**Site Information**

Location: Freising, Germany  
Purpose: Stop o-ring leakage and determine the effect of *iLEC*™ technology on permeate quality and energy consumption  
Date of Installation: May 2003  
Comparative Performance: *iLEC* stopped the leakage while improving permeate quality and decreasing energy consumption

The use of *iLEC*™ technology resolved leakage problems at the Texas Instruments–Freising plant. (Photo courtesy of Texas Instruments)

**Introduction**

Texas Instruments (TI) in Germany is headquartered in Freising, near Munich. The Freising site (TI-FFAB) houses research and development activities related to TI's mixed signal and logic products and includes an advanced BICMOS/CMOS wafer fab operation. Freising is also the headquarters for European sales and marketing activities for TI semiconductor products. The site was founded more than 30 years ago and today employs more than 1,200 people.

The sliding membrane interconnector, currently an industry-wide feature of spiral-wound membrane elements, must be lubricated to maximize sealing performance and to ensure longevity. Because the water at TI-FFAB is intended for use in semiconductor processing, o-ring lubricants are not permitted. The lack of lubricants shortens seal life and raises the likelihood of leakage from worn and abraded o-rings. Such leakage impairs permeate quality, while the associated o-ring abrasion is a source of particulate contamination.
FILMTEC™ semiconductor grade (SG) elements with \textit{iLEC™} were installed in one pressure vessel in the second stage of the reverse osmosis (RO) system. The objective was to stop the o-ring leakage and document improved permeate quality and reduced energy consumption. This was also an opportunity to demonstrate the benefits associated with FILMTEC SG elements. FILMTEC SG elements are specially formulated to provide low levels of total organic carbon (TOC) upon start-up and lower operating costs by reducing TOC rinse-out time.

**Benefits of iLEC™ Technology**

iLEC™ technology eliminates the need for multiple sliding seals between adjacent membrane elements, reducing the number of sealing surfaces per connection to a single, axially compressed o-ring. The result is a seal that is lubricant- and maintenance-free for the life of the element.

Long-term permeate quality is improved through prevention of o-ring leaks that occur as o-rings gradually become worn and abraded. In contrast to standard interconnectors, the possibility that o-rings will be pinched or damaged during installation, requiring the "debugging" of leaks upon start-up, is also eliminated.

The interlocking endcaps also remove the permeate-side flow restriction associated with the small flow diameter of conventional interconnectors, reducing energy costs. Figure 1 contrasts cross-section views of the small flow diameter and multiple sliding seals of the conventional interconnector with the larger diameter and fixed seal of the elements with iLEC technology.
Elements using iLEC™ technology are installed in minutes with a level of effort comparable to that associated with standard interconnectors. Special snap and alignment features provide tactile, audible, and visual feedback to inform the installer that a positive connection has been made between adjacent elements. Optional tools are available to make the handling of elements even easier (Figure 2).

Plant Design
A flow diagram of the TI-FFAB plant is shown in Figure 3. A system with three RO trains commenced operation in 1996, and a second system with three more trains was brought online in 2001. Each train comprises a 4-by-2 array of six-element pressure vessels.

The train retrofitted for this comparison operates at 90 percent recovery and produces approximately 40 m³/h (175 gpm) of permeate. A permeate concentration of 3 ppm TDS (total dissolved solids) is obtained from a feed of 535 ppm TDS. The permeate TOC concentration is typically below 100 ppt, measured using a Sievers Ultra TOC analyzer. The feed pressure is 20 bar (290 psi) and the temperature is 13°C (55°F).

While permeate conductivities of 10 μS/cm are typical, conductivities exceeding 20 μS/cm trigger corrective action. The cost associated with high conductivity is very real, approaching $2,200 per month per train in additional ion exchange regeneration expenses as permeate conductivities approach the 20 μS/cm limit.
Plant Performance Using \textit{iLEC}™ Technology

FILMTEC™ SG30-400 elements fitted with \textit{iLEC}™ and control elements commenced operation in May 2003. The \textit{iLEC} elements addressed the leakage problems associated with the plant’s sliding couplers. In Figure 4, a comparison of before-and-after conductivity profiles for Vessel 5 shows how the quality of the permeate, flowing from the end of the vessel near Element 1, was dramatically improved. The permeate conductivity decreased from 34 to 11 μS/cm. A leak between Elements 1 and 2, attributed to wear and abrasion of the sliding seal, was eliminated.

Figure 4. Comparison of conductivity probe data for Vessel 5, before and after replacement of 4-year-old elements with FILMTEC™ SG30-400 elements with \textit{iLEC}™.

Further evidence of the damaged seal is shown in Figure 5, where a photograph records the residue deposited by the worn o-ring. Leaks and contamination from worn o-rings are especially common in semiconductor applications, where lubrication of the seal is not permitted.

Figure 5. Evidence of o-ring abrasion found inside element at Position 1 of Vessel 5.
The sliding couplers removed from the system were also the source of energy-consuming backpressure. For comparison, FILMTEC™ SG30-400 elements with and without iLEC™ were installed into side-by-side vessels in Stage 2. The iLEC technology reduced the average backpressure from 3.3 psi (0.22 bar) to 0.8 psi (0.05 bar). A plot of the permeate backpressure at each element position is shown in Figure 6. The driving pressure for permeation through the membrane is directly impacted by permeate backpressure. Consequently, the reduction afforded by the iLEC technology would provide a one percent to two percent energy savings if deployed in all six vessels. This comprises approximately $25 per element in energy savings over five years, a small but significant decrease in element life-cycle cost. Significantly higher savings are observed in systems using vessels with seven or eight elements.

### Figure 6: Comparison of permeate backpressure for elements installed in side-by-side vessels in Stage 2.

Plant Performance Using FILMTEC™ SG Elements
The FILMTEC™ semiconductor grade (SG) elements offered dramatically reduced start-up time and cost. Previous start-up procedures for new elements required from several days to several weeks of rinse-out to prevent contamination of the downstream processes with organic compounds rinsed from the membrane. In addition, rinse-out was at reduced flux levels due to limited wastewater treatment capacity. The FILMTEC SG30-400 elements, by contrast, were rinsed for no more than a few minutes before the permeate was process-ready. Just minutes after start-up, the permeate TOC from a single vessel of new FILMTEC SG30-400 elements was 0.08 ppm, and the next day the concentration was 0.07 ppm. This was equal to the overall system permeate TOC of 0.07 ppm, obtained on a feed concentration of 4.55 ppm.

The cost of a 72-hour rinse-out procedure for a single train was estimated by Texas Instruments to include $700 for wastewater disposal, $250 for energy consumed, and $1,450 for additional labor. These charges amount to $67 on a per-element basis, a significant increase in element life-cycle cost.

Conclusion
The FILMTEC™ SG30-400 elements with iLEC™ technology exceeded the customer’s expectations. The o-ring problem was addressed and energy efficiency was improved. Rinse-out time was essentially eliminated, reducing start-up time and cost. Considering these results, the customer indicated a desire to refurbish two other RO trains with FILMTEC SG30-400 elements fitted with iLEC technology.
For successful RO system operation – permeate quality, energy efficiency, and start-up performance – revolutionary iLEC™ technology combined with FILMTEC™ SG30 membrane technology, are a perfect choice for today’s ultra-pure water systems.

For More Information
For more information about iLEC™ technology, call Dow Water Solutions:
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