By Brad Buecker

For years, clarification followed by media filtration was the common technique for removing suspended solids from steam generator makeup water. Now the membrane techniques of microfiltration (MF) and ultrafiltration are attracting interest as methods for suspended solids control.

These membrane processes have already gained significant popularity in the potable water industry, where suspended solids, including microorganisms, can be detrimental not only to the taste and odor of drinking water but also to the safety of such supplies. This case study examines the successful use of MF as a pretreatment technique at a large power plant.

The Need for Updated Pretreatment

At this power station, the makeup water flow treatment scheme for the plant’s 800-MW supercritical boiler is outlined in Figure 1. This system was utilized from 1985 to 2004, with the forced-draft decarbonator being added downstream of the reverse osmosis (RO) unit in the late 1990s.

Table 1 outlines a typical analysis of the lake water that is treated in the makeup system, where the normal turbidity range of the water is from 5 to 15 NTU.

By the mid 2000s, the clarifier was more than 30 years old and was beginning to show its age. When it operated properly, effluent turbidity could be lowered to 0.3 NTU, but upsets in lake water chemistry or the equipment itself often caused performance excursions such that effluent turbidities exceeded 1 NTU. In these cases, quick fouling of RO cartridges and bag filters and an increase in RO membrane differential pressures occurred. The clarifier was quite maintenance-intensive and consumed significant amounts of expensive coagulants and flocculants.

In September 2004, plant staff tested a Pall Aria 4 microfilter in the makeup water system to ascertain if it would produce cleaner water than the clarifier/sand filters for RO feed, and how this would affect downstream equipment. Whereas most RO systems for power plant applications utilize spiral-wound membranes, the microfilter is of hollow-fiber configuration, in which each module contains thousands of spaghetti-sized hollow-fiber tubes. To produce the 300-gal-per-minute flow required by the steam generator and its auxiliary systems, 24 membrane modules were necessary.

Process Flow

The MF process outlined in this article operates where the feed flows parallel to the external membrane surfaces with a very small reject return to the inlet feed tank. But unlike pure cross-flow filtration that is typical for RO, in this process the screened material collects on the membranes and thus resembles dead-end filtration. Therefore, the membranes must be scrubbed periodically with a water/air backwash. The design backwash frequency for this system is once every 20 minutes, but the operators can easily adjust the frequency as needed. The membranes are configured such that the raw water flows from outside to inside, with the reject passing along the outside surface of the fibers (see Figure 2 on page 8). Raw water enters tank T-1 for feed to the membranes. A level gauge in the tank controls inlet valve (LCV-1) operation to maintain a constant level in T-1. Pump P-1 (rated at 20 hp) moves the raw water to the membranes. The 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 (Skid A in the diagram) 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 production cycles. The common production time period for these systems is 20 minutes, followed by a one-minute air scrub/reverse flush (AS/RF) step 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 (NaOCl) has been added via pump P-3, its suction pulling from a drum of industrial strength (12.5% NaOCl) bleach. Air valve V7 opens to allow air to scrub the membranes while the chlorinated water flows inside-out through the membrane surfaces.

Pump P-2 also is powered by a VFD, which allows the operator to adjust the RF flow rate as necessary. Once the AS/RF process is complete, pump P-1 reactivates and forward 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 NaOCl to the tank. Pump P-3 automatically shuts down shortly after tank T-2 reaches full capacity.

The microfilter controls also include a timer that periodically backwashes the strainer with feed from tank T-1. In this process, a cylindrical column equipped with four water jets activates and moves up then down while rotating. The jets blast accumulated material off the ciliary screen, and the entire stream exits the strainer. The actual washing process takes 13 seconds.

The heart of the control system is a dedicated PLC mounted on the pump skid. Settings can be adjusted either at the skid or by an external computer, the latter of which was the method chosen for this application. The primary screen resembles the diagram shown in Figure 2. Operators set the flow rate, AS/RF frequency, strainer backwash frequency and other parameters from this PC. The PLC acts on any command changes instantly, and this
Figure 2. Basic Flow Chart of the Microfilter

provides flexibility for adjusting water flow to meet plant requirements.

Test Period

Pall personnel calculated that the MF would remove particles down to 0.1 micron in size and produce an effluent turbidity of less than 0.1 NTU. Within one hour after system startup, effluent turbidity levels had dropped to a range of 0.027 to 0.036 NTU, where they consistently remained. Observers found that the cartridge prefilters ahead of the RO, which normally had to be replaced every two to three weeks, did not have to be replaced for months at a time.

MF membrane pore sizes are larger than those of RO membranes, and corresponding inlet pressures are much lower than in RO units. Typical membrane inlet pressures on this system range from 10 to 20 psig. The minimal pressure requirement allows membrane construction of durable materials, in this case polyvinylidene fluoride (PVDF).

The project team encountered two problems during the initial test. First, on several occasions the MF strainer plugged with rust particles that broke loose from the very old makeup water supply line. Staff installed a Hayward, dual-compartment basket strainer ahead of the unit to minimize or prevent fouling. Care must be taken with these systems, however, as a massive influx of debris can cause a large increase in differential pressure that causes failure of the strainer baskets.

The second problem that developed was a malfunction of the automatic controller on inlet valve LCV-1. Vendor personnel promptly replaced the entire valve/controller assembly, and the valve has operated error free since.

Permanent Operation

When warm weather began to arrive in the spring of 2005, staff found that even with regular AS/RFs, membrane differential pressures—in the manufacturer’s language, the transmembrane pressure—would increase gradually from day to day. As an experiment, the team began treating the raw water feed with a small but continuous dosage of activated bromine to maintain a 0.2- to 0.5-ppm oxidant residual in the membrane permeate. The residual is allowed to carry to the RO, which is equipped with cellulose acetate membranes. It should be noted that this process would not be permissible if the RO had polyamide-based membranes.

Continuous biocide treatment is of value, but periodically offline membrane cleaning is required. The process consists of a step-wise procedure of treatment with a warm (about 100°F), dilute sodium hydroxide (1%) and NaOCl (500 ppm) solution, a rinse with filtered water, treatment with a warm citric acid solution (0.5%) and then another rinse. Cleaning takes approximately eight hours.

Higher concentrations of NaOCl can be employed if necessary to remove microbiological fouling, as the PVDF membranes are very durable. Cleanings should be performed on a regular basis, perhaps quarterly, or in severe applications more frequently. Membrane integrity has been ideal, with not one failure of the 140,000-plus membranes in five years.

New Developments

Standard equipment for new MFs is an automatic system that performs regular cleanings based on a preset time interval. The operator has only to worry about the proper chemicals being loaded into the clean-in-place skid. This latter development has allowed MF to be applied to high-turbidity raw waters such as river water, where the turbidity can at times exceed 2,000 NTU. A key point to remember is that regardless of whether inlet turbidity is relatively low or fluctuates to high concentrations at times, MFs will remove suspended solids without chemical conditioning of the raw feed water, unlike clarifiers.

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