# FILMTEC Membranes

## How FILMTEC Seawater Membranes Can Meet Your Need for High-Pressure Desalination Applications

Higher pressure operation of seawater desalination plants can deliver many benefits, including higher recoveries, higher flux rates and the ability to handle higher feed salinity. Responding to industry needs, FilmTec now offers seawater elements with the highest and most credible pressure specification available. This Tech Fact bulletin will discuss:

- Why and when high-pressure applications are needed
- What is important when constructing membrane elements for high-pressure applications
- How FILMTEC™ membranes have demonstrated long-term, stable performance at high pressures

### The Need for High-Pressure Applications

While operating pressures for seawater desalination in the range of up to 1,000 psi (69 bar) have been common since the early days of reverse osmosis (RO), some of today's applications require higher pressures, around 1,200 psi (83 bar). The main reasons for requiring higher pressure operation include the need for any or a combination of the following:

- Higher recoveries, e.g., up to 60 percent as opposed to conventional recoveries in the range of 30 percent to 40 percent
- Accommodation of feedwater with higher salinity, e.g., up to 45,000 mg/L in the Middle East as opposed to the usual 35,000 mg/L (1 mg/L = 1 ppm)
- Optimized plant output for seasonal temperature variations, such as low winter temperatures
- Improved rejection of specific ions such as boron and of overall salt content

High-rejection FILMTEC seawater elements have now been optimized for operation at high pressures, with a nominal maximum pressure rating of 1,200 psi. Detailed laboratory studies and long-term performance results from various plants have shown that element performance is not adversely affected by these higher pressures.

### When and Where to Use High-Pressure Applications

High-pressure elements were first used in special applications such as wastewater recovery. For example, landfill leachate disposal in countries with environmental restrictions can cost up to US$1,000.00 per cubic meter. Due to the high osmotic pressure of this problematic feed source and the high recovery required from this application, high pressures, of up to 1,400 psi (100 bar) and higher, are required.

## When and Where to Use High-Pressure Applications (continued)

Today, seawater desalination economics show that under certain conditions, it makes economic sense to pay for the higher energy cost and the higher membrane area necessary to obtain higher recoveries. This is especially true in cases where there are constraints on feedwater availability, pretreatment or brine disposal. Recently, there have been two typical situations where higher recoveries were targeted:

- Retrofit of DuPont element-using RO plants – Since DuPont announced its exit from the hollow fiber market, former DuPont customers have switched to spiral wound RO elements, which have proven superior performance in all segments of the RO market. The easiest case of a retrofit is to allow minor or no changes in pretreatment and low- and high-pressure pumping systems and change only the membrane stage. This means, however, accepting higher pressures.

- Capacity augmentations – Many plants want to increase their capacity without making major changes to their pretreatment, feed intake system or feed pumping system. One solution is to re-plumb the system, converting some of the first stage vessels to second stage vessels and adding a booster pump that operates at higher pressures, e.g., between 1,000 and 1,200 psi. This can increase the recovery from a level of 35-45 percent to a level of 55-60 percent.

Based on the above situations, pressures greater than 1,000 psi are needed to optimize the membrane system design. But there are many more situations in which there can be a benefit to high-pressure operation, such as when operating at higher average permeate, using lower temperature feedwater or using higher TDS feed.

## Why FILMTEC High-Pressure Elements Are So Effective

FILMTEC elements are among the most stable, due to the following features:

- High-pressure resistant upper thin-film composite layers (e.g., polyamide, polysulfone)
- High-pressure resistant supports (e.g., polyester, permeate spacer)
- Materials of construction capable of withstanding high pressures (e.g., precision glue lines, outer hard shell)

Various construction methods exist for enabling high-pressure operation, with varying levels of effectiveness. One membrane manufacturer uses a thicker polyester support layer to avoid a mechanical rupture of the membrane into the spacer. This fulfills the goal of higher applied pressures, but at the same time reduces the maximum membrane area that can be rolled into an element, thereby reducing the membrane area available and increasing flux. Less membrane area in turn requires an even higher operating pressure and a higher potential for fouling.

It is also important to produce a stable barrier membrane layer for rejecting the salts. If the layer is not stable enough, the membrane will collapse into the support or a stronger support may be needed to support the weaker membrane.

FilmTec uses a more stable support rather than a thicker support, resulting in pressure operation in the range of 1,200 psi, comparable support capability and increased membrane area. In addition, FilmTec has improved both the polysulfone and polyamide layers of its seawater membranes over the past several years and has succeeded in improving not only the flow capability and rejection performance, but also the stability of the top membrane layer.

## Lab Tests Confirm High-Pressure Capability of FILMTEC Elements

FilmTec has gained comprehensive performance data both in the lab and in the field on high-pressure applications. FilmTec began participating in tests and projects with pressures higher than 1,000 psi in 2001. Performance of the FILMTEC SW30HR-380 element during these tests caused us to increase its pressure rating to 1,200 psi under certain conditions.

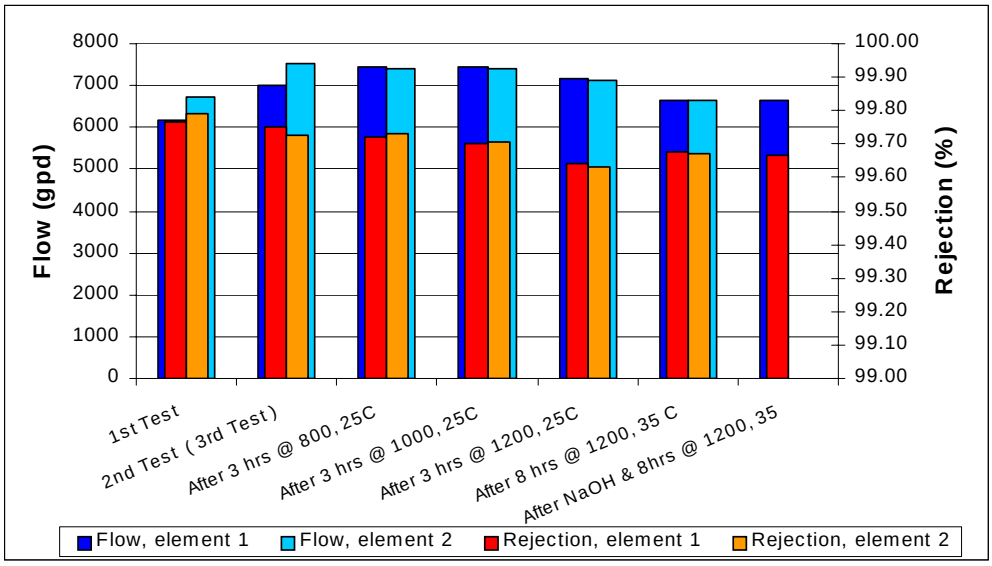
Both individual materials of construction and entire elements have been submitted for laboratory investigation, confirming the high-pressure capability of FILMTEC seawater membrane elements:

- Compaction evaluation of barrier layer – Stability of both membrane flow and rejection were tested at high-pressure conditions, in the range of 1,000 to 1,400 psi. A minor flow loss of 10 percent between 800 psi (55 bar) and 1,200 psi and 15 percent between 800 and 1,400 psi was experienced due to compaction. Rejection remained within +/- 0.1 percentage points of the original measurement. The compaction effect quantified here is reflected in the ROSA (Reverse Osmosis System Analysis) design tool.

- Study of membrane support capability – Typically, when pressure is applied on the membrane support, it deforms slightly. Deformation leads to reduced support and the risk of loss in flow and rejection. FilmTec has developed a new support material that reduces its low amount of deformation by a further 50 percent.

- Chemical stability study – FILMTEC elements were operated for several days at high flux and a high temperature of 95 degrees Fahrenheit (35°C). They then were cleaned at a combination of very high and low pH values at high temperatures (pH value up to 13 at a temperature of 95°F). They were re-tested various times before and after cleaning at a pressure of 1,200 psi. The element showed stable flow and rejection performance. Typical performance of two elements in the above described studies is shown in Figure 1.

Figure 1. Flow and rejection of two elements submitted to high-pressure tests



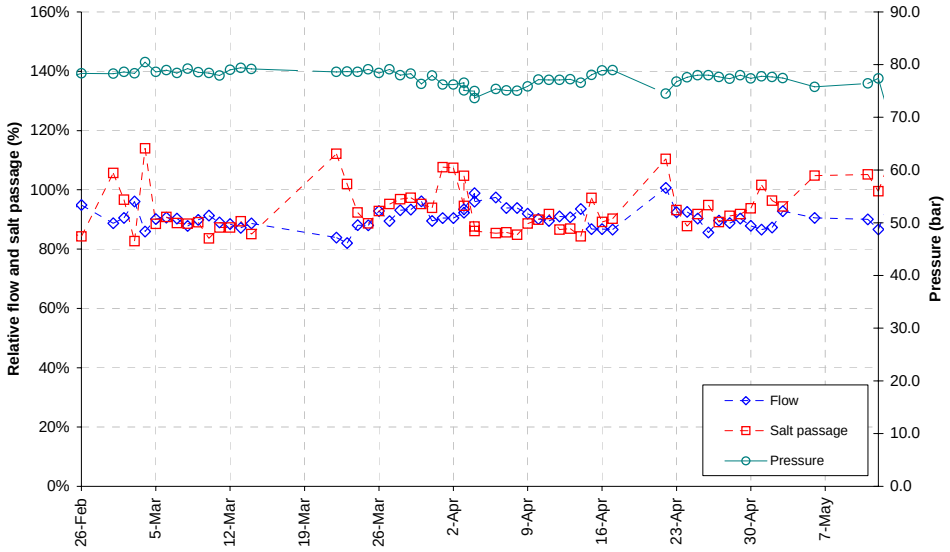
## Field Trials of FILMTEC Elements in High-Pressure Applications

FILMTEC elements have been used in various field trials running at higher pressures, and are operating at high pressures at various other plants. Five examples are given below, with the first described in greater detail.

- Example 1 – Red Sea water, 38,000 to 43,500 mg/L (average 40,500 mg/L), 72 to 84 degrees Fahrenheit, average 79°F (22°C to 29°C, average 26°C), 45 percent to 60 percent recovery. In this field trial, membrane elements were operated at typical permeate vessel flow rates of 16.7 gpm to 17.6 gpm (3.8 $m^3/h$ to 4.0 $m^3/h$). This corresponds to membrane fluxes of 7.9 gfd to 8.5 gfd, average 8.2 gfd (13.5 $L/m^2h$ to 14.5 $L/m^2h$, average 14 $L/m^2h$) with eight elements per pressure vessel. During the operation period, both flow and rejection performance were stable.

  Figure 2 shows two-and-a-half months of operating performance using Red Sea feed, normalized with FTNorm. Relative flow (blue diamonds) and salt passage (red squares) compared to the starting point are shown on the left axis of the graph, with the applied pressure (green circles) on the right axis.

Figure 2. Two-and-a-half months of operation on Red Sea feedwater




Salt passage is between 80 percent and 110 percent of the originally observed value, which amounts to permeate TDS between 260 and 300 mg/L. Flow is between 80 percent and 100 percent of the starting point. With regard to salt passage, there were occasional peaks in the system. Apart from the occasional peaks, however, flow and salt rejection are very stable, between 80 percent and 110 percent of the original value. No negative effect of the high-pressure operation can be seen.

- Example 2 – Caribbean feed, 37,000 mg/L, 84 degrees Fahrenheit (29°C), 40 percent recovery. For several years, elements have been operating with non-pretreated seawater with high iron and sulfur content that tends to deposit on the membrane surface. Considering the high fouling tendency of the feedwater, the plant was operated at relatively high average permeate flux (9.4 gfd, or 16 $L/m^2h$) and continuously operated at 1,200 psi. It showed stable flow and rejection performance.

## Field Trials of FILMTEC Elements in High-Pressure Applications (continued)

- Example 3 – FILMTEC SW30 membrane flat sheet has been used in plate and frame systems for many years on high fouling applications, such as land fill leachate concentrate treatment. Due to the high brine osmotic pressure, the typical pressures in this application are 1,400 psi and higher, up to 2,500 psi (170 bar). The long-term trouble-free operation of SW30 membrane in this application shows that the membrane itself is capable of significantly higher pressures than 1,200 or 1,400 psi.

- Example 4 – An RO plant previously using DuPont elements and operating on Mediterranean feed has been retrofitted with FILMTEC membranes. The need for high recovery resulted in a two-stage design with a first array at low pressure and a second array at higher pressure. The plant, designed at pressures up to 83 bar has been operating with stable performance for about a year.

- Example 5 – A plant with four trains and a collective 7.6 MGD (1,200 $m^3/h$) output, operated on Atlantic Ocean feed, had to increase output without major investment in pretreatment. The plant was able to increase the recovery from 45 percent to 55 percent and higher. Using FILMTEC SW30HR-380 membranes at a pressure of 1,100 psi (76 bar), the plant has enjoyed very stable operating performance for many years, with no cleaning required.

In all of the examples above, the customers involved have been extremely satisfied with the performance of FILMTEC membranes at high pressures.

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