Membrane Desalination
RO developments and outlook
Re reverse osmosis (RO) has come a long way since its first successful salt rejection application in 1959. Critics of RO desalination have pegged the process as too costly or too energy intensive, but upfront prices continue to drop, technology is advancing and alternative energy sources are more prevalent than ever. Additionally, as more facilities use RO to treat brackish water and seawater, the water industry is beginning to recognize some significant application benefits: a small footprint, high-quality finished water and long-term operation and maintenance cost savings, for example.

All the large-scale RO desalination facilities in the U.S. are newer, many having started up in just the past decade. More than 1,300 desalting plants are at work nationwide, producing 400 million-plus gal of (mostly potable) water per day, according to a 2007 report from the American Membrane Technology Assn. Some of these facilities use membranes to remove salt from water, and some employ thermal methods. It is vital to the future of RO desalination, especially here in the U.S., that we keep a close eye on the membrane operations and learn from their experiences. Important RO-desalination facilities to monitor include those operating in Tampa Bay, Fla.; El Paso, Texas; and Yuma, Ariz.

Several industry experts are predicting that the RO desalination market will grow significantly in the coming decade—both domestically and abroad—and I wholeheartedly agree. In the U.S., expect to hear more about RO on the coasts, in areas with saline groundwater and where population counts are closing in on or already exceeding water capacity. Rather than establish new water systems from scratch, utilities serving these areas may find that tapping into existing sources and applying RO for desalination proves to be a more cost-effective, environmentally friendly and publicly accepted decision.

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How did reverse osmosis (RO) technology get started? In order to understand its history, let’s begin with a close look into osmosis. One of the most interesting and fascinating natural phenomena, osmosis is the basis for RO, today’s fastest-growing desalination technology. Natural osmosis governs how waters transfer between solutions with different concentrations. It is also the basis for the way in which human skin and organs function, and how flora and fauna maintain a water balance.

Due to the nature of the RO process, it cannot be characterized as a filtration process or as treatment. As in natural osmosis, water tends to flow from a solution with a lower concentration to a solution with a higher concentration. Where there is a semi-permeable barrier such as a membrane, when pressure is applied to a concentrated solution that exceeds osmotic pressure, clean water will be displaced out of the concentrated solution while salts will remain in the concentrated solution.

Theoretically, salts should not pass through the membrane, but in practice salt leakages occur as a result of the diffusion despite the fact that membrane “openings” are much larger than the molecules of water and many other ions in the water that may pass through the membrane.

The RO process attracted the attention of many scientists and engineers in the middle of the 20th century, but efforts to develop a commercial RO membrane were unsuccessful until the late 1950s. In 1959, a group of scientists at the University of California Los Angeles (UCLA) led by Sidney Loeb and Srinivasa Sourirajan demonstrated an RO membrane that worked. The asymmetric, or anisotropic cellulose acetate, membrane demonstrated by the researchers provided adequate salt rejection at that time. This was the beginning of desalination by RO and membrane desalination. Besides membrane desalination, this was also the beginning of the commercial development of membrane technologies for solid-liquid separation.

The RO process has three major streams:
1. Feed;
2. Permeate (product water); and
3. Concentrate (reject or brine).

The mass balance for the entire system can be represented as follows:
\[ Q_f \times C_f = Q_c \times C_c + Q_p \times C_p \]

In this equation:
- \( Q_f \) = feed flow (gpm or cu meters/hour);
- \( C_f \) = salt concentration in feedwater (mg/L or ppm);
- \( Q_c \) = concentrate flow (gpm or cu meters/hour);
- \( C_c \) = salt concentration in concentrate (mg/L or ppm);
- \( Q_p \) = product flow (gpm or cu meters/hour); and
- \( C_p \) = salt concentration in product water (mg/L or ppm).

The smallest module of the RO system is the RO membrane element. As RO technology developed, the industry came to a consensus on manufacturing standard-size RO membrane elements. The major diameters of the spiral-wound elements are 2.5, 4 and 8 in., with the standard length of single elements at 40 and 60 in.

More recently, the RO industry has developed larger RO elements with diameters of 16, 17, 18 and 18.5 in. While there is no consensus currently on a standard for large-diameter RO—each supplier produces a different size—this situation may change as time passes. Each model of the RO element has certain “fixed” properties that are described and can be found in the element’s specification sheet. Little variation is allowed from the membrane element specification when each element is subjected to factory wet tests.
In a full-scale system, the RO elements are encapsulated in pressure vessels that can hold from one single element up to eight elements per vessel. A number of vessels are mounted on the RO rack or train and can be operated in parallel or in series. Despite the fact that an RO system comprises a number of RO membrane elements with very similar properties, there are a number of design and operational techniques that can make RO system design and operation extremely flexible.

Because they cannot tolerate particulate matter of any kind, RO membranes require pretreatment consisting of different types of filtration and/or separation processes as well as feedwater conditioning by chemicals. In addition, treated water or RO product water needs conditioning and stabilization due to the fact that it is unstable and corrosive as a result. The RO reject carries significant energy, which can be returned back to the process, minimizing and optimizing the overall energy demand for the RO process. The entire RO system should be optimized for capital, operation and maintenance (O&M) and life-span costs of the produced water.

Following the development of RO membranes came development of the low-pressure membranes: microfiltration (MF) and ultrafiltration (UF), which were commercialized for drinking water treatment about a decade ago. Because they provide significant technical benefits and have become cost-competitive, membrane technologies rapidly are displacing and replacing traditional processes verified by the centuries.

As a result, four major membrane types, categorized by membrane pore size, are in commercial use at the present time:

1. MF, with screens particles from 0.1 to 0.5 microns;
2. UF, with screens particles from 0.005 to 0.05 microns;
3. Nanofiltration (NF), with screens particles from 0.0005 to 0.001 microns; and
4. RO, with ranging molecular sizes down to 10 MWCO.

The differences in membrane shape and the type of driving forces can be categorized as follows:

- **Membrane shape type**: Spiral wound, hollow fiber or flat sheet; and
- **Membrane type depending on driven pressure**: Pressure driven (low-pressure MF, UF and high-pressure NF and RO) and immersed, vacuum driven (low-pressure MF, UF only).

### Desal by RO

Given the Earth’s available water resources, there are few alternatives. Engineers and scientists were challenged by President John F. Kennedy in April 1961 when he said: “If we could ever competitively, at a cheap rate, get freshwater from salt water, that would be in the long-range interest of humanity and would dwarf any other scientific accomplishments.” In the long run, seawater is the only long-term, completely reliable source of drinking water for future generations.

Long before desalination by RO was developed, thermal desalination processes already were well commercialized. The oldest non-membrane desalination methods are based on evaporating water and collecting the condensate. The best-known thermal technologies are: multistage flash (MSF), multi-effect distillation (MED) and vapor compression (VC). While MSF, MED and VC use thermal power to separate water from the brine, electrodialysis reversal uses high-voltage current to remove cations and anions from the stream.

The newest commercial technology for desalination is based on membrane treatment. RO and brackish water RO, or seawater RO (SWRO), are the fastest-growing desalination techniques, with the greatest number of installations around the globe. Desalination by RO is beginning to dominate the current and future desalination markets. Many business forecasts predict that desalination by RO will grow at a compound annual growth rate of about 10% annually and will eventually triple the market capacity over the next 10 years, reaching about 55 billion cu meters of water per year. Desalination by membranes, SWRO is beginning to dominate the current and future desalination markets due to the energy recovery utilization, improved membrane properties and lower costs for membrane elements. The current number of membrane desalination installations is close to 80% of all desalination facilities.

While membrane plants using desalination by RO have the largest number of installations, they still provide only a comparable capacity to the thermal processes. The lack of correlation between the number of installations and overall capacities can be explained by the development of desalination. Thermal processes have been on the market for more than five decades, and most of them...
provide relatively high capacities. This ratio is expected to change significantly, though, because most of the desalination systems currently designed, constructed and considered for construction are based on membrane technology.

For example, currently the largest operational membrane desalination plant in the U.S. is the Tampa Bay SWRO, with a capacity of 25 million gal per day (mgd), with provision for up to 35 mgd. The plant went into operation in 2003. The newly considered 50-mgd Carlsbad desalination plant plans to use SWRO membrane technology. A much larger membrane desalination facility was commissioned in May 2005 in Israel: the Ashkelon SWRO, with a capacity of 44 mgd, which was expanded to 88 mgd at the end of 2005. In addition, very large SWRO projects are currently being developed in Australia and Spain.

When different technologies, including thermal processes, were evaluated for these large desalination facilities, membrane desalination SWRO provided the most cost-effective solution for all considerations, including capital expenditures, O&M and cost per 1,000 gal of treated water based on 20 to 30 years of operation. As positive results emerge from large SWRO facilities in operation, there will be greater security and confidence in building SWRO plants with larger capacities. A major factor that has prevented the widespread use of membrane desalination has been the high energy demand for the process, which is affected mainly by the water salinity (total dissolved solids), water temperature and system recovery.

Advances in the development of major SWRO components have led to a preference for membranes over thermal processes and have boosted growth in the number of RO plants worldwide. These include:

- The development of the energy recovery exchangers of different configurations with a typical energy recovery of more than 90% of the concentrate stream;
- Development of new advanced membrane materials such as thin-film composite (TFC) membranes with advanced membrane properties;
- Advances and collection of design and operational experience in the use of SWRO;
- Improvements in pretreatment, such as the introduction of MF and UF; and
- Significant reduction in capital and O&M costs.

Salt rejection and individual ion rejection by RO technology is very high, reaching 99.8% salt rejection by a single RO membrane element at the standard conditions that are available on the market. When compiled with the RO system, the overall salt rejection by the RO system can reach 95% or more. The average nominal rejection of individual ions by RO is shown in Figure 1.

**Osmosis & RO Outlook**

Three major improvements in the technology can be identified:

1. **Improvements of the RO technologies and RO process.** Membrane materials, energy optimization, large-scale plant design optimization, construction and procurement optimization.

2. **Nanomaterials and nanoparticles.** Modification of the RO materials utilizing nanomaterials and nanoparticles to achieve lower energy demand for the process and higher permeability of the membranes while keeping membrane fouling low or comparable to the existing commercial RO membrane materials.

3. **Forward osmosis.** Utilizing draw solution with high osmotic pressure when utilizing ammonia, carbon dioxide or other ingredients for the draw solution.

4. **Pressure-retarded osmosis.** Utilizing differences in osmotic pressure of different solutions to generate osmotic power where rivers meet oceans or wastewater is discharged to the sea.

RO has become one of the key technologies for desalinating water. RO is one of the fastest-growing technologies spreading around the globe due to its advanced features and the reduction in cost as the technology develops. It has become cost effective for many water and wastewater treatment and desalination applications, replacing conventional processes while providing benefits for new construction, upgrades and retrofits of existing facilities.

RO also offers the advantages of high effluent water quality, a compact footprint and simpler operation compared to conventional treatment processes.

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For more information, write in 1101 on this issue’s Reader Service Card or visit www.wwdmag.com/lm.cfm/m031101.
Califonia’s Orange County Water District (OCWD) operates the Groundwater Replenishment System (GWRS), an advanced wastewater treatment facility located in Fountain Valley, Calif. As an indirect potable reuse facility, the GWRS provides 70 million gal per day (mgd) of purified wastewater for groundwater recharge and maintenance of a seawater intrusion barrier for protection of the local groundwater basin. The facility was commissioned in 2008 and consists of three major treatment processes: microfiltration (MF), reverse osmosis (RO) and advanced oxidation (ultraviolet disinfection with hydrogen peroxide). Source water to the GWRS consists of secondary municipal wastewater provided by the neighboring Orange County Sanitation District. The overwhelming success of the GWRS project has propelled OCWD officials to embark on an expansion from its current capacity of 70 mgd to 100 mgd. Increased capacity was already incorporated into the initial plant design, so current expansion efforts have focused principally on up sizing the three treatment processes. Increasing production to 100 mgd will require an estimated 42-mgd increase in RO pretreatment capacity. Because major infrastructure already exists, expansion is somewhat limited to the use of similar MF technologies. This would result in reduced capital cost, as the technology could be incorporated readily into the existing facility. Impacts, therefore, would be minimized.

**MF Process**

The GWRS currently utilizes the CS technology of Siemens Water Technologies. This process consists of a submersible MF system comprised of 26 basins, each housed with membranes constructed of polypropylene (PP) material. Since demonstration testing and commissioning of the GWRS, Siemens developed a polyvinylidene fluoride (PVDF) membrane that is interchangeable with the existing CS system. The chemistry of PVDF potentially offers several advantages over the PP membrane, including higher polymer durability (which can lead to prolonged membrane life and more aggressive chemical cleanings), higher permeability (reduced capital cost and operational cost) and improved filtrate water quality (enhanced RO pretreatment). The PVDF membrane represents the only alternative to the PP membrane presently installed in the GWRS due to existing patents. Advancements associated with the PVDF membrane could translate into providing all of the required production needed for expansion of the GWRS with limited investment in additional infrastructure. The 26 basins currently are loaded with 608 membranes each (the design capacity is 684). There are also two vacant basins that were constructed for eventual expansion.

By loading all 28 basins with PVDF membranes and operating the membranes at a higher flux rate (relative to the PP membranes), the needed increase in RO pretreatment capacity could be met without constructing additional MF basins and infrastructure. Continuing to utilize the PP membrane would require not only filling out all

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**Figure 1. MF Membrane Demonstration Cleaning Procedures**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Polypropylene</th>
<th>PVDF</th>
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<td>Chemical Cleaning</td>
<td>Step 1: 2% w/w caustic 0.5% w/w Siemens detergent</td>
<td>Step 1: 2% w/w citric acid</td>
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<tr>
<td></td>
<td>Step 2: 2% w/w citric acid</td>
<td>Step 2: 500 mg/L hypochlorite (free chlorine)</td>
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<tr>
<td>Maintenance Wash</td>
<td>N/A</td>
<td>200 mg/L hypochlorite (free chlorine) or 0.2% w/w sulfuric acid</td>
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Polypropylene membranes, each containing 15,000 fibers with a nominal pore size of 0.20 microns.
Objective

The objective of this study was to assess PVDF membrane performance and determine expansion design criteria based on operations with secondary wastewater unique to the GWRS. To satisfy the objectives, onsite pilot testing was conducted at the GWRS pilot-plant facility—a facility dedicated to the evaluation and optimization of the GWRS processes. Over the course of these trials, higher flux rates and alternative cleaning strategies (e.g., maintenance washes) would be tested to optimize PVDF membrane performance. This would provide critical information regarding flux improvements, chemical usage, power consumption and, most importantly, impacts of these process changes on existing operations.

Methods

Membrane operating parameters.
The guidelines for treating secondary wastewater with the Siemens CS process are not only membrane dependent, but site specific as well. Only through pilot testing can actual operating parameters be established successfully.

The typical operating flux for the PP membrane in the GWRS is 20 gal per sq ft per day (gfd), with a backwash interval of 22 minutes and an average chemical cleaning interval of 21 days. The stated range of operating flux for the PVDF membrane is 25 to 30 gfd, with a backwash interval of 22 minutes. The anticipated cleaning interval is 30 days. Additionally, the PVDF membranes routinely undergo maintenance washes—30-minute cycles in which the basin is taken out of service, chemicals added and the contents circulated. The frequency of maintenance washes depends on the fouling nature of the source water being treated, and can take place as often as daily.

Pilot systems. Evaluations were conducted using two Siemens pilot systems: one loaded with PP membranes and the other with PVDF membranes. This parallel evaluation allowed for critical comparisons between the two membrane chemistries. Without operating in parallel, it would be difficult to decipher PVDF performance relative to water quality, operating conditions, membrane type, etc.

The PVDF membrane was scheduled to be evaluated at elevated flux rates of 15% to 40% higher than the existing GWRS MF design flux of 20 gfd. Ultimately, the PVDF membrane would have to exhibit successful operations at a flux rate of 28 gfd to be considered in the present expansion scenario. Conducting these evaluations would allow staff to assess the claims of enhanced permeability and the potential increase in fouling kinetics commonly associated with operating high-flux membranes.

As the membranes continue to operate, backwashing becomes less effective as foulants accumulate on and within the membrane pores. Chemical cleanings are then employed to remove the foulants and restore membrane permeability. The cleaning regimens performed on both membrane types are presented in Figure 1.

Cleaning at the pilot scale was necessary to demonstrate effectiveness of the cleaning procedure. Because new membranes were used, their initial performance may not be representative of typical operations. Multiple trials were conducted, therefore, to assess PVDF runtimes to any appreciable extent.

Results

With the engineering team needing direction on which MF membrane to design into the expansion, testing was fast-tracked and completed over the course of six months. During this period, six trials were completed with the PVDF membrane and four trials with the PP membrane. A detailed breakdown of all trials is summarized in Figure 2.

Overall, the PP membrane outperformed the PVDF membrane in all trials, averaging 16 days vs. eight days for the PVDF membrane. Upon completion of trial No. 1, PVDF operating flux was increased 30% to 26 gfd. Additional trials were conducted at this operating flux with the inclusion of maintenance washes at various intervals—from 24 hours to 72 hours. These efforts failed to extend PVDF runtimes to any appreciable extent.

Conclusions

The PVDF MF membrane has exhibited successful performance on a variety of water types other than municipal wastewater. Demonstration testing using secondary wastewater at OCWD, however, indicated that the PVDF membrane could not achieve the projected runtimes while operating at the asserted elevated flux rates. Shortened runtimes precluded trials at the targeted 28-gfd flux rate. Routine maintenance washes with strong oxidants were introduced as a means of extending PVDF runtimes. The frequency and chemical composition of the maintenance washes provided no benefit in enhancing PVDF membrane permeability as well as the effectiveness of the cleaning procedures.
membrane operations. Even incorporating daily maintenance washes failed to extend the PVDF cleaning intervals.

Having a pilot-plant facility and onsite resources available to conduct these evaluations proved invaluable. It provided OCWD with critical information regarding the selection of MF membranes for the existing facility and future expansion of the GWRS. Relying on documented successes at other facilities as sole selection guidance would have resulted in plant performance that was significantly different from what was designed.

Membrane performance is highly dependent on the type of water treated as well as where the water is treated.

Collaborating with Siemens early in the procurement process proved to be beneficial to both parties, as these evaluations alleviated future problems the GWRS likely would have experienced by introducing the PVDF membrane. As a result, OCWD has continued using the PP membrane in the existing facility and will use it in any future GWRS expansion. MT

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### Table: MF Membrane Demonstration Performance Summary

<table>
<thead>
<tr>
<th>Trial</th>
<th>Flux (gfd)</th>
<th>Runtime (days)</th>
<th>Flux (gfd)</th>
<th>Runtime (days)</th>
<th>Maintenance Wash (hours)</th>
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Figure 2. MF Membrane Demonstration Performance Summary

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The PPL Montana (PPLM) Colstrip Steam Electric Station is a 2,276-MW coal-fired power plant located in Colstrip, Mont. It consumes 10 million tons of coal per year, which is harvested at the nearby Rosebud Mine in Colstrip. During daily operation of the power plant, up to 14 million gal of raw water from the Yellowstone River is pumped 30 miles to Colstrip for plant use.

The plant is permitted as a zero-discharge facility. The zero-discharge design and plant operation have resulted in numerous storage ponds at the power plant site, with about 1 billion gal of inventory. This excess inventory is threatening the plant’s operation. PPLM staff determined the need to reduce the inventory by 750 million gal with a treatment system—one operational within a year and capable of meeting the goal within five years. Reusing water internal to the system permits a reduction of raw water introduced to the system, as well as a reduction in the stored water inventory.

Initial Assessment

A review of the raw water quality and treated water requirements revealed several issues. All of the potential source waters are high in specific conductance, total dissolved solids (TDS), calcium, magnesium and sulfate. Substantial TDS removal is necessary to meet the treated water requirements of about 1,000 to 2,000 µS/cm.

Multiple technologies were investigated to determine their effectiveness in treating the identified source water. Two proven treatment technologies—membrane treatment and evaporation/crystallization—were determined to provide a treated water meeting the specific conductance requirement for these conditions. Other mature technologies (e.g., ion exchange, electrodialysis and thermal evaporation) had inherent qualities that, upon initial investigation, rendered them unsuitable for this application.

MF RO

The tight time frame of the project led to a more traditional treatment approach of microfiltration (MF) membranes followed by reverse osmosis (RO) membranes. The hardness of even the highest-quality waters would require softening for pretreatment. Bench tests were completed that resulted in two-stage softening with high lime and soda ash chemical doses. The two-stage softening followed by MF/RO would be an effective treatment process, but the high chemical doses and potential complex operations for the power plant staff led to further investigations.

A modified budgeting timetable allowed for evaluation of emerging technologies. A vibratory shear enhanced processing (VSEP) membrane technology that used little to no chemical pretreatment, required minimal manpower to operate and provided high-quality product water was applicable to the PPLM Colstrip conditions.

VSEP, manufactured by New Logic Research, uses membrane filtration such as nanofiltration (NF) or RO with one fundamental modification. The filtration method incorporates torsional vibrating action to hinder contact fouling of the membrane. The vibration discourages sustained corruption of the membrane’s pore structure by solid matter. The ability to separate concentrated solid solutions from water alleviates the chemical coagulation and precipitation pretreatment requirement inherent to RO technology.

Pilot-Testing Results

A pilot test was conducted during the period from late June to late October 2008. The pilot was run in different conditions.
modes to determine the optimum system operation. The approach was to start at a low recovery and work toward the highest recovery achievable in which the required cleanings were at least five days apart.

It was found that 75% recovery at 210 psi achieved the desired permeate quality with cleaning required about every five days. Figure 1 shows the feed water, permeate and concentrate water quality at the optimum pilot unit settings. The permeate conductivity of 1,400 µS/cm using an NF membrane is adequate to introduce permeate into the raw water feed to the plant. The concentrate conductivity averaged about 10,500 µS/cm. The concentrate of this water quality can be routed to one of the onsite evaporation ponds that has a conductivity of more than 15,000 µS/cm.

It had become evident a few weeks into the pilot study that the VSEP technology was going to meet the water treatment goals based on the water quality and flux. A full-scale plant design was initiated to include five VSEP NF membrane modules (expandable to eight modules) plus all of the ancillary components. Results of the pilot indicated that one membrane module should treat an average of about 45 gal per minute with a 75% recovery.

The NF-270 NF membranes selected are not capable of rejecting monovalent ions such as sodium and chloride. If the feed water characteristics change in the future or if the permeate conductivity is not reaching desired water quality, different membranes may need to be investigated.

Short-term piloting with energy-saving polyamide RO membranes showed significant ion rejection, but the pilot needed excessive cleaning when using these membranes. Another approach taken was to plan for the future installation of a traditional spiral-wound RO membrane system following the VSEP process. This would allow for removal of the larger ions in the VSEP units and polishing for monovalent ions in the RO polishing stage, resulting in a very low permeate conductivity without extensive cleaning of the polishing membranes.

Performance & Projection

The installation of the VSEP membrane system resulted in a technology that would successfully meet the goals of the project. The full-scale VSEP installation currently is providing the following water quality: an average conductivity of 1,600 µS/cm at 75% recovery.

This permeate water quality allows the water to be used at various points in the power plant process. The addition of the two additional full-scale plants in successive years will result in a net treated water volume of about 750 million gal over the next four to five years, effectively reducing the storage pond inventory.

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The Rio Del Oro Wastewater Treatment Plant, located in Los Lunas, N.M., is owned and operated by private utility New Mexico Water Services Co. In 2005, New Mexico Water began the upgrade of the 100,000-gal-per-day (gpd), single-train conventional activated sludge (CAS) system with an Enviroquip membrane bioreactor (MBR) system to meet Class 1A effluent for reuse.

Using flat-plate membrane technology allows for an 800% expansion of this facility without building any new tankage. The retrofit was estimated to be about half the cost of using conventional technology. Total installed cost for Phase I of the retrofit (200,000 gpd) was $1.3 million. It is estimated to cost an additional $700,000 to double the capacity again to 400,000 gpd.

The Approach
Because the New Mexico Environment Department would not approve a variance during construction, the existing facility had to remain in operation and still meet permit limits during the retrofit. The facility was able to take down the aeration basin and divert the flow to the emergency storage basin for three days. During those three days, a temporary MBR system was installed in the aeration basin. Six submerged membrane units (SMUs) were dropped into the basin and piped up. Other than a membrane piping support structure, no new walls or dividers were required.

The temporary MBR stayed online for about six months while the secondary clarifier was partitioned into two MBR basins and one swing basin. This 32-ft-by-32-ft clarifier now holds two membrane basins (each with four SMUs) and one swing basin. Six of these units were reused from the temporary MBR basin. The aeration basin that was used for the temporary MBR was then converted into a digester. Two of the plant’s existing 50-hp blowers were reused for the digester. This configuration represents Phase I of the project and treats 200,000 gpd of wastewater to Class 1A reuse water.

The effluent is pumped two miles up the canyon to a holding pond where the Valley Improvement Assn., a
nonprofit group, uses it to water the grass, landscaping and soccer fields of the Las Marivares Park and Veterans Park Soccer Complex. Visitors often fish in that pond, and occasionally a fishing tournament is held there. If the pond is full, the effluent is diverted to a natural riverbed, where it percolates into the ground.

Future Plans

Phase II includes installing eight more membrane units on top of the eight already there, and converting the existing pre-mix channel and chlorine contact basin into anoxic zones. Adding a couple of permeate pumps, recycle pumps and mixers will take the plant capacity to 400,000 gpd. To double the flow again to 800,000 gpd, the existing aeration basin will be converted to a duplicate image of the first MBR train. The existing plant, therefore, can increase in capacity by eight times and produce Class 1A reuse-quality water without building any new tanks.

Results

The MBR plant is operated by one full-time operator with a Class IV wastewater license. Although there is no separate anoxic zone in Phase I, the plant consistently produces effluent total nitrogen of 2 to 4 mg/L with only a swing basin. The new MBR went online in June 2006 as the complete facility, and July 2006 brought the first MBR power bill. There was a power increase of about $1,900 per month. This increase can be attributed to several items:

1. Increased capacity from 100,000 gpd to 200,000 gpd;
2. Effluent permit went from 30/30 to Class 1A Reuse;
3. MBR blowers sized for Phase II (0.4 million gal per day) and operating below their best efficiency point;
4. Disinfection changed from chlorination to UV disinfection;
5. Digester added (two 50-hp blowers for digester and two 60-hp for MBR); and
6. Power rate increased.

The two 50-hp digester blowers operate 12 hours per day (30 minutes on/30 minutes off). The addition of the digester reduced hauling loads by at least half. Figure 1 shows the power trend for that three-year period.

Conclusion

A single-stage CAS system can be upgraded to a Class 1A reuse facility using MBR technology without a variance, and it can be done affordably. The total installed cost of this design-build was $1.3 million. Furthermore, a reuse MBR facility can be operated by only one full-time employee.

The plant now produces Class 1A reuse water and ultimately will provide up to eight times the original capacity. In October 2010, New Mexico Water began upgrading its old blowers with new positive displacement blowers. Electricity usage will be monitored and trended after the switch to determine what a more efficient MBR can do. Although New Mexico Water does not charge for its reuse water, it is estimated that it could be sold for approximately $0.50 per 1,000 gal. Potable water costs are $1.09 per 1,000 gal.

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For more information, write in 1104 on this issue’s Reader Service Card or visit www.wwdmag.com/im.cfm/mt031104.
On Dec. 15, 2010, in a ceremony at its new water treatment plant, the town of Jupiter, Fla., unveiled a new and unique split-feed nanofiltration (NF) plant. Planning for this project started in 2004 and included extended pilot testing of the split-feed approach in both 4- and 8-in. formats. The plant replaces the town’s original lime softening plant and will operate in conjunction with an existing brackish water reverse osmosis (RO) plant. The blended output from these two plants will provide the water system’s users with a stable, balanced and reliable high-quality water supply.

Looking Back

David Brown, Jupiter’s director of utilities and an American Membrane Technology Assn. (AMTA) director and former AMTA president, acted as the master of ceremonies for the dedication. He described the activities of the past four years to an audience of more than 100, acknowledging the contributions made by the town’s elected officials and the project team, including Amanda Barnes, P.E., who as assistant utilities director had been Jupiter’s program manager. Brown acknowledged the forward-thinking approach of the town’s mayor and council to ensure a high-quality, reliable water supply for residents and reminisced about the first membrane plant that was built in the town: the 6-million-gal-per-day (mgd) Phase I brackish water RO plant, opened in 1990.

This was followed by Phase II in 1995 (also totaling 6 mgd) and Phase III in 2005. Phase III involved the addition of energy-recovery turbines to Phase I, together with membrane replacement after 15 years and feed pump rebuild to reduce the discharge head. This phase also included the addition of a 1.7-mgd train, bringing the total capacity of the RO plant to 13.7 mgd.

Brown introduced Jupiter Mayor Karen Golonka, who reiterated his comments about the visionary council and the strong commitment of the town to provide its residents with the best-quality and most reliable water supply that can be achieved. Mayor Golonka also commended Brown and his staff for the outstanding job that they had done over the years in supporting this commitment. Howard Osterman, the utility’s financial consultant, then commended Jupiter for its visionary approach to the water system and for taking the financial steps necessary to fulfill its commitment to its constituency.

Conventional vs. Split-Feed NF

In 2004, the idea of the split-feed approach was floated after a visit to the Netherlands by a utility department staff member. The employee brought back the concept of split feed, with which the Dutch had been working and had installed in some facilities. The driver for considering this concept was the potentially significant energy savings it offered.

A conventional Florida NF design traditionally has been a two-stage, seven-element vessel approach, operating at 85% to 90% recovery. In this design,
in which the feedwater passes through 14 membrane elements in series, the hydraulic pressure loss in the system dominates the membrane pressure equation, resulting in a feed pressure of about 90 to 100 psi.

In the split-feed approach, which utilizes specially designed pressure vessels with a center port, the feedwater passes through six elements in series, significantly reducing the hydraulic pressure drop.

Energy Savings

For Jupiter, piloting in both 4- and 8-in. configuration at 85% recovery and an average flux of 15 gal per sq ft per day demonstrated that a feed pressure of 50 to 55 psi could be expected in full scale, and that the unusual vessel characteristics would not lead to excessively rapid fouling or scaling issues.

At the time of the split-feed NF plant dedication, all five trains in the 14.5-mgd installation (17-mgd ultimate capacity) were operating at feed pressures of 53 to 55 psi, confirming the pilot study results and resulting in anticipated energy savings of 35% to 40% over the conventional Florida NF design.

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For more information, write in 1105 on this issue’s Reader Service Card or visit www.wwdmag.com/lm.cfm/mt031105.
In the last year, Sunil Kommineni and Jack Bryck of Malcolm Pirnie, the water division of Arcadis, met with membrane supply companies to learn about new technologies and to find out where the industry is headed. Here they discuss the latest trends in low-pressure membranes and the future of the industry with WWD Associate Editor Kate Cline.

Kate Cline: What are the current trends in low-pressure membrane filtration for drinking water?

Sunil Kommineni: Increasingly, low-pressure microfiltration (MF) and ultrafiltration (UF) membranes are being considered for smaller, 20-million-gal-per-day (mgd) and large, greater-than-20-mgd greenfield water treatment plants. The life-cycle costs for MF/UF membranes have been gradually declining over the past few years due to advances in membrane materials resulting in higher productivities and lower membrane fouling, operational experience on what works and does not work, and pretreatment selection (types and dosages of coagulants). Newer materials such as ceramic membranes are being evaluated for niche applications such as treatment of spent filter backwash water from conventional water treatment plants.

Jack Bryck: Low-pressure membranes are also being used in membrane bioreactors (MBRs) for treatment of wastewater. Large water providers are considering MBR for satellite wastewater treatment plants to conserve water and meet distributed, nonpotable water needs. The MF/UF membrane system costs are stabilizing due to increased industry experience. Because of the proprietary nature of the MF/UF systems, water providers are “wedded” to the chosen supplier. Therefore, water providers are factoring the ability to deliver service—repair, replacement parts and technical support—as one of the key drivers in the selection of a membrane supplier.

Cline: What did you learn in your meetings with membrane companies?

Bryck: Membrane suppliers anticipate continued growth in the sales and use of membrane systems globally and in North America. Membrane suppliers are conducting additional research to improve their products’ design and performance. Suppliers are paying additional attention to after-sales service and alternate project delivery methods, such as design-build and design-build-own, in the municipal market. Membrane suppliers are anticipating continued growth of 10% for the next few years.

Research and development is focusing on several things, including the development of ideal polymeric membrane fiber (fiber that maximizes permeability and recovery with minimal fouling); the development of optimal module and rack systems that are cost-competitive and easy to operate and maintain; new packing arrangements to reduce the membrane system area requirements by increasing the fiber area per area of the membrane filtration system; and more sustainable systems that use less energy, fewer chemicals and generate fewer residuals.

Kommineni: Ceramic membrane suppliers are exploring niche market areas such as treatment of high-particle streams with minimal pretreatment (no clarification ahead of membranes). Ceramic membrane suppliers are conducting additional research to improve membrane packaging, module design/manifold and operation.

Cline: And where do you see membrane technology heading in the coming years?

Bryck: Use of low-pressure membranes will continue to increase in the municipal market due to various drivers, such as population growth, stricter regulations, impaired source waters, low space availability and high automation requirements (low manual attention). Anticipate the development of alternates to polymeric membrane fibers, such as ceramic membranes with longer life and more robustness. MT

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