RO: Heart of a Makeup System

By Brad Buecker

Proper performance requires proper care

Much of my current workload concerns projects with reverse osmosis (RO) as an integral component for makeup water treatment and/or a pre-concentrator for zero-liquid discharge. RO has become the heart of many water treatment systems, either as a retrofit or as a key component in new designs. From previous direct experience with RO operation, it is evident that many issues affect RO performance and membrane longevity, including RO feed pretreatment, microbiological fouling, scale formation and others. Here we examine these issues and consider some case histories.

Beware of Microbes

Even when one thinks that microbiological fouling is under control, it can rise up to bite. This is true for makeup water systems, cooling towers, steam surface condensers and many other types of equipment. We begin with a case history to illustrate this point—one describing a manufacturing facility that required both softened water and deionized water for process and steam boiler makeup.

Makeup comes from three wells where iron content can reach 2 ppm. Aeration and chlorination are utilized to remove this iron, and chlorination also prevents microbiological growth of organisms, especially after the makeup water is exposed to air. I arrived at this facility a few months after an RO unit had been installed as the method to reduce load on a downstream cation/anion ion-exchange system. Even though the RO was new, the treatment system operators had to clean membranes every three days or so. The engineer who specified the system insisted that iron fouling was the problem, but analyses performed by the water treatment staff consistently showed RO inlet iron concentrations of 0.1 ppm or less.

It is worth noting that the process included sodium bisulfite ($NaHSO_3$) feed ahead of the RO inlet to remove chlorine and prevent damage to the RO membranes. The injection point was approximately 30 ft upstream of the RO. During a subsequent cartridge pre-filter changeout for the system, staff examined the old filters closely and discovered that they were covered with slime. The team arranged to have samples taken during the next cartridge filter changeout and analyzed for microbial counts by a reputable laboratory. The results showed counts of some bacteria in the millions per milliliter.

The upshot was that some organisms that survived chlorine treatment became reinvigorated downstream of the $NaHSO_3$ feed. These organisms fouled and expanded the RO membranes to the point that it proved nearly impossible to remove the membrane housings to install new membranes. A practical solution to microbiological fouling is outlined in the next case history.

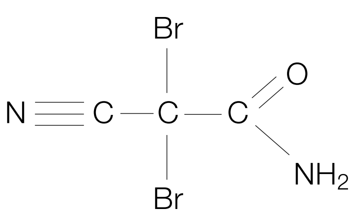
In this instance, at a power generation facility, autopsies on the membranes from two separate RO systems indicated microbiological fouling in both. The solution to the problem was different for each RO unit.

The first RO, which served a steam generator designated as Unit No. 1, utilized cellulose acetate (CA) membranes. CA membranes can tolerate small dosages of oxidizing biocides, and indeed a small residual is ideal for controlling microbes. This RO, however, had been placed downstream of an activated carbon filter, which removed all residual chlorine from the RO feed. Staff installed a separate oxidizing biocide (bromine) feed to the RO in conjunction with the installation of a pretreatment

Microbiological fouling in RO membranes.

microfilter (see July 2010 *Membrane Technology* article “Microfiltration: A Pretreatment Option”). Maintaining a residual oxidant concentration within a typical range of 0.3 to 0.5 ppm kept the RO membranes clean.

The Unit No. 2 RO at this same plant was equipped with the more common polyamide membranes, which cannot tolerate oxidizing biocides. The solution to microbiological fouling in this RO was feed of a non-oxidizing biocide to the RO inlet. Di-bromo-nitrilo-propionamide (DBNPA) was the chemical of choice, with feed every two days for one hour at a time. The structure of DBNPA is illustrated here:



Just a residual of a few parts per million was sufficient to kill microbes in the cartridge filters and RO membranes. Other choices besides DBNPA are available, but any chemical should be selected not only with efficacy in mind but also with regard to safety issues and what becomes of any residual in the RO reject. If the reject is blended with a wastewater stream that exits the plant, the issue of the plant’s National Pollutant Discharge Elimination System regulations comes into play.

Scale Control & RO Performance Monitoring

Consider a typical two-stage, single-pass RO system. During normal conditions, the first stage will process half of the influent as permeate and the second stage will process half of the first stage reject as permeate. Thus, the concentration of dissolved solids increases by fourfold at the trailing elements of the second stage. Quite naturally, the first compound that would begin to deposit in the RO membranes is calcium carbonate ($CaCO_3$). The scaling potential of $CaCO_3$ is easy to calculate and to control, but other minerals in the water can lead to scaling, with some of the most problematic being the sulfates (calcium, barium or strontium) and silica-based deposits.

Modern polymers are available to keep these bad actors in solution well above normal saturation levels, but how does one perform the calculations? Reputable membrane manufacturers offer downloadable programs on their websites that offer this capability.

Even with good pretreatment and chemistry control, RO membranes and the spacer material still accumulate suspended and dissolved solids that must be removed periodically. A well-designed RO will have instrumentation to measure a number of process variables, including inlet and reject pressures, flow rates, conductivities and temperatures, among others.

As membranes begin to foul, inlet pressure will rise and other variables may change as well. It is recommended that membranes be cleaned when operating conditions drop by 10% off design values, but detecting this change is complicated by the fact that RO membrane production changes with changing temperature. Thus, fouling or scaling can be masked by other factors. For this reason, it is always recommended that RO owners and/or operators acquire and use an RO normalization program. These programs, some of which have been developed in spreadsheet format, generally are straightforward to use and can prove valuable. If cleaning is not performed when needed, membranes can suffer from irreversible fouling, reducing performance and life expectancy.

Conductivity monitoring of RO reject and especially permeate is vital toward evaluation of membrane integrity. A membrane tear or other mechanical failure will be evidenced quickly by an increase in permeate conductivity. Gradual membrane degradation is, of course, more difficult to detect, but it will become visible over time. A feature that many feel is great to have on an RO unit is the ability to individually grab-sample the permeate from each RO pressure vessel. If the online permeate conductivity monitor from either the first or second stage indicates a problem, the chemist or operator can check each pressure vessel in an attempt to pinpoint the source. MT

Brad Buecker is process specialist for Kiewit Power Engineers. Buecker can be reached at brad.buecker@kiewit.com.