

TECHNOLOGY BRIEFING

MICROFILTRATION FOR MAKEUP WATER PRETREATMENT: A DEVELOPING TECHNIQUE FOR THE POWER INDUSTRY

Pretreatment to remove suspended solids from raw makeup water is a requirement for the potable water industry, but it is also a critical application in many process industries, including steam-generating electric utilities. In the 1980s and 1990s, reverse osmosis (RO) exploded in popularity as a retrofit technique ahead of existing deionizers at power stations. Reverse osmosis membranes, whose pore sizes are only angstroms in diameter, will remove most dissolved ions from water, thus greatly reducing the load on downstream ion exchange units.

At Kansas City Power & Light Company's La Cygne generating station, an RO system was placed in the Unit 1 (820 megawatts [MW], supercritical boiler) makeup water system in the 1980s. As part of a major upgrade in the 1990s, an RO unit and downstream ion exchange system replaced the original flash evaporator in the Unit 2 (720 MW, drum boiler) makeup train. Both RO systems were designed for 75% recovery with a maximum product water flowrate of 200 gallons per minute (gpm).

Even though both La Cygne makeup water systems were fitted with RO units, they continued to operate with the original clarifier/sand filters for suspended solids removal. By the early 2000s, combined chemical costs for the two clarifiers had easily exceeded \$100,000 annually, with labor and routine equipment repair costs adding considerably to 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 malfunc-

tions periodically caused excursions in clarifier performance, such that effluent turbidities might exceed 1.0 NTU. In these cases, we would see quick fouling of RO pre-filters and an increase in RO membrane differential pressures. The Unit 1 clarifier was particularly troublesome in this regard.

In autumn 2004, based on reliable information from colleagues within the power industry, we 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, for power plant applications at least, use spiral-wound membranes, the MF 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 (Figure 1) were necessary.

The MF process, like RO, operates via cross-flow filtration, in which the raw water flows parallel to the membrane surface. Water that passes through the membranes and is purified is known as permeate. Not all water passes through each membrane, as a small

portion at least must flow along the surface to carry away the suspended solids. This stream is known as the reject.

The membranes in the unit we tested are configured such that the raw water flows from outside to 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. This pump is controlled by a variable frequency drive (VFD) to adjust the output based on the flowrate 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 our system is 10 to 15 minutes of water production followed by a 1-minute air scrub/reverse flush (AS/RF) to remove solids that collect on the membrane surfaces.

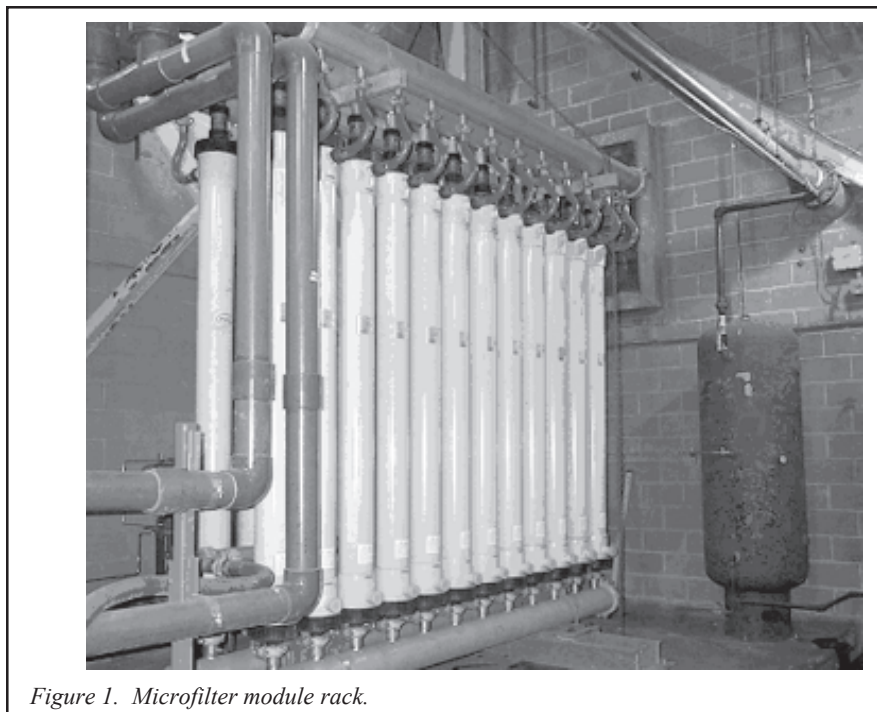


Figure 1. Microfilter module rack.

By Brad Buecker
Kansas City Power & Light

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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 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 flowrate 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 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 only significant cost to operate the unit is for the electricity that powers the P-1 and P-2 pumps. This cost is negligible compared to what we were spending on the clarifier and sand filters. The heart of the control system is a dedicated programmable logic controller (PLC) mounted on the pump skid, which we control from a personal computer (PC) in the Unit 1 laboratory. The primary screen resembles the diagram shown in Figure 2. We set the flowrate, AS/RF frequency, strainer backwash frequency, and other parameters from this PC. The PLC acts upon any command changes instantly, and this gives us 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. We were given performance criteria that indicated the MF would remove particles down to 0.1 micron in size and produce an effluent turbidity of less than 0.1 NTU. Within an hour after system start-up, effluent turbidities had dropped to a range of 0.027 to 0.036 NTU. We found that the cartridge pre-filters ahead of the Unit 1 RO, which normally had to be replaced prior to MF installation now do not have to be replaced for months.

Microfilter membrane pore sizes are larger than those of RO membranes, which requires much less pressure to push water through the membranes. Typical membrane inlet pressures on our system range from 10 to 20 pounds per square inch gauge (psig). The minimal pressure requirement allows membrane construction of coarser but much more durable materials, in this case polyvinylidene fluoride (PVDF). This aspect proved to be very important. We found early on during

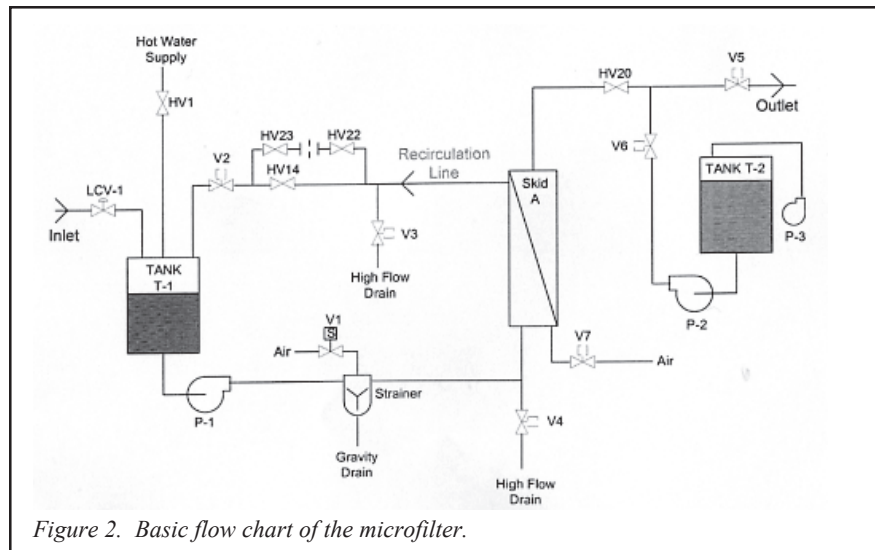


Figure 2. Basic flow chart of the microfilter.

the test that even with regular air scrub/reverse flushes, membrane differential pressures (DP) would gradually increase from day-to-day. As an experiment, we began treating the raw water feed with a small but continuous dosage of sodium hypochlorite to maintain a 0.2 to 0.5 parts per million (ppm) chlorine residual in the membrane permeate. This improved membrane cleanliness.

Other than a faulty inlet valve that the vendor replaced promptly, the reliability of the system has been superb. Results were so impressive that we purchased the unit and installed it in a permanent location in February 2005. Operation since has been very steady. We calculate that payback for the MF will be less than 3 years. One issue has come to our attention, however. We had assumed that off-line cleaning was not needed until the membrane DP approaches its maximum limit.

The process involves a step-wise procedure of cleaning with a dilute sodium hydroxide (1%), sodium hypochlorite (500 ppm) solution, a rinse with filtered water, cleaning with a citric acid solution (0.5%), and then another rinse. Cleaning takes approximately 8 hours. From March 2005 to October 2005, we operated continuously before taking the unit off for cleaning. The DP did not recover to original values. We have experimented with enhanced membrane cleaning techniques using stronger sodium hydroxide/bleach and citric acid solutions, and these have had success. However, we have been enormously pleased with the reliability of the pumps, valves, and instruments on the system. It requires just a few minutes of operator attention per day, all from the computer. ■

Author Brad Buecker is the air quality control specialist, and formerly plant chemist, at Kansas City Power & Light Company's La Cygne, Kansas, power station. He has previous experience as a chemical cleaning services engineer, a water and wastewater system supervisor, and a consulting chemist for an engineering firm. Mr. Buecker has written more than 70 articles and columns on steam generation, water treatment, and FGD chemistry, and he is the author of three books on steam generation topics. Mr. Buecker is a member of ACS, AIChE, ASME, and NACE.

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