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# MEMBRANE MAGIC

**Kansas Power & Light Co.'s La Cygne generating station finds success with membrane filtration water pretreatment technology.**

Pretreatment to remove suspended solids from raw makeup water is a requirement for many industries. In the potable water industry, suspended solids, including microorganisms, can be detrimental not only to the taste and odor of drinking water but also to water supply safety. Many potable water plants have incorporated membrane filtration to remove benign solids and harmful organisms. While bacteria and virus removal isn't normally necessary for power plant makeup water production, membrane techniques are becoming a viable replacement for clarification/sand filtration.

## THE LA CYGNE EXPERIENCE

The membrane filtration process of reverse osmosis (RO) technology exploded in popularity in the 1980s and 1990s as a retrofit technique ahead of existing demineralizers. RO membrane pores are extremely small, only angstroms in diameter, and will remove most dissolved ions from water, thus greatly reducing the load on downstream ion exchange units. La Cygne (Photo 1) was no exception to the retrofit craze, adding an RO system to the Unit 1 (800 MW, supercritical boiler) makeup water system in the 1980s. As part of a major upgrade in the 1990s, La Cygne replaced the original flash evaporator in the Unit 2 (720 MW, subcritical boiler) makeup train with an RO unit and downstream ion exchange system. Both RO systems were designed for 75 percent recovery with a maximum product water flow rate of 200 gpm.

Even though both La Cygne makeup water systems were fitted with RO units, they continued to operate with the original clar-

*Photo 1. The La Cygne station.*

ifier/sand filters for suspended solids removal. By the early 2000s, combined chemical costs for the two clarifiers exceeded $100,000 annually, with labor and routine equipment repair costs further increasing that amount. When each clarifier operated properly, effluent turbidity could be lowered to around 0.3 nephelometric turbidity units (NTU). However, upsets in lake water chemistry or chemical feed equipment malfunctions periodically caused excursions in clarifier performance, such that effluent turbidities might exceed 1.0 NTU. In these cases, the plants' RO prefilters quickly fouled and RO membrane differential pressures increased. The Unit 1 clarifier was particularly troublesome in this regard.

In autumn 2004, based on reliable information from colleagues within the power industry, La Cygne chemists tested a Pall Aria 4 microfilter (MF) in the Unit 1 makeup water system to ascertain if it would produce cleaner water for RO feed, and how in turn this would affect downstream equipment. Whereas most RO systems in power applications use spiral-wound membranes, the microfilter at La Cygne is of hollow-fiber configuration, in which each module contains thousands of spaghetti-sized hollow fiber tubes. To produce the 300-gpm flow required by Unit 1 and auxiliary systems, 24-membrane modules (Photo 2) were necessary.

The microfilter process, like RO, operates via cross-flow filtration, in which the raw water flows parallel to the membrane surface (Figure 1). The water that passes through the membranes and is purified is known as permeate. Not all water passes through each membrane, as at least a small portion must flow along the surface to carry away the suspended solids. This stream is known as the reject.

The tested membranes are configured such that the raw water flows from the outside in, with the reject flowing along the outside surface of the fibers. The basic water flow path is outlined in Figure 2.

Raw water enters tank T-1 for feed to the membranes. A level control gauge in the tank modifies inlet valve operation such that the tank maintains a constant level. Pump P-1 (rated at 20 hp) moves the raw water to the membranes (Skid A in Figure 2). This pump is controlled by a variable frequency drive (VFD) to adjust the output based on the flow rate requested by the operator. The feed to the membranes passes through a basket strainer to remove any large solids that might otherwise foul the membrane surfaces. The permeate flows directly to an existing storage tank, while the reject flows back to tank T-1. Thus, no water is lost during normal operation. The standard mode of operation for the La Cygne system is 25 minutes of water production followed by a one-minute air scrub/reverse flush (AS/RF) to remove solids that collect on the membrane surfaces.

When the AS/RF sequence initiates, pump P-1 stops and pump P-2 (also rated at 20 hp) feeds water from tank T-2. This tank contains previously filtered water to which sodium hypochlorite has been added via pump P-3, which takes simple feed from a drum of hypochlorite. Air valve V-7 opens to allow air to scrub the membranes while the chlorinated water flows inside out through the membrane surfaces. Pump P-2 is also powered by a VFD to allow the operator to adjust reverse flush flow rate as necessary. Once this process is complete, pump P-1 reactivates and flushes the system for a short period followed by a return to permeate production. At the beginning of the new production

*Photo 2. Microfilter module rack.*

cycle, tank T-2 fills with clean water while pump P-3 injects fresh sodium hypochlorite to the tank. The controls also include a timer that periodically backwashes the inlet strainer with feed from tank T-1.

The cost of electricity that powers the P-1 and P-2 pumps is the only significant operating cost. This cost is negligible compared to the clarifier and sand filter costs. The heart of the control system is a dedicated PLC mounted on the pump skid, which is controlled from a personal computer in the Unit 1 laboratory. The primary screen resembles the diagram shown in Figure 2. Plant chemists set the flow rate, AS/RF frequency, strainer backwash frequency, and other parameters from this PC. The PLC acts upon any command changes instantly, allowing excellent flexibility for adjusting water flow to meet plant requirements.

## Results and Lessons Learned

Makeup water for the boilers is taken directly from Lake La Cygne, where the typical turbidity ranges from 5 to 15 NTU. Initial performance criteria indicated the microfilter would remove particles down to 0.1 micron and produce an effluent turbidity of less than 0.1 NTU. Within one hour after system start-up, effluent turbidities dropped to a range of 0.027 to 0.036 NTU, where they have consistently remained. The cartridge pre-filters located ahead of the Unit 1 RO, which normally had to be replaced every two to three weeks, did not have to be replaced at all during the initial three-month test.

# High-Purity Water Production Is Not the Only Power Plant Water Issue

*By Brad Buecker, Contributing Editor*

Water treatment articles in *Power Engineering* often focus on production methods and chemical treatment programs that ensure high-purity water enters and circulates through steam generators. However, treatment of other water streams at a plant is important, albeit for other reasons.

Consider discharge water streams. These may come from ash ponds, coal pile runoff ponds, roof and floor drains, boiler blowoff tanks, and other sources. Manmade water discharges from all power plants in the United States fall under National Pollutant Discharge Elimination System (NPDES) guidelines. While each plant has its own permit guidelines, some items are common to most facilities. For example, the typical pH range allowed by NPDES guidelines is 6.0 to 9.0. Another universally regulated parameter is total suspended solids (TSS). This value may be limited to 30 mg/l or less. Oil and grease also must be monitored and controlled.

Some power plants are plagued by discharges that exceed the 9.0 pH limit. These violations are often due to alkaline minerals in ash pond waters or to algae growth on ponds during warm weather. Treatment of an algae-infested pond with an algaecide may not be possible due to discharge of chemicals potentially toxic to downstream aquatic life. A practical and usually simple solution to lower the discharge pH is to inject gaseous carbon dioxide into the pond upstream but near the discharge point. Often just a small flow of $CO_2$ is enough to lower pH below the 9.0 limit. The simplest systems require only a refillable tank with cooling system and safety vent, piping to the injection point, and a pressure regulating valve on the discharge line to control flow. Placing a distribution grid on the piping discharge can enhance system efficiency, improving $CO_2$-water mixing.

Serious pH excursions can occur during unit outages if plant personnel or contractors water blast boiler tubes and the boiler backpass to remove slag and ash. Sulfurous compounds in the ash drive pH down, and if the rinse water is allowed to exit through normal plant drains, the result will be NPDES violations. Plant personnel tend to forget about this issue during outages, as these events keep most of them busy and at times rather frazzled. Solutions to water-wash waste disposal can sometimes be problematic, as large quantities of wastewater are typically generated during the process. One possible solution is to route the waste through a mix tank, or even an accessible manhole, where a neutralizing compound such as sodium carbonate can be added. If the plant has self-contained ponds that do not discharge to outside bodies of water, the waste can be pumped or trucked to these locations if the plant's environmental permit allows such disposal.

An issue that affects many plants is control of fine particle discharge from coal pile runoff ponds and ash ponds. Very fine particles tend to remain in suspension and carry over to discharge streams. Injecting a settling agent into the stream or streams that enter the ponds works well at reducing carryover. Polymers are the choice for this application. Gary Antony, an expert in this chemistry points out that, "In general, high solids effluents require high molecular weight polymers of 12,000,000 to 16,000,000 plus. These polymers are typically cationic polyacrylamides with high charge densities." The polymer molecules act as bridges between solid particles, and as the polymers grab solids, the overall particle weight increases causing settling to occur. The chemical is often so effective that only a slight residual of perhaps one or two parts-per-million is sufficient for solids agglomeration.

Solids can build up rather rapidly when the settling polymer is doing its job. It is critical that the settling take place in areas of the pond or even inlet ditches where dredging or removal with a backhoe is practical. Inability to remove solids from the pond can result in situations where the pond can overflow during heavy rainfall. Environmental authorities are never happy when this occurs.

Oil or heavier organics such as grease and thick lubricants are other potentially troublesome discharge contaminants. Oil leaking from heavy equipment into floor drains is a common source of these impurities. A well-designed oil/water separator is often sufficient to maintain oil and grease concentrations well below the plant's NPDES limits. However, 100 percent reliability must never be taken for granted. Cases have occurred where extremely heavy rainfall overloaded the separator and allowed some oil to overflow with the water discharge. Systems need to be designed to handle maximum rainfall events. In the Midwest, this could be six to eight inches of rain in a few hours, but in areas near the Gulf Coast rainfall totals could be much higher.

MF membrane pore sizes are larger than those of RO membranes, requiring much less pressure to push water through the membranes. Typical membrane inlet pressures on the La Cygne system range from 10 to 20 psig. The minimal pressure requirement allows membrane construction of coarser but much more durable materials, in this case polyvinylidene fluoride (PVDF). This proved to be important. Early testing revealed that even with regular air scrub/reverse flushes, membrane differential pressures (DP) would gradually increase. As an experiment, plant chemists began treating the raw water feed with a small but continuous dosage of sodium hypochlorite to maintain a 0.2 to 0.5 ppm chlorine residual in the membrane permeate. This did wonders for the membrane cleanliness, and the gradual DP increase ceased and in fact dropped to near start-up levels. Subsequently, at times during the spring and summer, the membrane DP may increase gradually. During these events, AS/RF frequency is increased to better scrub the membranes.

If the membrane DP climbs too high (30 to 35 psi), or the microfilter needs to be taken out of service for an extended period, the membranes are cleaned with a dilute solution of sodium hydroxide followed by a rinse and then a cleaning with a citric acid solution followed by another rinse. Chemicals are added manually to tank T-1 and then pump P-1 is used to circulate the solution through the membranes. The system has only required one off-line cleaning, for unit transfer from the test location to a permanent site.

La Cygne encountered two problems during the test. First, on several occasions the mechanical strainer plugged with rust particles that broke loose from the very old makeup water supply line. Once the microfilter was placed in its permanent location, a dual-compartment basket strainer was installed ahead of the unit to minimize or prevent future plugging issues. The second problem was a malfunction of the automatic controller on inlet valve V1. Vendor personnel promptly replaced the valve, and the system has operated error free since. Results were so impressive that La Cygne purchased the unit and installed it in a permanent location in February 2005. Operation since has been nearly flawless. The calculated payback for the MF is less than three years. As the budget permits, plant chemists hope to replace the Unit 2 clarifier and sand filters with another microfiltration unit.

A microfilter that will produce clean water within just one or two minutes after start-up is of potential interest to personnel who operate steam generators that must be started quickly, such as combined-cycle plants. Downstream equipment such as a RO unit or demineralizer can be energized quickly without concern for suspended solids fouling. More importantly perhaps, or certainly on a broader scope, is that microfiltration has the potential for pretreatment of less-than-pristine source water — for example, discharge from a sewage treatment plant — as makeup. More than one power plant sits close to a sewage treatment facility, where the sewage plant discharge would be an inexpensive source of makeup, and where the power plant would receive positive publicity from an environmental standpoint for recycling water. Mi-

FIGURE 1
CROSSFLOW FILTRATION

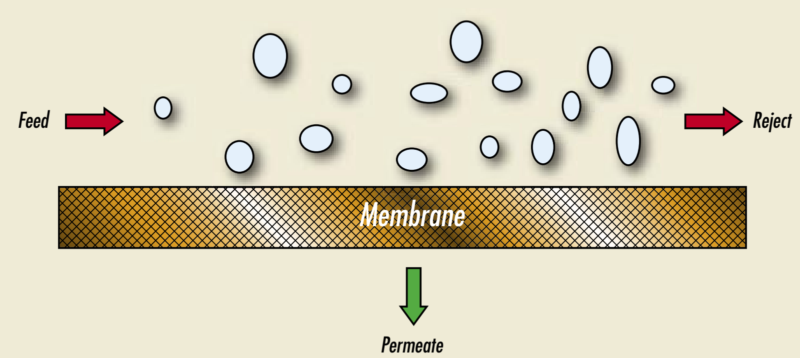
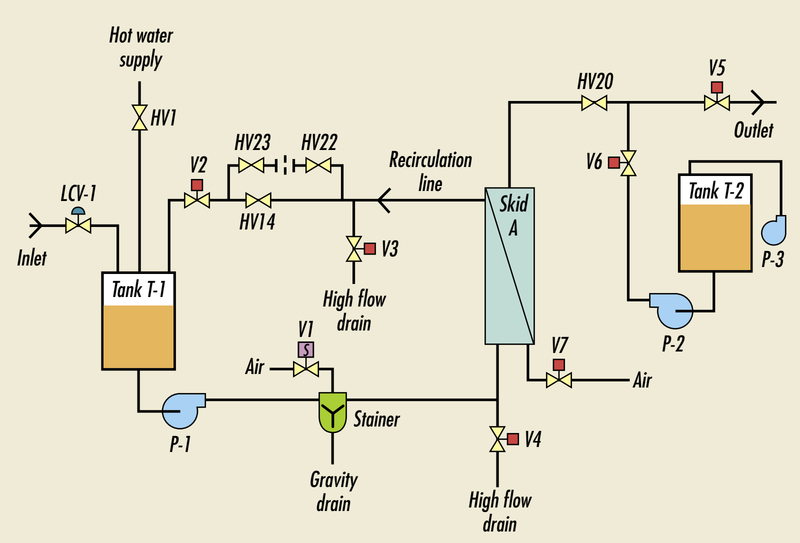



FIGURE 2
BASIC FLOWCHART OF THE MICROFILTER



crofiltration for this application would require close monitoring of membrane differential pressure; however, systems utilizing this type of makeup can be set up for enhanced flux maintenance (EFM). A microfilter arranged for EFM uses an additional, small skid that periodically subjects the membranes to short-duration chemical washes to remove accumulated solids, including organic materials. EFM extends the time between manual, off-line cleanings from weeks, or perhaps days, to months. PE

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