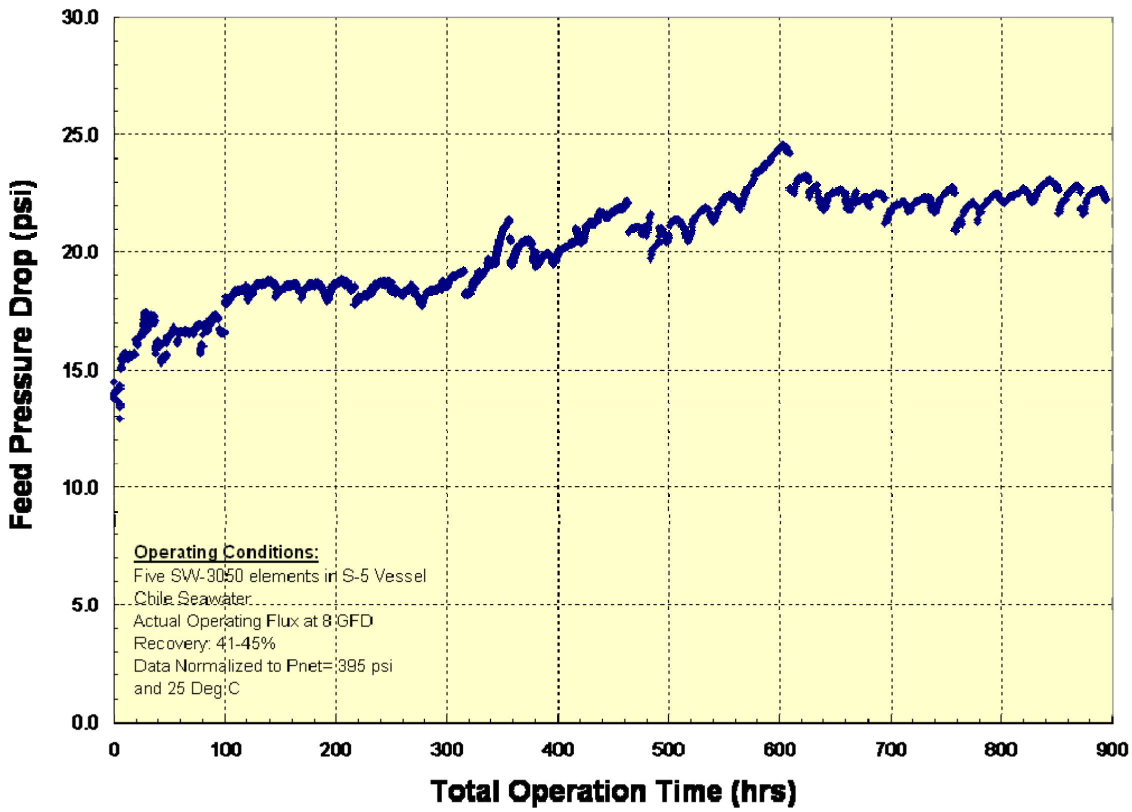

Figure 8: Feed Pressure Drop versus Time

5.3 Phase 2 RO Operation

Lessons learned from the operation of Phase 1 led to changes being made in the design of Phase 2. The intake location was moved, and pretreatment design parameters were changed. This led to a significant improvement in the RO feed, with the SDI in the range of 2.5 – 3.5 most of the time. The Phase 2 design flux was also 14.5 lmh (8.5 gfd), but the actual flux in the first three months of operation was 12 lmh (7.5 gfd) due to low water demand, as shown in Figure 9. This has helped the system handle upsets in feed water quality, but increased the salt passage compared to the projected passage at 8.5 gfd. Salt passage was relatively stable as shown in Figure 10. Element pressure drop was also stable as shown in Figure 11. Data is presented for one of the two trains, but both trains showed similar results.

NOTE: Additional operating data will be added by the time of the final draft submission.

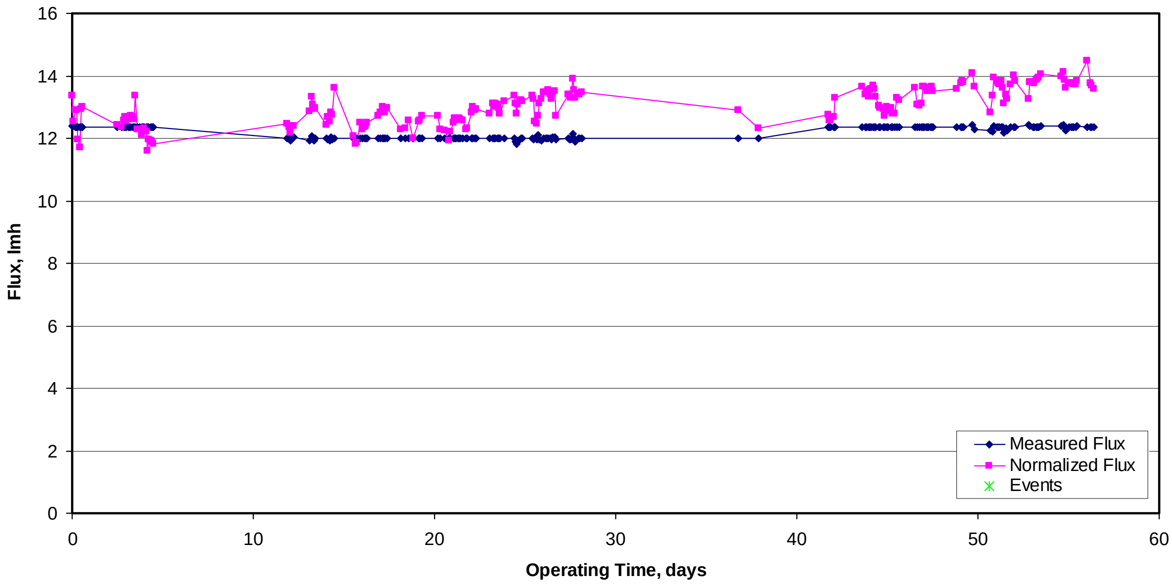

Figure 9: Train 1000 Flux versus Time

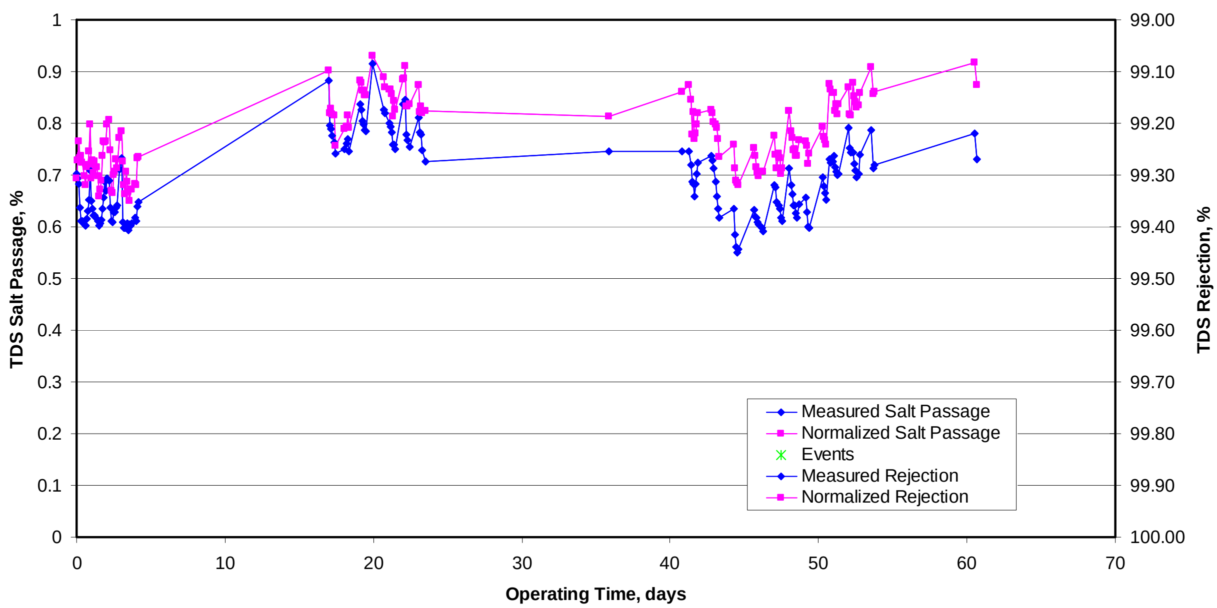

Figure 10: Train 2000 Salt Passage versus Time

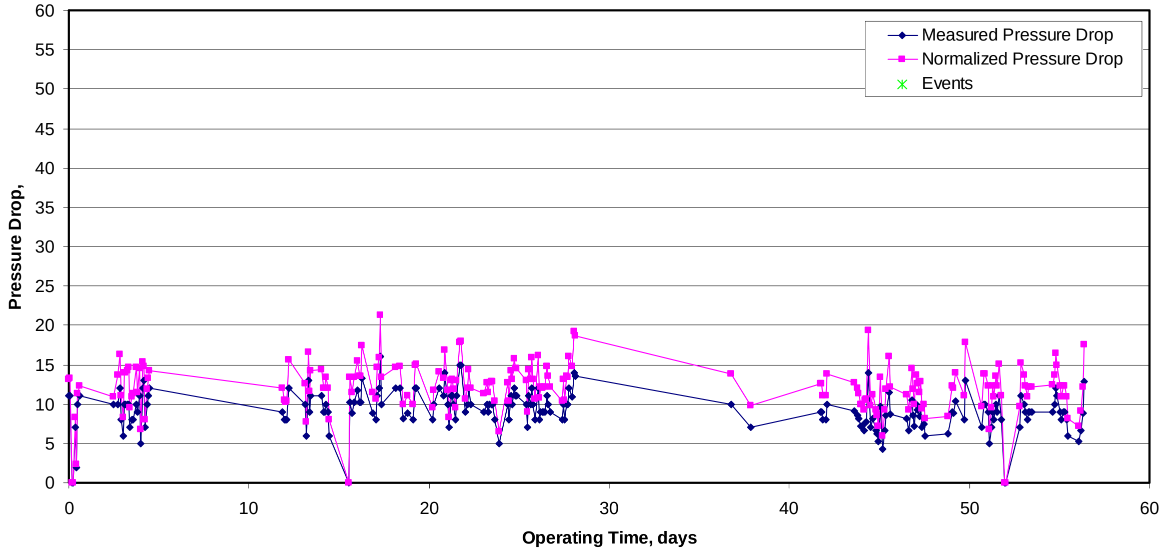

Figure 11: Train 1000 Pressure Drop versus Time

VI CONCLUSIONS

This paper describes the seawater RO systems using large diameter elements for the Esperanza Project in Chile. Both Phase 1 and Phase 2 meet water quality requirements. Phase 1 experienced fouling due to the intake location and pretreatment. Changes in the intake location and pretreatment design enabled Phase 2 to better handle upsets. The performance of this plant shows that, as expected, large diameter elements perform in the same way as typical 8-inch diameter elements, and, just like for 8-inch systems, pretreatment to seawater RO systems is important.

VII ACKNOWLEDGEMENTS

The authors would like to acknowledge the skilled and dedicated plant operators for their hard work and assistance on this project.

VIII REFERENCES

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