Use of Spiral Wound UF in RO Pretreatment

Authors: Harry Dalaly, Asia Pacific Sales Manager, Hydranautics and Yeoh Cheik How, Facilities Senior Engineer, Hewlett-Packard Singapore

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The Hewlett-Packard Singapore Inkjet Supplies manufacturing facility has successfully used ultrafiltration as pretreatment for reverse osmosis since late 1996. The application of an ultrafiltration membrane in combination with a reverse osmosis membrane is the Integrated Membrane Solution (IMS™) approach to resolving a particular water quality situation. This presentation provides information on the process selection, system design and performance data of a water treatment system for high purity water.

Introduction

Interest in the application of a membrane as a pretreatment unit process for reverse osmosis systems began in the 1980's. The various conventional unit processes for a water treatment plant were usually considered as the preferred design approach. Even with this design there was a high probability that the use of surface water supplies could result in fouled reverse osmosis membranes. This remains one of the main concerns of both the water treatment system designer and end user. The application of the ultrafiltration process was generally considered to be too high in capital and operating costs. The application of membranes in both the pretreatment and reverse osmosis units is the Integrated Membrane Solution™. Several years ago the Hewlett-Packard Corporation's Singapore inkjet printer products manufacturing facility reviewed available pretreatment options to minimize membrane fouling of the reverse osmosis plant. In addition to RO membrane protection, the facility required maximizing water conservation.

Hewlett-Packard's senior staff water treatment manager, responsible for company-wide water treatment solutions, reasoned the ultrafiltration process could provide the protection for the RO plant and contribute to water conservation goals. The location available for the water treatment plant presented the opportunity to compare and evaluate the ultrafiltration process with conventional pretreatment unit processes.

Project Review

The manufacturing facility water supply was relatively good quality (Table 1). At times it had unacceptable levels of BOD, bacteria, high SDI values (6-10) and moderate TOC levels. Previous experience indicated that cleaning the existing RO systems was expensive due to plant down time and resultant decreased production, water costs, cleaning chemicals, waste water production and post treatment prior to discharge, plus operator time. The evaluation of initial capital costs and projected operating costs over the life of the plant supported the decision to select the ultrafiltration membrane process in the pretreatment section of the water treatment plant. Study of the plant source water and the treated water requirements for process use focused on minimal wastewater production and minimal chemical addition in the treatment plant design. In addition, space available for the water treatment system was very limited. A compact layout, flexibility in design and selection of process units for future expansion were required to meet these design constraints.

Pretreatment Options

Employing a combination of conventional pretreatment process methods (Table 2) is usually sufficient to meet most water quality requirements and further treatment may be used to produce high purity quality water. Where potentially fouling waters are the only available source for processing into high purity water, the conventional process methods may not be adequate. In addition, the conventional clarification/precipitation and media filtration processes each produce wastewater from periodic concentrate discharge and backwash cycles. These wastewater volumes are not recovered and result in higher water usage. Associated with these processes is the real probability that upsets during operation or with variable influent quality will result in a less acceptable treated water quality. With these limitations the system designer favors the unit process that provides acceptable capital and operating costs, consistent performance with equivalent or better water quality.

Ultrafiltration membrane process operates with relatively low feed water pressure. It has the capability to remove in one process the undesirable materials in the feed water that usually require several unit processes. The dissolved gases O_2 and CO_2 , ionic inorganic substances in the water, e.g. cations, anions and soluble silica, pass through the membrane with the water. The UF process provides a more consistent performance level without chemicals and with minimal water loss during the service cycle and periodic unit flushing on shut down and start-up. The availability of different types of membrane chemistry and configurations provides flexibility in selecting performance capabilities to meet process requirements for a specific application. The comparison and evaluation study of UF with conventional pretreatment methods indicated a UF membrane would best meet the facility’s objectives of service reliability, minimal wastewater, no chemicals, improved operation economics and consistent water quality.

System Design

The water treatment plant consists of a Primary Loop (pretreatment and make-up water system) and a Secondary Loop (polishing system) as shown in the plant flow diagram (Figure 1). The system utilizes unit designs of minimum size to maximize use of space. Process units were also selected and designed for maximum water production with minimum wastewater volumes and high water recovery for both the UF and RO units to meet the site conservation criteria. The other client manufacturing facilities were initiating upgrades to their water treatment plants. New facilities were to include water recovery and conservation processes/procedures for water reuse and cost savings.

The Primary Loop reduces particle loading by utilizing tubular, media and cartridge filters prior to the single stage UF unit designed for 85% recovery with concentrate recycle. The UF system has nine (9) low pressure rated FRP vessels in parallel and each contains five (5) 8”x40” spiral wound polysulfone UF elements. Sodium bi-sulfite chemical is injected prior to the 1.0 micron cartridge pre-filters. An anti-scalant chemical is injected prior to the RO units. Each of the (2) RO units has a 3x2x1 concentrate staged array containing five (5) 8”x40” spiral wound polyamide composite type RO elements in each low pressure FRP vessel. The RO permeate is stored in two (2) storage tanks sized for 6000 US gal each. Level controls feed back for On-Off operation of the RO units to maintain tank capacities.

The Secondary Loop passes the stored RO permeate water through a 254 nm UV system and two (2) polishing mixed bed ion exchange resin units to provide a minimum of 17.5 megohm quality water for process use. The water then passes through a 185 nm UV system and final filtered with 0.1 micron rated cartridge filters.

Selection of the spiral wound type UF membrane was based on the characteristic advantages of large surface area and high water volume production from this element configuration (Table 3). Expansion would be relatively easy with minimal time required and low additional materials cost. UF permeate water quality was projected to provide the required level of RO protection with relatively easy and economical operation.

The overall design succeeded in achieving the criteria of consistent operation, reliable performance and RO protection. Employing UF in the plant resulted in a pretreatment system of minimal physical size, ease of expansion, high water recovery, low wastewater volume, minimal or no chemical consumption and high permeate quality. Performance history has shown UF to be the best solution – an Integrated Membrane Solution (IMS™).

System Performance

The water treatment system was installed and initial operation began in October 1996. The anticipated UF performance was proven from the initial start-up of the pretreatment system in the Primary Loop (Table 4). There were excursions in the source feed water quality. The pretreatment system was challenged to remove higher than normal levels of objectionable material prior to the RO system. Although receiving a lower quality feed water from the other process units, the UF system provided the rated flow and a higher water quality than projected. The UF system continues to provide this high level of performance and produces a very low SDI value (< 0.7) permeate to the RO units (Figure 3).

Several adjustments in the UF recycle flow rate were made to balance the system to meet varying process requirements (Figures 2 and 4). Other UF and RO variations in flows and pressures are primarily due to adjustments prior to and after unit cleanings. Occasional minor adjustments were also made to maintain overall system performance.

The cumulative performance data from the initial start-up in October 1996 through June of this year shows the UF high quality permeate provided the RO units the required protection to maintain on line service. RO permeate conductivity was 5 μS/cm or less through this operating period as shown in the cumulative performance data (Figures 5, 6 and 7).

During operation of the water treatment system, there have been occasional upsets and usual trouble shooting efforts to determine a course of action. Chemical cleanings of the UF and RO units have been minimal; once or twice a year since 1997. Normal chemical cleaning regimen is a solution of either low pH with acid or high pH with caustic chemicals. These cleanings were indicated by an increase in differential pressure across either the UF or RO units and were primarily due to slight accumulation of biological fouling over time. Daily monitoring of the performance of both the UF and RO systems for indications of decreased performance has averted any unusual decrease in rejection, water productivity or service life performance of the membrane elements. There have been no replacements since initial plant start up. All chemical cleanings have returned the respective unit to original performance specifications. The total cost to produce the final treated water in this facility including raw water, wastewater, chemicals, electrical and labor is approximately S$4/m^3.

CONCLUSIONS

The evaluation and selection of a spiral wound polysulfone type UF membrane element and its performance characteristics compared to conventional pretreatment methods achieved objectives for the plant site. As a key component of the pretreatment system, UF overcame formerly accepted negative evaluation of economics and reliability. To the contrary, the UF system has contributed to both operating cost savings and performance reliability under difficult supply conditions. The spiral wound UF membrane performance data over almost four years operation have shown the application of the Integrated Membrane Solution (IMS™) provided the means to resolve a set of site constraints.

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Cheryl Lim Siew Choo is a Facilities Engineer at Hewlett-Packard Singapore and has 5 years experience in UPW systems and operations. She is a graduate of National University of Singapore and provided the performance data on the water system.

James Iong is the Hydranautics Regional Sales Engineer for Southeast Asia located in Singapore. He has experience in distillation, UF and RO systems design and operation. He is a graduate of Nanyang Technological University School of Mechanical & Production Engineering. His assistance was greatly appreciated in preparing this presentation.

AUTHORS

Harry Dalaly is Asia Pacific Sales Manager for Hydranautics located in Perth, Western Australia. He has over 25 years of experience in design and application of UF, RO and ion exchange water treatment systems in high purity water applications.

Yeoh Cheik How is Facilities Senior Engineer at Hewlett-Packard Singapore and has 8 years experience in UPW systems and operations.

Table 1. Water Analysis

(October 1996)

Parameter	Value	Parameter	Value
Temperature	28°C		
pH	6.8	COD	5
Turbidity	0.7 NTU	BOD	< 5
TSS	< 5 mg/l	Bacteria	106 CFU/ml
Conductivity	112 mmhos	Detergent	< 1 ppm
TDS	70 ppm	Oil/Grease	< 1 ppm
SDI	4-6	(n-hexane extract)	

Cations		Anions	
Total Hardness	33 ppm/CaCO3	Total Alkalinity	15 ppm/CaCO3
Calcium	10 ppm	Chloride	20 ppm
Magnesium	0.9 ppm	Sulfate	7 ppm
Sodium	3.1 ppm	Nitrate	0.8 ppm/NO3
Potassium	7 ppm	Fluoride	0.5 ppm
Iron	< 0.1 ppm	Phosphate	0.2 ppm
Manganese	0.1 ppm	Silica	5.5 ppm
Copper	< 0.1 ppm	CO_2	1.8 ppm
Aluminum	0.1 ppm		

Table 2. Pretreatment Processes Comparison

	Clarifier	Precipitator	Media Filter	GAC	Micron	Ultrafiltration
TDS	x	x				
SS	x	x	x	x	x	x
Color	x	x	x	x	x	x
BOD	x	x		x		x
COD	x	x		x		x
Organic	x	x	x	x		x
Bacteria	x	x				x
Colloids	x	x	x	x		x
Chemicals	Yes	Yes	Yes	No	No	No

Table 3. UF Membrane Characteristics

Membrane type:	Polysulfone
Configuration:	Spiral wound
Active Membrane Area:	320 ft^2 (29.7 m^2)
Spacer Thickness:	28 mil
Molecular Weight Cut-Off:	Nominal 100,000 Daltons
Permeate Flow:	Nominal 17,500 gpd (66.2 m^3/day)
Maximum Applied Pressure:	150 psig (1.05 MPa)
Maximum Operating Temperature:	113°F (45°C)
Feedwater pH Range:	1-13
Feedwater Chlorine Concentration:	150 ppm maximum

Table 4. Start-up Data

(October 1996)

Ultrafiltration

Design Recovery of 85% (single stage with recycle)

	Flow rate (gpm)	Pressure (psi)	SDI (units)
Feed	214	100	4.2
Permeate	177	66	0.6
Concentrate	37	80	
Recycle	150	50	

Reverse Osmosis

Design Recovery of 85% (three stage)

			Conductivity (µS/cm)
Feed	178	137	119.6
Concentrate	37	63	
Permeate	120		2.6

Figure 2 UF System Flowrate

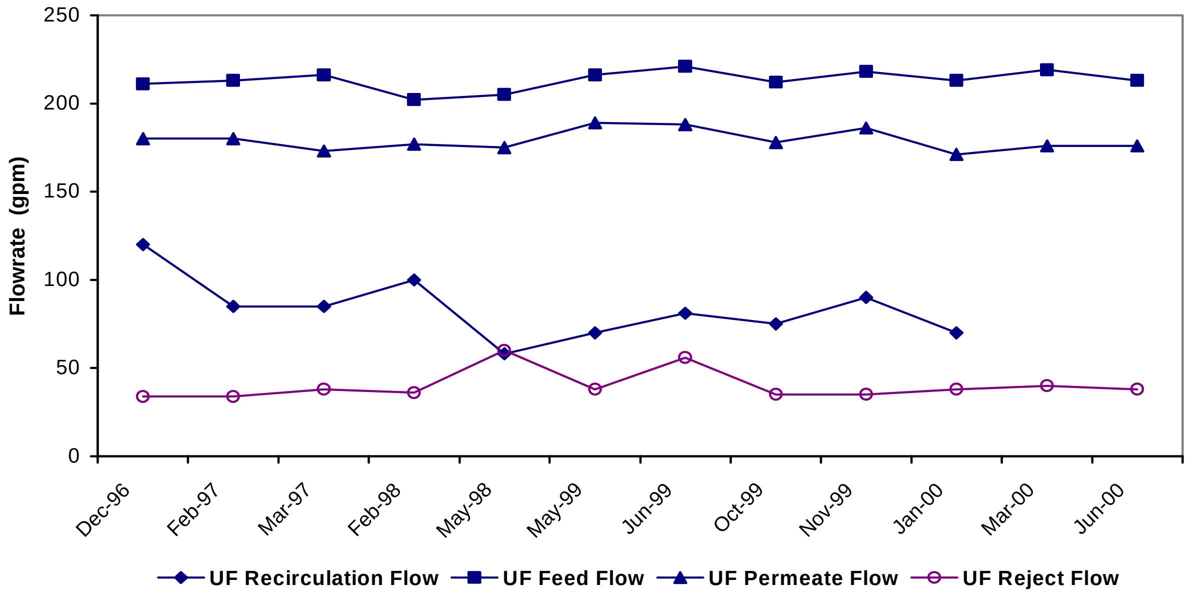


Figure 3 UF System Performance Based on SDI

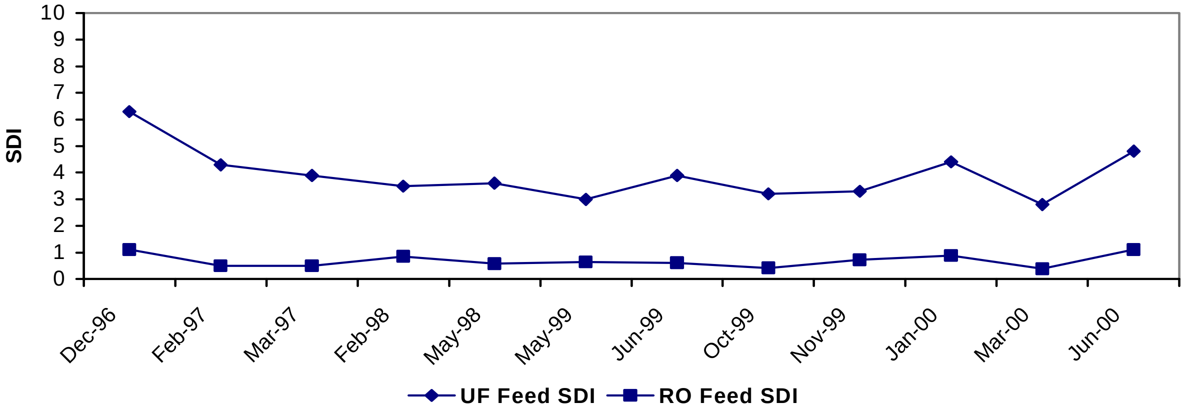


Figure 4 UF System Operating Pressures

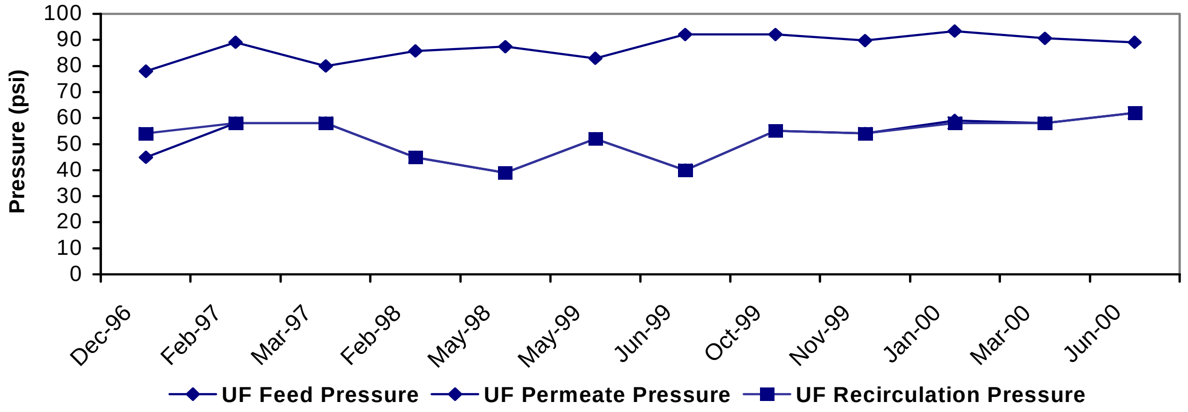
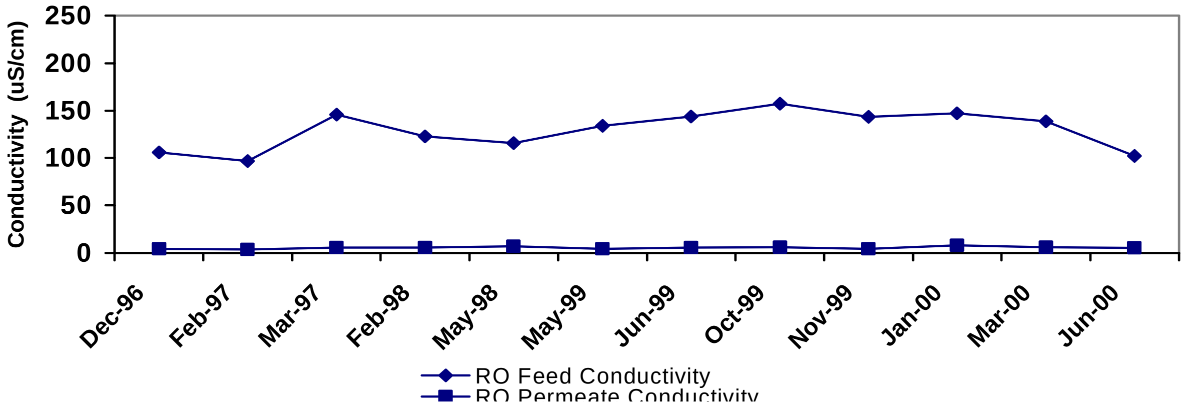


Figure 5 RO System Conductivity Performance



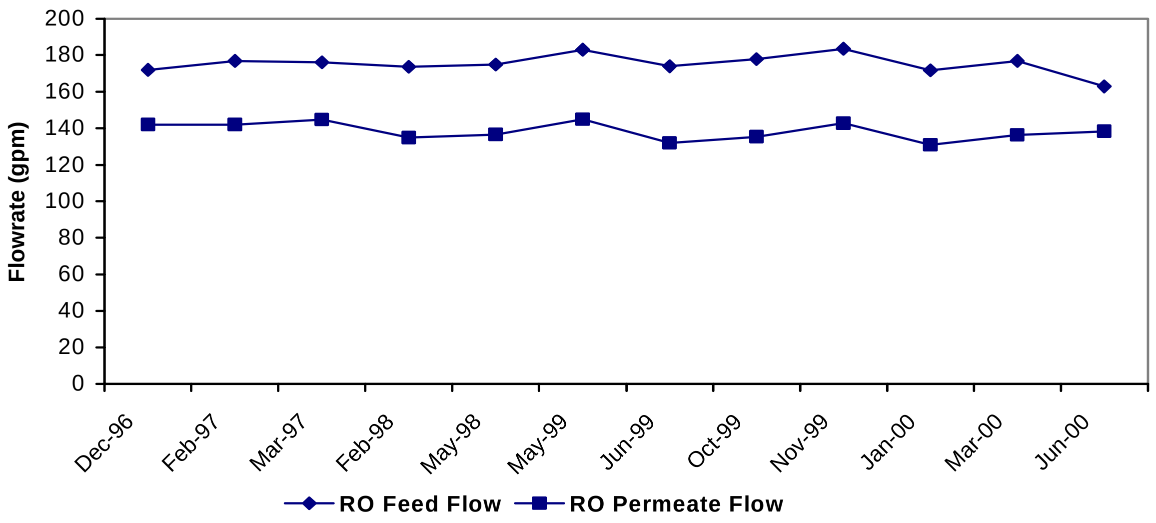


Figure 6 RO System Flowrate

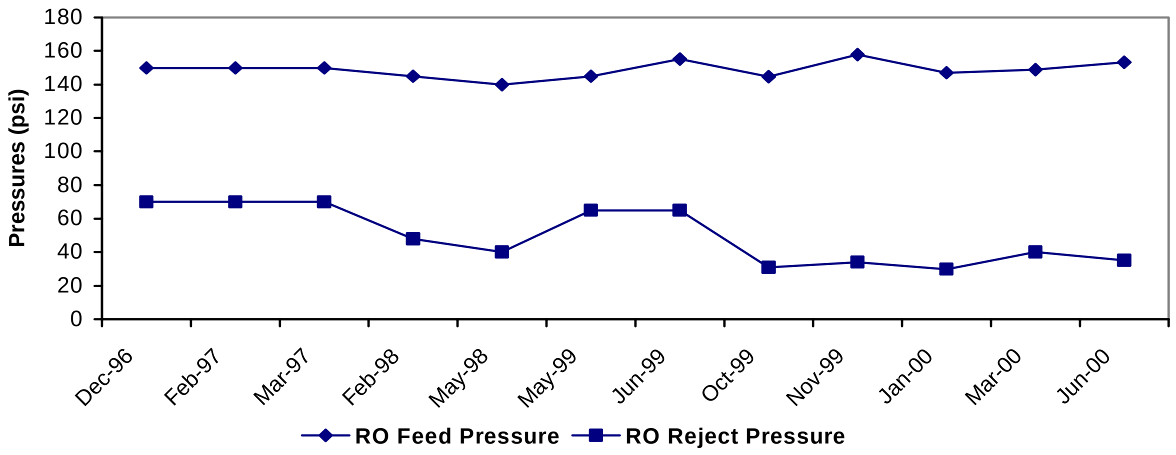


Figure 7 RO System Pressures