FILMTEC Membranes

How FilmTec's New High-Rejection, Low-Energy Seawater Element Can Reduce Your Desalination Costs

Seawater desalination is an increasingly important method for the production of drinking water. The new high-rejection, low energy/high productivity FILMTEC™ SW30HR LE-400 element allows desalination plants to reduce the cost of producing drinking water from seawater. This Tech Fact bulletin will discuss:

- The benefits of using a high-rejection, high-productivity / low-energy element, including reduced capital and operating expenses
- How to retrofit lower flow systems to take advantage of the cost savings available with the new FILMTEC SW30HR LE-400 element

Reducing Your Operating Costs and Capital Requirements

The FILMTEC SW30HR LE-400 element can reduce your production costs by up to 20 percent by lowering both your operating costs and your capital requirements.

Lower cost operation – When used in a system that was designed with FILMTEC SW30HR-400 elements, the FILMTEC SW30HR LE-400 element offers about 2 to 3 bar (30 to 50 psi) lower pressure with equal salt passage. This amounts to energy savings of about 4 to 5%. For large desalination systems this can be a significant savings.

Lower capital requirements – When operated at higher flux than previously, the FILMTEC SW30HR LE-400 element enables an increase of system water output by up to 20%. This amounts to a capital cost reduction of up to 20%.

There are also combinations that allow lower capital and lower operation cost, e.g. when the recovery of a plant is augmented. The absolute savings will depend on each specific scenario considered. For example, do we aim at a reduction of capital or power cost? Will devices be used? In some situations the savings can amount up to 1.6 US cents per m^3, which is equivalent to an added value of 190 USD per element. The exact savings will be based on your actual design and project parameters.

Designing for Cost Savings

Recently, designers of desalination plants have taken more responsibility in projects by using the "BOOT" type organizational model. BOOT ("Build Own Operate Transfer") and similar concepts require the designer to take greater responsibility for the typical performance of the plant, especially with regard to the cost of desalination. Some BOOT projects have drastically reduced the costs of desalinated water, achieving levels lower than US$0.50 per cubic meter.

Since energy cost is the single largest factor in the cost of a sea water system (usually 20-30% of the total cost of water), it is an obvious target for cost reduction. Customers have recognized that the unique construction and outstanding productivity of FILMTEC elements offer the lowest cost of water.

Form No. 609-00437-804

Designers and operators of sea water desalination plants can take advantage of the higher productivity and higher rejection of the FILMTEC SW30HR LE-400 element to achieve an even greater level of water cost reduction. This element has the following properties:

Topic	Description	Comments
Product name	SW30HR LE-400	
Permeate flow	7,500 gpd (28 m^3/d) $\pm$ 15%	
NaCl rejection	99.75% typical 99.60% minimum	The typical NaCl rejection with this product in the field is 99.75-99.80%.
Boron rejection	90% typical	Two plants had typical boron rejections of 90% and 92%.
Maximum allowable pressure	1,200 psi / 82 bar	An additional brochure on pressure capability of FILMTEC SW30 seawater product is available.

Additional Benefits of Using the FILMTEC SW30HR LE-400 Element

New seawater desalination plants designed to use the 7,500 gpd (28.4 m^3/d) flow and 99.75% rejection FILMTEC SW30HR LE-400 element may gain additional benefits, including:

- Lower pressures
- Higher recoveries
- Higher permeate flow rates

The following example compares the typical pressure, recovery, permeate flow rate and costs of a plant using FILMTEC SW30HR LE-400 elements with the same plant using FILMTEC SW30HR-380 elements. The plant operated on a feed with 38,000 mg/L at 25 degrees Celsius (77°F). Various options for designing this plant are shown and compared to a 6,000 gpd (22.7 m^3/d) and 99.70% rejection element, as offered currently by various manufacturers. 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 percent.

We will evaluate the cost of the membrane stage, which includes the energy cost during 5 years operation ("power cost") and amortization of the investment cost for pressure vessels and membrane elements ("capital cost"). We will not consider pretreatment, cleaning and other membrane plant costs. This is done for the reason that the new 7,500 gpd element can be cleaned as easily as the previous 6,000 gpd element. Due to higher recovery, there might be additional savings in the pretreatment cost, which will however not be included in this analysis. The following assumptions will be taken:

- Operation time: 5 years
- Replacement rate: 20%
- Pump efficiency: 90%
- Power cost: 8 US $ / kWh

We are including two scenarios, one with energy recovery devices (90% efficiency), and another one without. In addition to the power and capital cost in 5 years we will also calculate the added value per element. This is the added value per element that corresponds to the FILMTEC SW30HR LE-400 power and capital cost savings compared to the FILMTEC SW30HR-380.

Form No. 609-00437-804

Additional Benefits of Using the FILMTEC SW30HR LE-400 Element (continued)

With the FILMTEC SW30HR-380 element, which has 6,000 gpd permeate flow and 99.70% stabilized rejection, a pressure of 58.3 bar (857 psi) is needed and the permeate TDS is 248 mg/L. A second pass is not needed to produce a drinking water quality of 500 mg/L. Feed flow to the stack is 7.6 m^3/h (33.5 gpm) and concentrate flow is 4.2 m^3/h (18.5 gpm). The capital cost is 581,000 USD and the power cost in 5 years is 2,390,000 Mio USD with energy recovery and 4,220,000 Mio USD without energy recovery. The power cost amounts to 13.8 US cents 20 per m^3 produced water with energy recovery and 24.3 US cents/m^3 without energy recovery. The water cost, when the membrane stage operation (capital and power) are considered is 19.0 US cents per m^3 with energy recovery and 29.6 without.

Convention on units reported are:

Parameter	US unit	Metric unit
Feed and brine flow	GPM (gallons/minute)	m^3/h (cubic meters per hour)
Permeate flow and daily water production	GPD or MGD (gallons/day or mega gallons/day)	m^3/h or m^3/d
Water cost	USD per 1,000 gallons	US cents per m^3

With the FILMTEC SW30HR LE-400 element, which has 7,500 gpd permeate flow and 99.75% stabilized rejection, there are various design options to achieve economic advantage. Below are three design approaches:

- **Reduce operating pressure of the plant.** In this example the feed pressure can be reduced from 58.3 bar to 55.8 bar (857 to 820 psi) and the permeate TDS would slightly increase from 248 to 258 mg/L. The pressure delta of 2.5 bar corresponds to savings of US cents 0.5 per m^3 with energy recovery (efficiency of 90 percent) and US cents 0.10 per m^3 when energy recovery devices are not used. Over 5 years, the savings would be US$61 per element in the case with energy recovery and US$128 per element in the case without energy recovery.

- **Increase recovery of the plant and increase water production.** The increase in output would be about 5.3 percent at exactly the same capital or operation cost as with a 6,000 gpd and 99.70% product. Recovery would increase from 45 to 47.3 percent, which in many plants would be a desired outcome, since more water can be produced with the same feed source and pretreatment. However, in some plants, the discharge concentration limits would need to be checked and solubility calculations done to check supersaturation of scale-forming salts. Brine-control valves, product tubing and post-treatment capacity would also need to be checked. The permeate TDS would change slightly from 248 to 253. Average permeate flow would change from 14.0 to 14.7 L/m^2h (8.2 to 8.6 gfd), which is in the acceptable range for both open intakes and beach wells. In this option we will reduce the operation cost by producing more water at the same pressure. The savings would amount to 0.5 US cents per m^3 with energy recovery (61 USD added value of an RO element) and 1.4 US cents per m^3 without (187 USD added value per element). There would be additional savings due to smaller pretreatment requirements.

Parameter	SW30HR-380	SW30HR LE-400	SW30HR LE-400	SW30HR LE-400	SW30HR LE-400
Remark	- / -	More permeate, lower OPEX (increased recovery)	More permeate, lower OPEX (same recovery)	Lower pressure, lower OPEX (same recovery)	Less elements, lower CAPEX (same flow)
Permeate flow, m^3/d	9,500	10,000	11,500	9,500	9,500
Recovery, %	45	47.3	45	45	45
Feed flow, m^3/d	880	880	1,070	880	880
Feed TDS, mg/L	38,000	38,000	38,000	38,000	38,000
Permeate TDS	248	253	216	258	216
Pressure	58.3	58.3	58.3	55.8	58.3
Number of elements	805	805	805	805	665
Number of pressure vessels	115	115	115	115	95

Pump efficiency 90%, energy recovery efficiency 90%

Power cost, US$ / 5 years	2,390,000	2,470,000	2,890,000	2,290,000	2,390,000
Water cost, US cents / m^3	19	18.5	18.1	18.5	18.1
Added NPV/element, US$/element	- / -	61	136	61	136

Pump efficiency 90%, no energy recovery

Power cost, US$ / 5 years	4,220,000	4,230,000	5,440,000	4,040,000	4,220,000
Water cost, US cents / m^3	29.6	28.2	28.7	28.6	28.7
Added NPV/element, US$/element		187	136	128	136

Additional Benefits of Using the FILMTEC SW30HR LE-400 Element (continued)

Use same recovery and produce more water or use fewer elements. At the same recovery and same pressure as with a 6,000 gpd, 99.70% rejection element, up to 20 percent more water can be produced which reduces operating cost (OPEX), or the amount of elements can be reduced by 20% which significantly reduces the capital cost (CAPEX). It should be confirmed that the 20-percent higher average permeate flux is operationally acceptable. In this example we could either increase capacity by 21%, from 9,500 m^3/d to 11,500 m^3/d, or we could also reduce the amount of pressure vessels from 115 to 95. The financial impact would be the same and we would reduce the cost of water in the membrane stage by 0.9 US cents/m^3 (saving 136 USD/element), mainly due to a reduction of capital cost from reduced element and pressure vessel requirement. Additional savings would come from associated reduction in piping, racks, etc.

How to Retrofit Seawater Desalination Plants

When a plant operating with 6,000 gpd FILMTEC SW30HR-380 elements is retrofitted to operate with the 7,500 gpd FILMTEC SW30HR LE-400 element, there are various ways to take advantage of the improved flow capability. These are described below.

Reduce pressure of the plant and produce same amount of water as before.
This option requires no constructional change in the pretreatment. Depending on the feed pumps, this can be achieved in various ways.

- For centrifugal pumps with variable speed drives and positive displacement pumps (all positive displacement pumps have variable drive speeds), the power can be reduced, which will translate into direct energy savings.
- For centrifugal pumps without variable speed drives, the pump curve needs to be considered and the pump would usually produce a higher feed flow at the lower pressure. In order to enjoy the benefit of lower energy costs, the pump can be modified by reducing the size of the impellers.
- If this is not possible or desired, then it is not possible to make use of the potential energy savings and the pump has to be throttled by closing the valve between the feed pump and the pressure vessels of the first array.

The reduction of operating pressure leads to a lower membrane flux, whereas the salt flux is only a function of the net salt concentration difference across the membrane and permeability and temperature. Therefore, in this case, it is important to check how the salt concentration of the permeate would change in the projections. As a rule of thumb, the following approach can be used:

$$SP_{new} = SP_{old} * \frac{QP_{new}}{QP_{old}} * \frac{1 - R_{new}}{1 - R_{old}} = SP_{old} * \frac{7500}{6000} * \frac{0.25}{0.3} = SP_{old} * 1.04$$

This means that plants designed with FilmTec or competitive 6,000 gpd flow and 99.70% rejection type products would observe TDS passage increases of 4 percent, which is negligible. The same type of calculation for plants designed with FilmTec or competitive 6,000 gpd flow and 99.60% rejection type products shows that salt passage in these plants would decrease by 22 percent.

Increase recovery of the plant and produce more water.

This option would allow the same feed water flow to be used; hence, there would be no change in intake, pretreatment and feed pumps. It should be verified that the capacity of product tubing, storage and post-treatment can accommodate the higher plant productivity. It should be noted that the average permeate flux would increase slightly, and the flow on the lead element might increase too, however the favorable economics may justify higher rates of fouling associated with higher operating flux.

Supersaturation of salts at the concentrate end of the system should be checked, too. If necessary, the appropriate anti-scalants should be used or the acid dosing increased. Based on a typical recovery of about 40 percent in many sea water desalination plants, the recovery would increase by 2 to 5 percentage points to levels of about 42 to 44 percent. The TDS of the permeate also should be verified, but would usually be equal to or lower than that projected with a 6,000 gpd flow, 99.70-percent rejection element.

Before a decision for this option is made, the higher expected brine concentration also should be compared to the discharge concentration limits and other environmental regulations. It should be verified that brine-control valves, product tubing and post-treatment can handle modified flow rates.

Therefore, increasing recovery to achieve higher productivity with minimal constructive changes is an attractive option.

Follow the pump curve and produce more water.

This option is influenced by the typical pump curve and is a combination of options A and B. At lower pressure, the pump can produce more feed flow, enabling a lower recovery than in option B. The lower recovery results in a lower net driving pressure, which again enables the production of more water out of a plant than option B. It should be verified if the pretreatment is capable of producing a higher amount of feed water.

How to Retrofit Seawater Desalination Plants (continued)

Use same recovery and produce more water.
This option might require a new pump and most likely an increase of the pretreatment capacity. The benefit here is producing more water from the same number of membranes, in cases where an increase in production needs to be higher than in options B and C. The output of the plant would be significantly increased – by up to 20 percent. Fouling should be evaluated due to the higher flux. It also should be verified that, as a consequence of higher feed flow, physical stress on the elements is not increased too much (vessel pressure drop), and physical stress on the elements should be evaluated to ensure that higher feed flow doesn't cause pressure to drop.

A point should be made on fouling with these four options, especially in options B through D, where higher permeate flows from the lead element, higher lead element recoveries and higher average permeate fluxes would be observed. More experience with operation of RO has been gained over the last decade and many plants can be operated harder, causing FilmTec to change its design recommendations. Based on the new recommendations, plants with a design or operation constrained by one of these parameters should explore the benefits of options B through D. In plants that are operating close to the maximum permeate flow, we recommend using retrofit option A. Risk and benefit of the above options will depend on site-specific conditions and the priority of operational vs. capital cost.

Based on the above evaluation, it seems that option B could be the most attractive option: it brings very high impact on water cost reduction with a minimum of changes required and little additional risk. If none of the options above is attractive, then FilmTec recommends using an element with the same flow of 6,000 gpd.

How much can you save?

Consult your Dow representative to determine the economic benefits of using FILMTEC SW30HR LE-400 in your specific case.

FILMTEC Membranes
For more information about FILMTEC membranes, call the Dow Liquid Separations business:

North America:	1-800-447-4369
Latin America:	(+55) 11-5188-9222
Europe:	(+32) 3-450-2240
Pacific (ex. China):	+800-7776-7776
China:	+10-800-600-0015

http://www.filmtec.com

Form No. 609-00437-804