Water Solutions

The Evolution of High Rejection and Low Energy Products for Ultrapure Water System

DuPont™ FilmTec™ ECO elements helped a Taiwanese facility save energy and reduce cleaning frequency

Fast Facts

Plant Location:	Taiwan
Application:	Ultrapure Water for Semiconductor Industry
Number of trains:	5
Capacity per train:	50 m^3/h (permeate)
Recovery rate:	90%
Array:	4 Vessels (6 elements) + 2V (6E) + 1V (6E)
DuPont™ FilmTec™ RO Elements:	1994 BW30LE-440 2011 Replacement HRLE-440i 2013 1 train replaced with ECO-440i
Design Flux:	29.1 LMH
Inlet Silica:	4-8 ppm
Inlet Conductivity:	80-150 μs/cm
Inlet pH:	8-9 (After NaOH added)

In high-purity water systems, reverse osmosis (RO) membrane technology plays a key role in producing semiconductor-grade purity water. For more than 20 years, a Taiwanese facility has operated a water system supplying high-purity water to manufacture 8-inch wafers.

The raw water comes from the city reservoir, is filtered by multi-media filtration, passes a heat exchanger, and is then deionized by an ion exchange resin system that consists of strong acid cation (SAC), and weak base anion (WBA) exchangers. Apart from weak carbonic acids and silica, most ionic species are removed in the deionization section. The treated water has a conductivity of ≤ 50 μS/cm and a pH range from 5.0 to 6.0. The advantage of using WBA resins in the deionization section is due to their higher operating capacity and regeneration efficiency. However, the weak carbonic acids and silica are not removed from the units.

In order to increase the RO removal efficiency of the weak carbonic acid, silica and total organic carbon (TOC), sodium hydroxide is added to raise the pH before the water is fed into the RO system. Vacuum degasifiers and TOC ultraviolet destruction units (TOC-UV) are used to remove gases (oxygen and remaining CO_2) and trace amount of organic matter. Since the silica level is still high after the RO, a so called Merry-Go-Round configuration is adopted for the mixed-bed (MB) system to ensure the high-purity water is stable and high quality prior to entering the polishing loop[1].

The treated water has a silica level of ~2 ppb and a theoretical water resistant value of 18.2 MΩ/cm. The RO system consists of five trains with a total capacity of 250 m3/h. Each train involves three stages in order to achieve high recovery rate (≥90%). Four pressure vessels are required in the first stage, two in the second stage, and one in the third stage. Each vessel contains six RO elements.

DuPont™ FilmTec™ BW30LE-440 RO elements, the original low-energy RO elements, were used to save energy before June 2011. In order to have higher silica rejection and further increase energy savings, two trains were replaced with DuPont™ FilmTec™ DuPont™ HRLE-440i RO elements (Generation II low-energy RO element) in June 2011 and February 2012, and one train was replaced with DuPont™ FilmTec™ ECO-440i (renamed ECO Platinum-440i) RO elements (Generation II low-energy RO elements) in July 2013.

[1]Possible Energy and Chemical Savings through Upgrading RO Elements, Andy W.C. Chow, Chih-Neng Chang, Joseph S.M. Wang, Chun-ju Chen, and Ronald Wen-Jung Chang, Ultrapure Water, March/April 2013

The initial operating data of BW30LE-440, HRLE-440i and ECO-440i RO elements are listed in Table 1. Key observations include:

- Performance of BW30LE-440 versus HRLE-440i:
  - HRLE-440i RO elements produce 15.6% more water at a better quality (55.2% less silica) at the same feed pressure.
- HRLE-440i versus ECO-440i:
  - ECO-440i elements require 2.7 bar lower feed pressure while producing the same permeate flow.
  - The LDP (Low Differential Pressure) feed spacers used in ECO-440i RO elements are a key advantage which reduce pressure drop across the RO unit and lower energy consumption.
  - ECO-440i element's permeate silica quality is much better.

When the upstream RO elements reject more silica, regeneration frequency of the mixed bed system can be reduced, leading to more cost savings in chemical consumption and wastewater discharge.

As shown in Figure 1, from 2008 to 2012, the RO elements had to be cleaned once a year on average. Figure 2 compares the permeate flow and system pressure drop of HRLE-440i RO elements with ECO-440i RO elements in the first cycle of cleaning. The results illustrate that when the ECO-440i RO elements are used, the RO unit has a lower initial pressure drop and a lower pressure drop increase during the cycle than with HRLE-440i.

ECO-440i RO elements not only operate at lower feed pressure which results in energy saving but also have a lower fouling tendency which reduce the RO cleaning frequency from once every year to one and half years.

Table 2 demonstrates how the continuous development of low-energy RO elements can help you reduce operating costs. When aged BW30LE-440 RO elements were upgraded with HRLE-440i RO elements, each RO element saved an estimated USD $223 in total operating costs over its lifetime. An extra USD $165 was saved with the use of ECO-440i RO elements.

Table 1: Startup data of BW30LE-440, HRLE-440i and ECO-440i

RO Elelments	BW30LE-440	HRLE-440	ECO-440
Feed pressure (bar)	10.5	10.5	7.8
System pressure drop (bar)	4.4	4.7	1.9
Permeate flow (m^3/h)	45	52	52
Permeate silica (ppb)	344	154	106

Table 2: Cost saving via upgrading the aged

RO Elelments	BW30LE-440	HRLE-440	ECO-440i
Specific energy (KWH/m^3)	0.43	0.40	0.33
Energy saving per element NPV ($)		135	270
Cost saving by prolonging MB cycle time per element NPV ($)		88	118
Cost saving per element NPV ($)		223	388

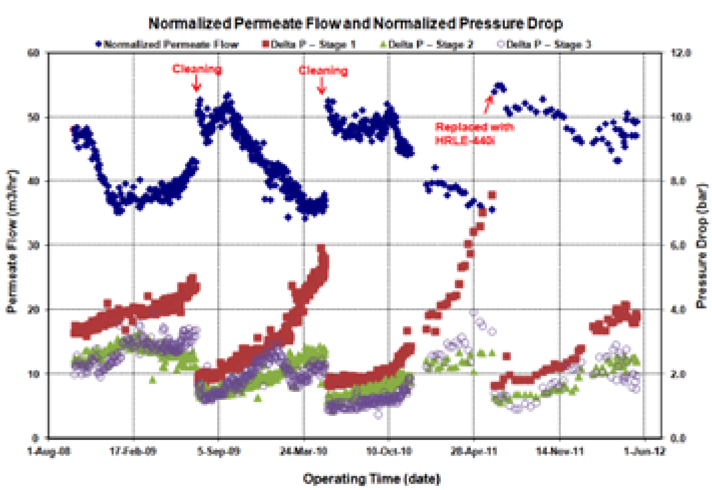

Figure 1. Normalized permeate flow and normalized stages pressure drop in 2008-2012.

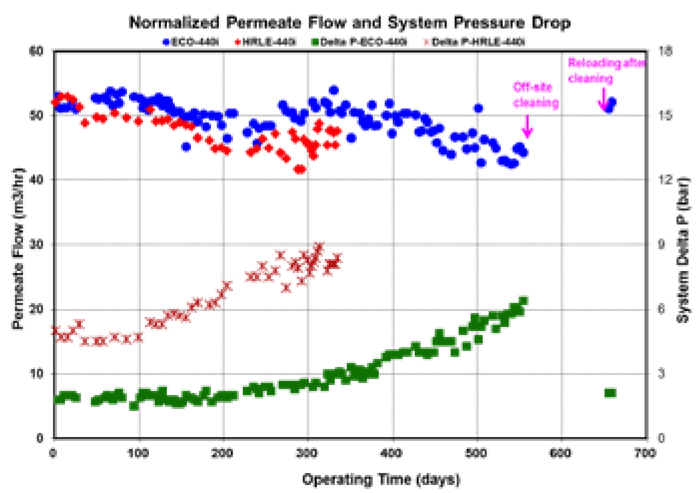

Figure 2. Permeate flow and normalized system pressure drop comparison between HRLE-440i and ECO-440i elements in the first cycle of cleaning.

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