Thin-Film Nanocomposite Membranes Yield High Rejection and Reduce the Need for a Second Pass

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How did the industry get to 99.85% rejection?

SWRO membrane performance improvements between 1978 and 2012.

The published specifications have been normalized over time against Fluid Systems' TFC 1501 elements used in the original 1978 Jeddah RO plant. Each Fluid Systems element contained 14 m^2 (150 ft^2) of membrane area. The published data sheets indicate the elements produced 5.7 m^3/day (1,500 GPD) at 55 bar (800 psi), 10% recovery and NaCl rejection of 98.60%.

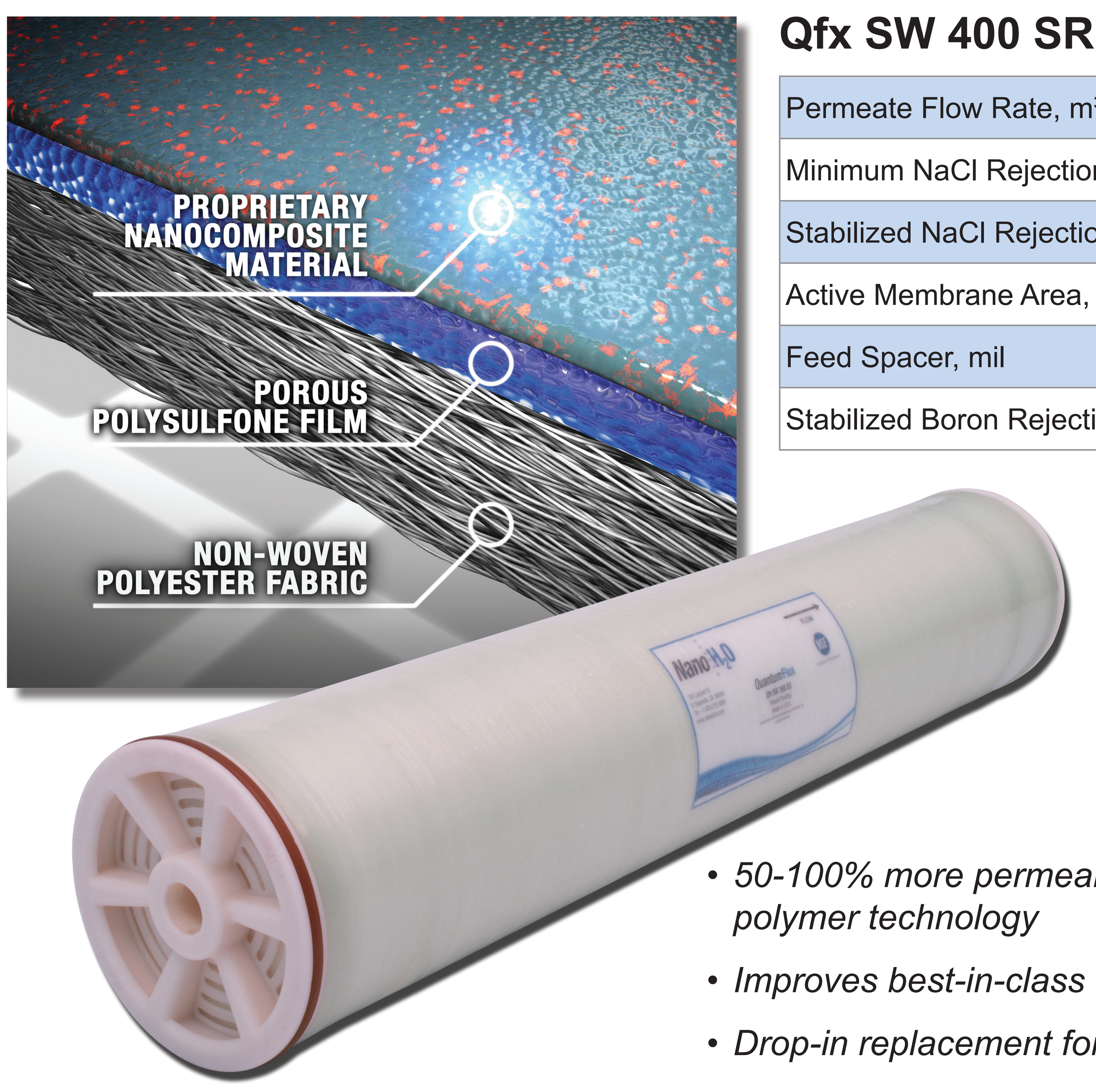
Over time, there have been incremental improvements in both membrane rejection and flux. However, with the introduction of NanoH$_2$O's *thin-film nanocomposite (TFN)* **Qfx SW 400 SR** high-rejection SWRO membrane in early 2012, a new industry standard has been set with 99.85% rejection at 24.6 m^3/day (6,500 GPD).

Year	Salt Passage %	Norm. Salt Passage	Membrane Life Years	Norm. Membrane Life
1978	1.4	1	3	1
1989	1	0.71	3	1
1995	0.8	0.57	5	1.7
2000	0.5	0.36	5	1.7
2002	0.4	0.29	5	1.7
2006	0.2	0.14	7	2.3
2008	0.2	0.14	7	2.3
2010	0.2	0.14	7	2.3
2012	0.15	0.11	7	2.3

Thin-Film Nanocomposite (TFN) Membranes

Qfx SW 400 SR Specifications

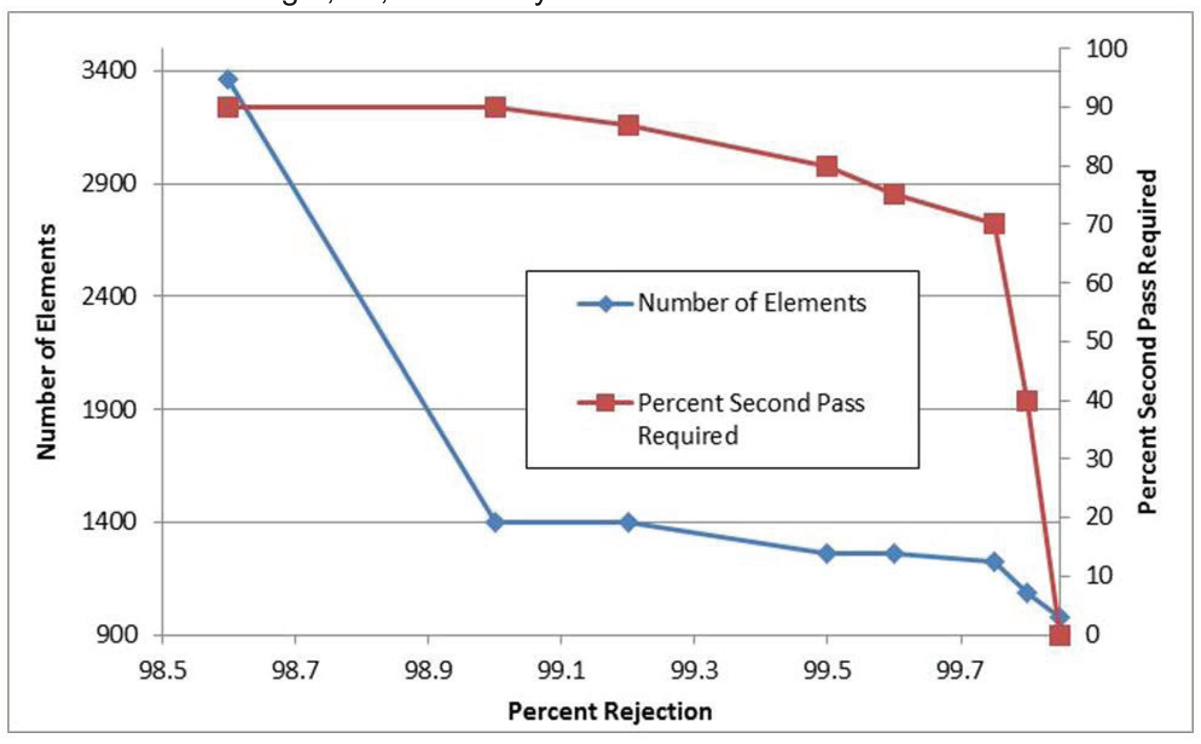
Permeate Flow Rate, m^3/d (gpd)	24.6 (6,500)
Minimum NaCl Rejection, %	99.75
Stabilized NaCl Rejection, %	99.85
Active Membrane Area, m^2 (ft^2)	37 (400)
Feed Spacer, mil	28
Stabilized Boron Rejection: %	93



- *50-100% more permeable than existing polymer technology*
- *Improves best-in-class salt rejection by 25%*
- *Drop-in replacement for existing membranes*
- *5 Patents / 3 Applications in 11 Countries*

The impact of TFN elements on size of second pass

- Inputs: Feed = 40,000 mg/L, 30°C
- Design: 45%, 7 elements per pressure vessel, 15 LMH
- Outputs: Permeate = 200 mg/L, 12,500 m^3/day



Theoretical Study - El Prat de Llobregat, Barcelona

- 200,000 m^3/day, 10 trains (7M x 230 PV)
- Small 2nd Pass (546 PV)
- Worst case scenario of feed salinity and temperature used (from literature)
- Permeate Boron target 1.0mg/L
- If TFN elements existed: ***complete removal of second pass***

Input					
Water Type	Units	Case 1	Case 2	Case 3	Case 4
Feed TDS	mg/L	37,206	37,206	38,681	38,681
Temp	°C	30	30	30	30
Yr of operation		0	5	0	5
Output					
TDS	mg/L	170.1	213.4	179.2	224.7
Boron	mg/L	0.78	0.94	0.83	0.99
Average Flux	LMH	14.0	14.0	14.0	14.0
Max. Element Recovery	%	12.5%	11.1%	12.7%	11.3%

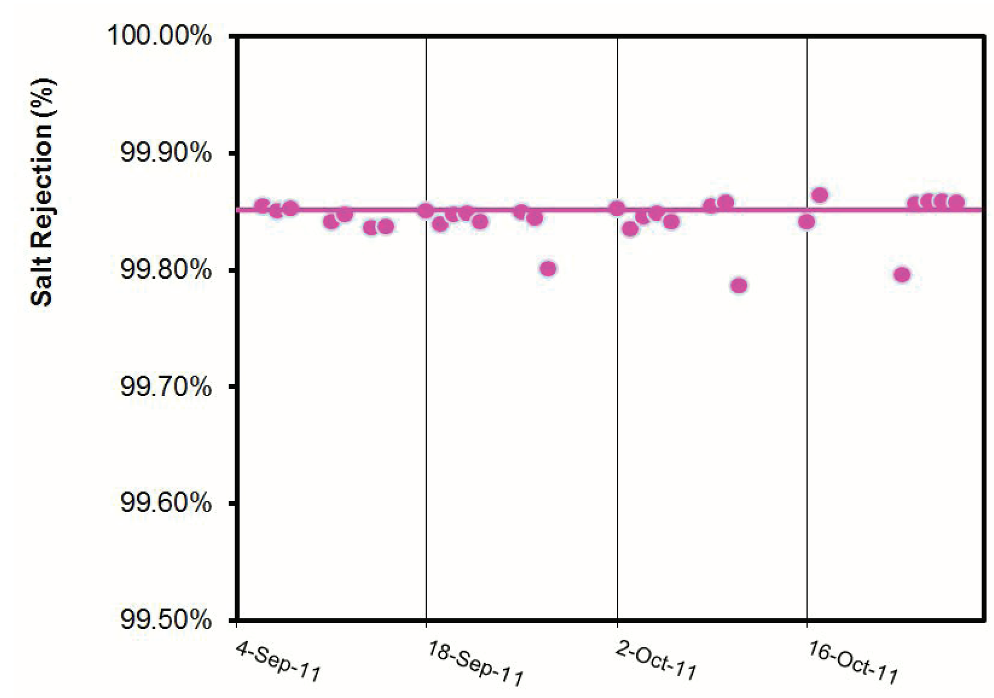
Theoretical Study - Shuwaikh, Kuwait

- 36,000 m^3/day, 10+1 trains (7M x 154 PV), 40% FWR
- 2nd Pass 4+1 trains (7M x 112 PV) = 448 Competitor Elements
- Worst case scenario of feed salinity and temperature used (from literature)
- Permeate Boron target 1.0 mg/L, TDS 300 mg/L
- If TFN elements existed: ***only 152 TFN elements required in 2nd Pass***

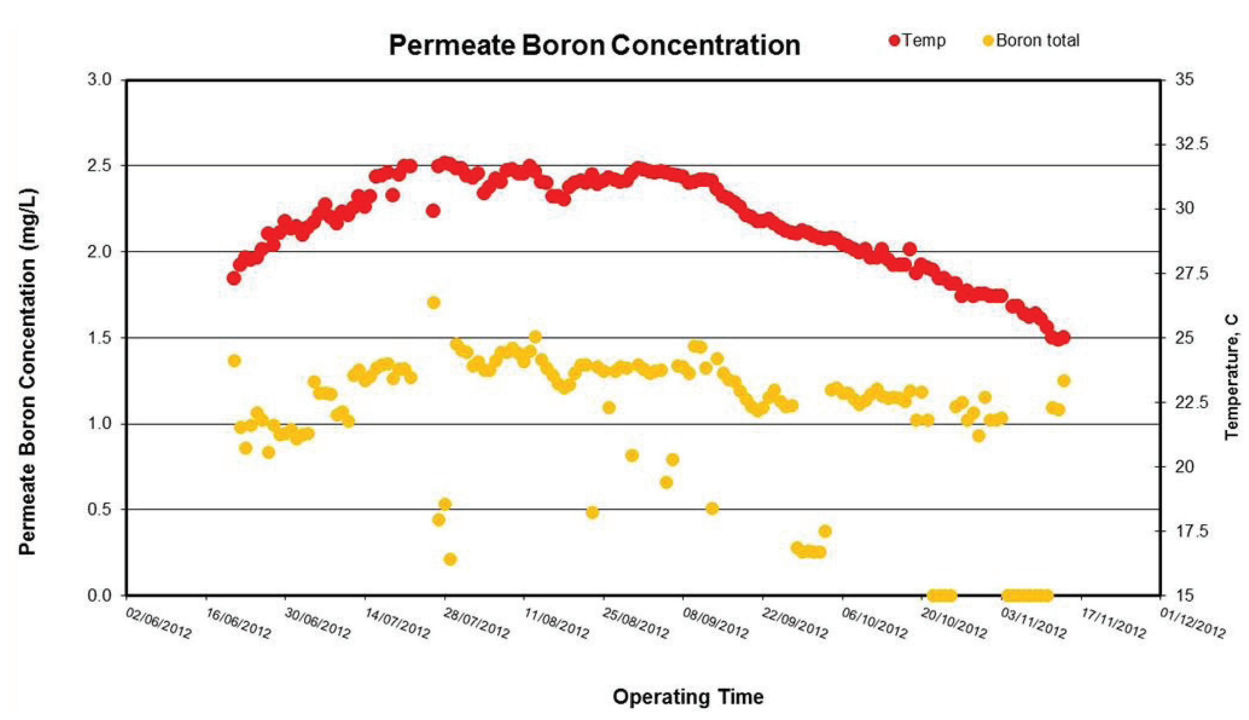
		Case 1	Case 2	Case 3	Case 4
Inputs					
Temperature	°C	18	18	35	35
Year of Operation		0	3	0	3
Bypass Flow	m^3/h	4725	4725	4725	4725
First-Pass Average Flux	LMH	15.8	15.8	15.8	15.8
Outputs					
First-Pass TDS	mg/L	110.4	126.9	290.3	332.8
First-Pass Boron	mg/L	0.58	0.65	1.14	1.27
Second-Pass Flow	m^3/h	1,418	1,418	1,418	1,418
Second-Pass TDS	mg/L	1.6	2.1	10.4	13.3
Second-Pass Boron	mg/L	0.2	0.25	0.69	0.81
Totals					
Combined TDS	mg/L	85.3	98.1	225.7	259.1
Combined Boron	mg/L	0.49	0.56	1.04	1.16
Combined Boron with pH 11.0	mg/L			0.90	1.00

Field Pilot Results - Eastern Mediterranean

- Single pressure vessel (8M) over 56 days
- Average TDS 40,682 mg/L, Average Temp 29° C, Average pH 8.
- 70 bar, 50% recovery
- ***Excellent system rejection***



Full Scale Plant - Eastern Mediterranean



Conclusions

Demonstrated ability to reduce the need for a second pass using high-rejection membranes featuring 99.85% NaCl rejection. This was illustrated by:

1. undertaking projections using the element performance outlined in Table 1 to show the decrease in the amount of water requiring treatment by a second pass
2. an example of how the need for a second pass can be completely avoided by using a 99.85% rejection membrane in the first pass.

- A simulation using parameters from well-known full-scale plants, El Prat de Llobregat (Barcelona) demonstrate the potential of completely removing the second pass.
- A second example using the Shuwaikh Desalination Plant in Kuwait shows that despite high seawater TDS, the size of a second pass can still be dramatically reduced.
- Finally, operational data from both the pilot test and the full-scale system at a large Eastern Mediterranean plant illustrate how these high-rejection TFN elements deliver the reliability and quality to encourage designers to reduce the size of the second pass.

Reduced dependence on a second pass has the potential to decrease capital expenditure by minimizing membrane and equipment needs, and lower operating expenditures through energy and maintenance savings.

NanoH$_2$O