FILMTEC™ Membranes

Retrofitting Hollow Fiber Elements with Spiral Wound RO Technology in Agragua, Spain

Site Information

Location:
Agragua (Galdar), Canary Islands, Spain

Size:
3 x 4,700 m^3/d (3 x 1.24 MGD)

Purpose:
Seawater desalination for agricultural use

Time in Operation:
20 months

Comparative Performance:
Train retrofitted with FILMTEC™ spiral wound elements operates at 16.5 bar lower feed pressure and exhibits 28% lower salt passage than the replaced hollow fiber installation.

Train 2 at the Agragua, Spain, seawater reverse osmosis facility (shown as the middle train in the background of this photo) was retrofitted with FILMTEC™ spiral wound elements. The high pressure pump is shown in the foreground. (Photo courtesy of Agragua Desalination Plant)

Introduction

Until the end of the 1990s the reverse osmosis (RO) desalination technology for medium and large capacities was based mainly on two configurations of membrane modules: spiral wound elements and hollow fiber bundles (HF). The withdrawal of Permasep HF technology from the market by DuPont provided an opportunity to retrofit existing HF plants with today's advanced spiral wound elements. The major criterion for success was to improve the process economics and the permeate quality with limited capital expenditure.

In March 2003, one of three trains equipped with Permasep HF at the 14,100 m^3/d (3.77 MGD) seawater RO plant in Agragua, Canary Islands, Spain, was retrofitted with FILMTEC™ SW30HR LE-400 elements. After 20 months of operation, the train retrofitted with FILMTEC elements provides permeate with 21% lower total dissolved solids (TDS) than the trains running with Permasep HF. RO feed pressure is lower by 16.5 bar (239 psi), offering a potential energy cost reduction of 21%.

In the first part of this case history, three different retrofit options with FILMTEC spiral wound elements are described. These options are based on the existing Permasep Train 1 at the Agragua seawater RO facility. In the second part of the case history, the actual performance of Agragua Train 2, which was retrofitted based on one of the options discussed previously, is compared with Permasep Train 1.

FILMTEC™ Membranes

The two types of membranes considered for the retrofit options were FILMTEC™ SW30HR LE-400 and FILMTEC SW30HR-320 spiral wound high rejection sea water elements. The main technical parameters of the elements are given in Table 1. The values are normalized to the following conditions: 32,000 ppm NaCl, 5 ppm boron, 5.5 MPa (55 bar, 800 psi), 25°C (77°F), pH 8, 8% recovery.

Table 1. Technical parameters of FILMTEC™ seawater elements considered for retrofit.

Element	Active Area m^2 (ft^2)	Nominal Flow Rate m^3/d (gpd)	NaCl Rejection (%)	Maximum Pressure bar (psi)	Feed Spacer mm (mil)
FILMTEC SW30HR-320	30 (320)	23 (6,000)	99.75	83 (1,200)	0.86 (34)
FILMTEC SW30HR LE-400	37 (400)	28 (7,500)	99.75	83 (1,200)	0.71 (28)

Retrofit Options

The seawater RO plant of Agragua operates at medium temperature and medium salinity. The plant consists of three trains, each with a capacity of 4,700 m^3/d (1.24 MGD) product water. Train 1 operates at 22.4°C (72.3°F), 42% recovery, and 74 bar (0.4 bar backpressure) [1073 psi, 6 psi backpressure]. The raw water source is sea well aquifer with 38,000 mg/L TDS and SDI < 3. Feed flow is 11,190 m^3/d (3 MGD). The product water is used for agricultural purposes.

Table 2 gives an overview of the key parameters of the original Permasep design at Agragua and the retrofit options. The design options with FILMTEC™ spiral wound elements are based on a fouling factor of 0.8, which is typical for a spiral wound element operated for 3 years in a sea well aquifer application. Because all options were based on the same feed flow of 11,190 m^3/d (3 MGD), the size of the pretreatment did not need to be changed.

Table 2. Retrofit options for Agragua SWRO plant.[a]

Parameters	Permasep	Option 1 Less energy, better quality	Option 2a	Option 2b	Option 3 More water, better quality
			More water, better quality		
Capacity, m^3/d (MGD)	4,700 (1.2)	4,700 (1.2)	5,936 (1.6)	5,936 (1.6)	6,720 (1.8)
Recovery, %	42	42	53	53	60
Feed press., bar (psi)	74 (1072)	59.6 (864)	68.7 (996)	68.3 (991)	72.8[b] (1056)
Element	Permeator B-10	SW30HR LE-400	SW30HR-320	SW30HR LE-400	SW30HR LE-400
Design	—	55(6)	74(7)	60(7)	44(6)+34(6)
Flux, $L/m^2/h$ (gfd)	—	15.97 (9.4)	16.06 (9.5)	15.85 (9.3)	16.10 (9.5)
Product TDS, mg/L	268	191	220	225	233

[a]Operating values from August 2004.

[b]Feed pressure of first stage; second stage is boosted by 12 bar (174 psi).

Option 1 Less energy, better quality

Option 1 is based on FILMTEC™ SW30HR LE-400 elements at the original capacity and recovery of the Permasep installation, which was 4,700 m^3/d (1.26 MGD) and 42%, respectively. The required feed pressure is 59.6 bar (864 psi), which is considerably lower than in the Permasep installation (74 bar, 1073 psi). Therefore, the capacity of the high-pressure pump must be reduced by modification or throttling. The quality of the product water is improved and the TDS of the permeate is 191 mg/L, which is 29% lower than in the original Permasep installation.

Retrofit Options, cont.

Option 2
More water, better quality

In Option 2 reserve power of the pump due to the lower operational pressure of the spiral wound elements is used to increase the recovery from 42% to 53%. The feed flow is the original flow of the Permasep train; the permeate flow is increased by 26%. At these conditions for temperature and feed TDS, 53% is the maximum recovery for a single-stage design, which is still in line with Dow's guidelines for FILMTEC™ membranes for sea well RO feed water. A higher recovery would result in less than the recommended minimum brine flow or would exceed the maximum allowable recovery of a single element.

Options 2a and 2b use FILMTEC SW30HR-320 elements or FILMTEC SW30HR LE-400 elements, respectively. FILMTEC SW30HR-320 elements use a wide feed spacer of 0.86 mm (34 mil), which reduces the pressure drop along the membrane and enables more effective cleaning of the feed channel. Due to better cleanability, the membrane is especially suitable for feed waters with relatively high fouling potential. For average and good-quality feed waters, FILMTEC SW30HR LE-400 elements with the 0.71 mm (28 mil) feed spacer would be the best choice because they have 25% more area and, at the same specific permeate flux, 25% fewer elements would be necessary. The feed pressure and permeate quality of both system options are almost the same, since both membrane elements are operated at the same flux and contain the same type of flat sheet membrane. Although the recovery is increased by 26%, the feed pressure and the permeate TDS are still significantly below that obtained with the Permasep system.

Option 3
More water, better quality

To further increase the recovery, a 44 + 34 vessel, two-stage design is applied in Option 3. The feed to the second stage is boosted by 12 bar (175 psi) with a booster pump up to 82.4 bar (1195 psi), which is close to the maximum allowable pressure for these elements. In the past the maximum recommended operating pressure for FILMTEC™ elements was 70 bar (1000 psi). Recent improvements in membrane stability increased the maximum pressure to 83 bar (1200 psi). This development enables the elements to work at relatively high osmotic pressure, increasing the recovery up to 60% and more. Improved rejection of the membranes compensates for the higher salt passage that accompanies a higher recovery.

To equilibrate the permeate flow in both stages and keep the size of the second-stage booster pump as small as possible, a permeate backpressure of 8 bar (116 psi) is applied in the first stage. The feed pressure of the first stage is still 1.2 bar (17 psi) lower and the TDS of the total product is still 15% lower than the Permasep installation.

Energy Costs

Table 3 gives a comparison of energy costs for the different retrofit options. Costs for energy are approximately 30% to 35% of the total costs. With respect to energy consumption, Options 2a and 2b are identical. They are summarized under Option 2. For Option 3 the feed pressure after the booster pump of the second stage is considered for the energy calculation.

The energy requirement for all options is significantly lower compared to the Permasep installation. This is due to the relatively high permeability of the low energy membranes for the retrofits. Option 1 allows a direct comparison with the Permasep design since it is based on the same system recovery and same capacity. The reduction in energy costs based on product water is 18.2%. Options 2 and 3, which are based on higher recoveries, result in energy savings of 15.6 and 4.6%, respectively.

Energy Costs, cont.

Table 3: Comparison of energy costs for the retrofit options.

Parameters	Permasep	Option 1	Option 2	Option 3
System recovery, %	42	42	53	60
RO feed pressure, bar (psi)	74 (1073)	59.7 (866)	68.7 (996)	81.2 (1178)
RO system pressure drop, bar (psi)	0.01 (0.15)	1.2 (17)	1.0 (14.5)	2.9 (42)
High pressure pump and motor efficiency, %	85%	85%	85%	85%
Efficiency of energy recovery, %	85%	85%	85%	85%
Energy consumption, kWh/m^3 (kWh/gal)	3.35 (0.012)	2.75 (0.010)	2.83 (0.01)	3.20 (0.012)
Power cost, $/kWh	0.080	0.080	0.080	0.080
Energy cost, $/$m^3$ ($/thousand gal)	0.268 (1.02)	0.220 (0.83)	0.226 (0.86)	0.256 (0.97)
Relative energy cost comp. to Permasep, %	100.0	81.8	84.3	95.4

Plant Performance after Retrofit

In March 2003 the B-10 Permasep permeators of Train 2 were replaced by FILMTEC™ SW30HR LE-400 spiral wound elements with an active area of 37 m^2 (400 ft^2). The rejection and capacity is 99.75% and 28 m^3/d (7500 gpd), respectively. Parameters of Train 2 include:

- Capacity: 4,700 m^3/d (1.24 MGD)
- Recovery: 42%
- Temperature: 22.4°C (72.3°F)
- Feed TDS: 38,000 mg/L
- Configuration: 60 (6) FILMTEC SW30HR LE-400
- Average permeate flux: 15.41 L/m^2/h (9.1 gfd)
- Original feed pump (throttled)

The retrofitted train comprises 60 pressure vessels with 6 elements per vessel. The raw water is taken from a sea well aquifer. Because of the tight product water requirements, it was not possible to increase the recovery as described in Options 2 and 3. Option 1 was the best choice, keeping the feed flow and recovery of the former Permasep train constant. The higher permeability of the new membranes is not used to increase the productivity of the current plant. Instead, the high pressure of the pump is throttled to the pressure required by the spiral wound elements. Table 4 shows the performance of Train 2 at start-up and after 20 months of operation compared to the retrofit design values and to the still-operating Permasep Train 1.

Table 4: Performance with Permasep and retrofit design with FILMTEC™ elements.

	Feed Pressure bar (psi)	Flux L/m^2/h (gfd)	Product TDS mg/L
Permasep Train 1	74 (1050)	—	268
Retrofit, design with FILMTEC elements (after 3 years)	59.7 (850)	15.41 (9.1)	212
Retrofit Train 2, start-up (normalized)	56.9 (800)	15.41 (9.1)	207
Retrofit Train 2, 20 months after start-up (normalized)	57.5 (834)	15.41 (9.1)	193

Plant Performance after Retrofit, cont.

The operational data of Train 2 is normalized to a temperature of 22.4°C (72.3°F), a capacity of 4,700 m^3/d (1.24 MGD), and a recovery of 42% using the ROSA design program. The performance of Permasep Train 1 was determined under these conditions. The design pressure of Train 2 with FILMTEC™ elements is based on a fouling factor of 0.8, which corresponds to approximately 3 years of operation (sea well). After 20 months, the operational data gave a fouling factor of 0.94, which is reflected by a feed pressure of 57.5 bar (834 psi) at design conditions. The feed pressure of the retrofitted train is significantly lower (Δ = 16.5 bar; 239 psi) than the pressure of the Permasep installation.

After 20 months, the permeate TDS of Train 2 is lower than that of Permasep Train 1 and also lower than the design value after 3 years of operation. Since the start-up no cleaning has been done.

Conclusions

The market withdrawal of Permasep hollow fiber technology offers an excellent opportunity to retrofit HF facilities with today's advanced spiral wound RO elements. Three retrofit options are offered that improve economics of the process and permeate quality with limited capital expenditure. After 20 months of operation, the implementation of one option at the seawater reverse osmosis facility at Agragua, Spain, resulted in 28% lower salt passage and 16.5 bar (239 psi) lower feed pressure without any cleaning. Energy costs could decrease by as much as 21%.

FILMTEC™ Membranes
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