FILMTEC Membranes

Strategies for Using FILMTEC Elements to Lower Your Total Cost of Seawater Desalination

As demand for drinking water continues to increase – particularly in regions of the world with limited fresh water resources – advances in reverse osmosis (RO) membrane technology continue to make seawater desalination a progressively more economical and sustainable option for producing potable and process water. This Tech Fact bulletin will discuss:

- The evolution of RO membrane technology and the economics of desalination.
- How to take advantage of high-flow, low-energy FILMTEC™ membrane elements to further lower desalination capital expenses, operating expenses or both.

The Evolution of RO Membrane Technology and Desalination Economics

Membrane and element construction technology improvements over the past decade have led to significant cost reductions and reliability improvements in reverse osmosis systems. Improved RO economics have in turn increased the attractiveness and use of seawater reverse osmosis (SWRO) technology for many large drinking water projects throughout the world.

For example, in the early 1980s, a desalination plant on the island of Malta operating at 30-33% recovery produced water at a cost of 1.08 US$ per m^3. A governmental study in Spain estimated that a 20,000 m^3/d plant in 1987 would produce water at 0.9 US$ per m^3. In the late 1980s, higher salinity feeds (42,000 mg/L) in the Arabian Gulf resulted in even higher total costs of 1.26 US$ per m^3. By the late 1990s, however, RO membranes with higher flow rates and higher rejections had helped reduce the cost of desalination to an estimated 0.73 US$ per m^3. More recent cost proposals, such as for Israel's Ashkelon desalination project, have included costs as low as 0.52 US$ per m^3.

Using FILMTEC SWRO Membrane Elements to Further Lower Total Desalination Costs

Further cost reductions are being enabled through a new generation of FILMTEC membrane elements that offer economic benefits including unprecedented productivity with high rejection (see Table 1), and improved cleanability and resistance to fouling.

Table 1. Characteristics of new FILMTEC SWRO membranes

Product name	Active area	Flow rate	NaCl rejection	Boron rejection	Maximum pressure	Feed spacer	Primary benefits
FILMTEC SW30XLE-400*i*	400 ft^2 (37.2 m^2)	9,000 gpd (34.1 m^3/d)	Typical 99.70% Minimum 99.55%	88.0%	1,200 psi (83 bar)	28 mil	Lowest energy use, lowest cost of water, highest productivity.
FILMTEC SW30HR LE-400*i*	400 ft^2 (37.2 m^2)	7,500 gpd (28.4 m^3/d)	Typical 99.75% Minimum 99.60%	91.0%	1,200 psi (83 bar)	28 mil	Widely usable, high flow, high rejection, best boron rejection.
FILMTEC SW30HR-380	380 ft^2 (35.3 m^2)	6,000 gpd (22.7 m^3/d)	Typical 99.70% Minimum 99.60%	n/a	1,000 psi (69 bar)	28 mil	Proven industry standard.
FILMTEC SW30HR-320	320 ft^2 (29.7 m^2)	6,000 gpd (22.7 m^3/d)	Typical 99.75% Minimum 99.60%	91.0%	1,200 psi (83 bar)	34 mil	Widely usable, high fouling resistance.

The physical property data listed are considered to be typical properties, not specifications.

Standard test condition: NaCl feed of 32,000 mg/L, recovery of 8%, 77°F (25°C), 800 psi (55 bar) and pH 8.

Using FILMTEC SWRO Membrane Elements to Further Lower Total Desalination Costs (cont.)

FILMTEC SWRO membrane elements can deliver a number of benefits to lower the total cost of desalination in a variety of new and retrofitted systems. The potential savings available depend on variable parameters such as your specific site conditions (e.g., feed water salinity, temperature), design and operation conditions (e.g., recovery, flux) and permeate quality requirements.

Below is a product selection overview to help you determine which FILMTEC SWRO element can deliver optimal savings for different applications and situations.

FILMTEC SW30XLE-400*i* element

The FILMTEC SW30XLE-400*i* offers the lowest energy consumption in the industry and an unprecedented combination of high flow (9,000 gpd) and high rejection.

As a replacement element it enables significant energy savings and/or increased productivity from existing systems.

In new systems, it is an excellent choice for:

- The first stage of double-pass designs with permeate quality requirements of boron less than 0.5 ppm, chloride less than 25 ppm and TDS less than 50 ppm
- Single-pass designs with permeate quality allowing less stringent boron requirements, chloride of 200 ppm or more and TDS values of 350 ppm or more.

FILMTEC SW30XLE-400*i* comes with the unique *iLEC*™ interlocking endcaps that reduce system operating costs and reduce the risk of o-ring leaks that cause poor water quality. See Form No. 609-00446 for information on the trouble-free cost-saving benefits of *iLEC* interlocking endcaps.

FILMTEC SW30HR LE-400*i* element

The FILMTEC SW30HR LE-400*i* element offers low energy use and a previously unattainable combination of high flow (7,500 gpd) and high rejection. This widely usable element also features extremely high boron rejection of 91%.

FILMTEC SW30HR LE-400*i* elements deliver performance-enhancing replacement value in systems using traditional 6,000 gpd elements, by enabling lower energy operation and/or higher productivity.

In new systems, these elements are an excellent choice for:

- The first stage of double-pass designs with permeate quality requirements of boron less than 0.5 ppm, chloride less than 25 ppm and TDS less than 50 ppm
- Single-pass designs with permeate quality requirements of boron less than 1.0 ppm, chloride of less than 25-200 ppm and TDS of less than 350 ppm

FILMTEC SW30HR LE-400*i* features the unique *iLEC* interlocking endcaps that reduce system operating costs and reduce the risk of o-ring leaks that cause poor water quality. See Form No. 609-00446 for information on the trouble-free cost-saving benefits of *iLEC* interlocking endcaps.

FILMTEC SW30HR-380 element

With years of proven performance, the FILMTEC SW30HR-380 element is the industry standard for high productivity and high rejection which delivers the highest boron rejection to help meet World Health Organization and other drinking water standards, making it an ideal choice for single-pass systems.

Using FILMTEC SWRO Membrane Elements to Further Lower Total Desalination Costs (cont.)

FILMTEC SW30HR-320 element

The FILMTEC SW30HR-320 element is useful across a wide range of conditions, and features a wide 34 mil feed spacer that resists fouling and enables more effective cleaning. This element offers the lowest cost for drop-in replacement, delivering solid performance in systems using competitive 4,000-6,000 gpd elements such as:

- Hydranautics SWC3, SWC4, SWC4+
- Toray TM820-370
- Toray SU-820, SU820L, SU820FA

The wide 34 mil feed spacer also makes FILMTEC SW30HR-320 element an excellent choice for systems treating water with higher fouling potential, such as water from an open intake with marginal pre-treatment or with a high TOC (SDI greater than 3, NTU greater than 0.4 more than 50% of the time). It is also useful for single-pass systems with permeate quality requirements of boron less than 1.0 ppm, chloride of less than 25-200 ppm and TDS of less than 350 ppm.

How to Reduce Your Capital and Operating Expenses

Designing systems around high-flow, low-energy FILMTEC SW30XLE-400*i* and SW30HR LE-400*i* elements can enable significant reductions in capital expense (CAPEX), operational expense (OPEX) or a combination of both, according to the preferences of system designers and operators.

To reduce capital expense, designers can take advantage of the membranes' higher productivity to increase capacity using the same number of pressure vessels and membrane elements, or use fewer pressure vessels and membrane elements to achieve the same level of capacity.

To reduce operating expense, the feed pressure can be reduced while using the same number of elements to achieve the same flow rate, thereby resulting in lower energy costs at lower flux.

To reduce both capital and operating expense, water production and recovery can be increased using the same number of membranes, resulting in lower pump and pre-treatment capital and operating costs.

Table 2 shows each of these options and their practical implications in greater detail.

Table 2. Cost reduction strategies with high-flow, low-energy FILMTEC SWRO membranes

Option	Design strategy	Resulting impact
Option 1: Reduce feed pressure (OPEX reduction).	Compared to design with lower productivity membrane elements, use the same number of pressure vessels and membrane elements, produce same flow rate at same recovery (constant permeate flow).	Lower feed pressure results in a lower energy consumption of the feed pressure pump. Hence, savings in energy cost can be captured.
Option 2: Increase plant output and recovery (OPEX and CAPEX reduction).	Compared to a design with lower productivity elements, use the same feed pressure and the same number of pressure vessels and elements.	Increase water production and recovery. Higher water production means capital savings in pressure vessels and elements; higher recovery means reduced capital cost in pre-treatment and reduced operation cost for pumping and pre-treatment.
Option 3: Higher flux operation at same recovery (CAPEX reduction).	Compared to a design with lower productivity membrane elements, use the same feed pressure and the same recovery, but increase average permeate flux.	Option 3a: Retain same plant output while reducing capital cost with fewer pressure vessels and elements.
		Option 3b: Achieve capacity increase with same number of pressure vessels and elements.

How to Reduce Your Capital and Operating Expenses (cont.)

Table 3 compares the typical pressure, recovery, permeate flow rate and costs of a plant using high-flow, low-energy FILMTEC SW30XLE-400*i*, and SW30HR LE-400*i* elements with the same plant using a standard 6,000 gpd element. The options shown for reducing operating and capital expenses represent basic strategic routes, which may be combined or varied at the discretion of system designers.

We will assume the plant in Table 3 is operated on a feed with 38,000 mg/L at 25 degrees C (77°F). The design is 115 vessels with seven elements per pressure vessel, and a vessel produces 3.45 m^3/h (15.2 gpm). Overall the production of the plant is 9,500 m^3/d. The average flux of this design is 14.0 L/m^2h (8.2 gfd). Recovery of the plant is 45%.

We will evaluate the cost of the membrane stage, which includes the energy cost during five years of operation ("power cost") and amortization of the investment cost for pressure vessels and membrane elements ("capital cost"). Due to higher recovery, additional savings in the pretreatment cost may be achieved, but such savings are not included in this analysis. The following assumptions are taken:

- Operation time: 5 years
- Replacement rate: 20%
- Pump efficiency: 90%
- Power cost: 0.08 US$/kWh

Table 3 includes two scenarios: one with energy recovery devices (90% efficiency), and another without energy recovery. In addition to the power and capital cost over five years, we will also calculate the value per element of converting the plant to the new designs with new elements. The added value per element corresponds to the power and capital cost savings gained by replacing the conventional 6,000 gpd elements.

Whether operating pressure is reduced or output and recovery are increased using FILMTEC SW30HR LE-400*i* elements, the permeate quality (253-258 mg/L) stays roughly the same as with the conventional 6,000 gpd elements, at 99.70% product (248 mg/L).

The permeate quality is improved by 13% to 216 mg/L, however, when higher output is chosen at the original recovery of 45%. Using FILMTEC SW30XLE-400*i* elements, the permeate TDS is still well below the WHO 500 ppm limit (359-368 mg/L) in the case of reducing operating pressure or increasing output and recovery.

In the case of operating at high output and the original recovery, the permeate concentration increases slightly, from 248 to 261 mg/L. All of the scenarios meet a drinking water quality of 500 mg/L and offer a safety buffer of at least 27% for post-treatment and/or variation of operating conditions.

Table 3. CAPEX and OPEX savings with high-flow FILMTEC SWRO membrane elements

Parameter	Standard 6,000 GPD element (reference case)	SW30HR LE-400*i*				SW30XLE-400*i*		
		Option 1: Reduce pressure	Option 2: Increase output & recovery	Option 3a: Higher flux	Option 3b: Higher flux	Option 1: Reduce pressure	Option 2: Increase output & recovery	Option 3: Higher flux
Permeate flow, m^3/d	9,500	9,500	10,000	11,500	9,500	9,500	10,400	9,500
Recovery, %	45	45	47.3	45	45	45	49.2	45
Feed flow, m^3/d	880	880	880	1,070	880	880	880	880
Feed TDS, mg/L	38,000	38,000	38,000	38,000	38,000	38,000	38,000	38,000
Permeate TDS	248	258	253	216	216	368	359	261
Pressure, bar	58.3	55.8	58.3	58.3	58.3	53.8	58.3	58.3
Number of elements	805	805	805	805	665	805	805	567
Number of pressure vessels	115	115	115	115	95	115	115	81
Pump efficiency 90%, energy recovery efficiency 90%								
Energy use, kWh/m^3	2.27	2.17	2.34	2.27	2.27	2.09	2.19	2.27
Power cost, 10^6 US$ in 5 years	2.39	2.29	2.47	2.89	2.39	2.21	2.31	2.41
Water cost, US cents per m^3	19.0	18.5	18.5	18.1	18.1	18.0	18.3	17.6
Added NPV, US$ per element	0	61	61	136	136	129	95	248
Pump efficiency 90%, no energy recovery								
Energy use, kWh/m^3	4.01	3.84	4.01	4.01	4.01	3.70	3.66	4.01
Power cost, 10^6 US$ in 5 years	4.22	4.04	4.23	5.44	4.22	3.90	3.86	4.23
Water cost, US cents per m^3	29.6	28.6	28.2	28.7	28.7	27.7	27.2	28.0
Added NPV, US$ per element	0	128	187	136	136	231	307	271

The physical property data listed are considered to be typical properties, not specifications.

Option 1: Reduce operating pressure.

In this option, operating pressure can be reduced by 2.5 bar using FILMTEC SW30HR LE-400*i* elements or 4.5 bar using FILMTEC SW30XLE-400*i* elements. This corresponds to energy consumption reductions of 4-8% and with high efficiency motors, pumps and energy recovery, energy consumption of 2.09 kWh/m^3 can be achieved. A lower flux design would enable even lower energy consumption, of below 2.0 kWh/m^3. Note that operating higher productivity elements at lower pressure to match the design flow of lower productivity elements may result in an increase in permeate salt concentration; this should be checked.

With FILMTEC SW30HR LE-400*i* elements, the savings in water cost are 0.5 US cents per m^3 with recovery and 1.0 US cent without recovery. With FILMTEC SW30XLE-400*i* elements, even greater savings are possible: 1.0 US cent per m^3 (with energy recovery) and 1.9 US cents (without recovery). Under the financial conditions chosen in this case, the added value is between 61 (FILMTEC SW30HR LE-400*i* elements with energy recovery) and 231 US$ per element (FILMTEC SW30XLE-400*i* elements without energy recovery). This means as long as the price delta is below these limits, the end user will still break even.

To contemplate even greater reductions in operating expenses, we could modify the financial examples of our standard scenario to consider a longer project lifetime than in the example (e.g., 10 instead of 5 years), a lower replacement rate (10% instead of 20%) and use of energy recovery. The water cost then drops from 13.6 to 12.7 US cents per m^3 and the operational cost savings per element is 227 US$.

Option 2: Increase output and recovery.
In this option, water production and recovery are increased to achieve savings in both capital and operating costs. Higher water production means capital savings in pressure vessels and elements; higher recovery means reduced capital cost in pre-treatment and reduced operation cost for pumping and pre-treatment. Note that increasing average flux and recovery may result in changes to permeate quality, fouling behavior and scaling potential; the possible impact should be assessed.

With FILMTEC SW30HR LE-400*i* elements, the added value per element under this option is 61 US$ with energy recovery and 187 US$ without recovery. With FILMTEC SW30XLE-400*i* elements, the operational cost savings per element is 95 US$ with energy recovery and 307 US$ without recovery.

Option 3: Reduce number of elements and pressure vessels and operate at higher flux.
In this option, the number of pressure vessels and elements can be reduced by 17% using FILMTEC SW30HR LE-400*i* elements or by 30% using FILMTEC SW30XLE-400*i* elements. This corresponds to a reduction in water cost of 0.9 US cents per m^3 (operational cost savings of 136 US$ per element) using FILMTEC SW30HR LE-400*i* elements and 1.6 US cents per m^3 (260 US$ per element) using FILMTEC SW30XLE-400*i* elements.

It should be noted that increasing average flux at the same recovery leads to a reduction of salt passage, making this a good option when improved permeate quality is desired.

Alternately, the same number of pressure vessels could be used (115) to increase water production. In this case, the savings would be the same as in the case of reducing the number of elements.

Other options for cost savings.
These are just three examples of how savings can be achieved with the high-rejection, low-energy FILMTEC SW30XLE-400*i* and SW30HR LE-400*i* membrane elements. Plant designers and operators can employ many other methods to optimize their costs, according to the specific project conditions.

How Much Can You Save?

FILMTEC membrane elements can be used across the entire range of seawater applications to lower your total desalination costs. Consult your Dow representative to determine which elements can provide the greatest economic benefit for your specific case.

For More Information

More details about the performance and economic advantages of FILMTEC seawater RO membrane elements are available on our website, www.filmtec.com/sw:

- "*How to Achieve the Lowest Energy Desalination with FilmTec's New High-Flow, High-Rejection Seawater Element*", Form No. 609-00472
- "*Success with FILMTEC SW30HR LE-400 Elements*", Form No. 609-00473
- "*Solutions from FilmTec – Improve Your Desalination Economics*", Form No. 609-00475
- "*Solutions from FilmTec – High-Flow, High Rejection Membranes for the Lowest Total Cost of Desalination*", Form No. 609-00476
- "*How FilmTec's New High-Rejection, Low-Energy Seawater Element Can Reduce Your Desalination Costs*", Form No. 609-00437

Learn more about the economic and performance benefits of ***iLEC*** interlocking endcaps:

- "*Say 'Goodbye' to the Weakest Link*", Form No. 609-00447
- "*How to Improve Permeate Quality Using FilmTec's Interlocking Endcaps*", Form No. 609-00446
- "***iLEC*** *Interlocking Endcaps Make Sea Water Desalination Processing Easier, Less Expensive*", Form No. 609-00466
- "***iLEC*** *Interlocking Endcaps Solve Leakage Problems and Improve Energy Efficiency in Semiconductor Plant*", Form No. 609-00467
- "***iLEC*** *Interlocking Endcaps Withstand Severe Treatment at Reverse Osmosis Facility*", Form No. 609-00468

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