REVERSE OSMOSIS

REDUCE MEMBRANE FOULING WITH GOOD CIP PROCEDURES

An integrated water management strategy to optimize a system's performance uses the best technical and operational principals combined with new or existing assets. Applying an existing asset to accomplish this goal with simple and economical standard operating procedures is like *having your cake and eating it too!*

Reverse osmosis (RO) systems are used to produce high-purity water for boiler make-up water, process waters, wastewater reuse, and numerous other applications. In a well-managed system, operational parameters are measured on a regular basis to assess functionality of the machine and determine when RO membrane cleanings are required. The higher the dissolved and suspended solids in the RO feedwater, the more frequent and important the cleanings become.

Some RO systems do not operate 24 hours a day and are turned off for part of the day or week to support the operational requirements of the facility. Typically, when the RO shuts down, the impurities that have been concentrated on one side of the membrane remain in the membrane housing until flushed out with fresh makeup water when the RO starts back up. The system is essentially "put away dirty." Being "put away dirty" can allow for further inorganic deposits to develop or microbiological activity and fouling to increase. Both have negative affects on the RO membranes and performance.

Many RO systems have clean-in-place (CIP) equipment installed as an integral part of the system. Smaller RO applications may contract to have a CIP performed on an as-needed basis. A typical CIP for polyamide membranes is outlined below:

Typical CIP Procedure

Here are 13 steps normally associated with a typical CIP procedure.

Step 1. Install new cartridge filters on the CIP system and make sure that the piping is clean, with no stagnant water from previous cleanings and no microbiological build-up.

Step 2. Mix chemicals in clean, high-purity water, such as deionized water, RO permeate water, or condensate. If these choices are not available, then use soft water. The estimated water requirement for the cleaning solution is 20 to 25 gallons per 40-inch (in) long, 8-in diameter element.

Add the chemical cleaning products to the CIP tank. Commonly, a low-pH cleaning is conducted first at a pH of 2 to 3.

The solution temperature should be increased to 105ºF to 110ºF and maintained during the cleaning. Warm or hot water can be used when making the solution, and a heater should be maintained in the cleaning solution to stabilize the temperature at 105º to 110ºF.

Step 3. Drain as much water from the RO system as possible; then, begin introducing the solution to the first stage of the RO machine. Introduce the solution slowly to displace any remaining water in the RO machine to the drain. Use a pH or conductivity meter to determine when the water has been flushed from the RO machine and the cleaning solution appears. After the cleaning solution has displaced, the water in the housings, reroute the cleaning solution back to the chemical cleaning tank. The permeate should also be routed back to the CIP tank.

The number of housings cleaned at a time depends on the capacity of the CIP pump. The CIP pump *must* be able to provide 8 to 40 gallons per minute (gpm) per 8-inch housing at 30 to 60 pounds per square inch gauge (psig). The system is best cleaned by stage, or groups of housings in a stage, depending upon the CIP pump capacity.

Step 4. Circulate the cleaning solution at low flow of approximately 8 to 12 gpm per each 8-in housing. Typical cleaning times are 15 to 30 minutes. The purpose of the low flow is to dislodge foulants gradually to avoid plugging up feed spacers with any loose debris.

Step 5. Increase the flowrate to a more moderate flow of 16 to 24 gallons per minute for an 8-in housing for 15 to 30 minutes.

Step 6. Circulate 30 to 60 minutes at high flow of 40 gpm for an 8-in housing.

Step 7: Soak for 30 to 60 minutes.

TABLE A
Examples of Cleaning Solutions

- Mineral Scaling: 50% liquid citric acid dosed at 10 to 20 pounds/100 gallons of permeate in the CIP tank.
- Organic and Microbiological Fouling: 50% sodium hydroxide dosed at 8 ounces per 100 gallons of permeate in the CIP tank. Target pH is 11.5 S.U.
- Microbiological Fouling: 20% 2,2dibromo-3-nitrilopropionamide (DBNPA) dosed at 3 ounces per 100 gallons of permeate in the CIP tank.

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Step 8. Circulate at 40 gpm for another 60 minutes, or until the feed pressure and flow stabilizes. Sometimes air bumping may be used in this step.

Note: In most cases, CIP connections will be made to isolate housings during the cleaning process. If CIP solution must be circulated through the concentrate-throttling valve, it should be fully open during the cleaning procedure to minimize backpressure. The circulation of the solution should typically be in the normal direction of flow through the RO system, returning to the cleaning tank. Ideally, the flowrates and the differential pressures should be monitored during the cleaning cycle, and cleaning is determined to be completed when the flowrates and the differential pressures stabilize. The benefits of soaking are deposit and system dependent.

Never exceed the membrane manufacturer's recommended maximum feed pressure and pressure drop when determining flowrates for cleaning.

Step 9. Check the pH of the cleaning solution periodically to make sure it has not risen above a pH of 3.5 to 4.0. Add additional low-pH cleaning chemical if necessary. If the solution becomes excessively colored or dirty, dump the solution and repeat the process with a fresh solution.

Step 10. Drain the cleaning solution and rinse with fresh, clean water, and monitor the point of discharge until the pH stabilizes close to the feedwater pH.

Step 11. Repeat the low-pH cleaning procedure for the subsequent groups or stages of housings. Operate the RO and check parameters to determine what was gained by the cleaning. Typically, the next step is to perform a high-pH cleaning, which follows the same procedures that were used previously. However, this time the procedure uses a high-pH cleaning chemical solution at a pH of around 11.0.

Step 12. When cleaning is completed, place the RO back into service and record flows, differential pressure, and percent salt rejection. When restarting the RO system, set the feedwater and concentrate throttling valves to approximately 50%. Start the machine and adjust the throttling valves until the machine flows return to specifications. Divert the RO permeate water to drain until the conductivity returns to normal.

Step 13. Thoroughly rinse all cleaning components before storing.

CIP for RO Wet Lay-up

Having a CIP system on-hand can offer the user an added opportunity to keep the RO clean on an ongoing basis. The CIP system may be used to lay-up the RO membranes during periods of time when the unit is not operational without affecting the availability of the unit to provide its intended service. This approach is very similar in principal to the chemically enhanced backwashes (CEB) used in many industrial and municipal ultrafiltration (UF) systems today.

The principal is to use the existing CIP equipment as an integrated component of the regular startup and shutdown of the RO system. Typically, the CIP system is infrequently used in the day-to-day operation of the RO system and is only utilized when a dedicated full-scale cleaning is required.

Some prime applications for using CIP for temporary RO wet lay-up include:

- **Wastewater reuse:** These applications typically have significant concentrations of organic and inorganic impurities that can foul the membranes.
- **Microbiologically active systems:** Applications with significant microbiological contamination that could foul and/or damage the membranes.
- **Intermittent systems:** Systems that operate inconsistently or are off more often than they are running might be prime candidates.

CIP Automation Description

Using CIP for wet lay-up can be a manual or automated process. With automation, the RO can always be placed in a cleaner-than-typical condition. Care should be taken to ensure that this type of strategy does not have the potential to harm a downstream process in the event of a poor permeate flush (CIP fluid flush) and that the chemistries involved do not invalidate a downstream process.

Automation can be achieved by implementing some additional control logic, a couple of self-actuated valves, and appropriate piping. Assuming the CIP tank has been properly designed to handle the holdup volume of the RO system, the basic logic of using CIP for wet lay-up is as follows:

1. RO turns on and the first sequence is to fill the CIP tank. Some RO systems divert the initial permeate (permeate divert) to drain during startup to ensure that high-purity water is sent to the downstream process. This diverted water could be used to fill the CIP tank instead; thus improving the efficiency of the system. The CIP tank fill can be a timed function programmed into the programmable logic controller (PLC), also a level transmitter or float at the CIP tank can send a signal to the RO control system to terminate the CIP tank-filling sequence.

2. If cleaning chemicals are to be used in the wet lay-up, a chemical pump(s) is energized at the same time the CIP tank is being filled to automatically add the desired dosage of chemical(s) to the CIP tank.

3. Once the CIP tank has been filled and the permeate quality has been satisfied for the downstream process, the RO permeate is diverted back downstream and produces the high-purity water for which it was designed.

4. The RO unit turns off when the high purity water demand is met.

5. When the signal to shut down the RO is received, automatic valves are actuated and aligned and the CIP pump is energized to force the stored permeate or cleaning solution (permeate plus any desired chemistry) through the RO membranes. A high CIP pump discharge pressure is not required because the CIP water is not being forced through the membranes but is used to displace the concentrate at the membrane surface prior to shutdown instead. The application point can be upstream or downstream of the existing RO unit prefilter, depending upon the targeted contaminants.

6. When the CIP tank reaches a low level, the CIP pump turns off. The machine is now stored in the lay-up solution for the duration of the unit shutdown.

7. When the RO turns on, it diverts the initial permeate to drain (typically a timed sequence determined by the calculated holdup volume of the RO machine and the pumping capacity of the high-pressure RO pump) and then to the CIP tank. The cleaning solution and any contaminants exit with the concentrate.

Note: Care must be taken if the RO concentrate is being used for some ancillary use (i.e., wash down water, or cooling tower makeup) to ensure that the processes are not adversely affected by the concentrate chemistry.

Another point to consider when using the CIP for RO wet lay-up is that RO systems commonly have a dechlorination step upstream of the RO, either before the RO pump or before the prefilter. When the water lies stagnant in these areas during times of shutdown, this can become a breeding ground for microbiological activity that can inoculate the membranes and cause microbiological fouling. If the CIP system is also designed to include the RO pump and prefilter, using a non-oxidizing microbiocide with an automated CIP system would reduce microbiological fouling problems because of increased system sterility.

The CIP can be used for wet lay-up using several different cleaning solutions. These solutions can be full strength or diluted forms for a more gradual, gentler cleaning of the RO membrane. Cleaning strategies include the use of the following:

RO permeate. Displacing the concentrated water with high-purity permeate water on the concentrate side of the membrane accomplishes a reduction in the concentration of dissolved impurities exposed to the membrane surface and may even help dissolve existing deposits.

Non-oxidizing microbiocide. For RO applications with microbiological problems, the CIP could be used to intermittently sterilize the RO membrane with a non-oxidizing microbiocide prior to shutdown. This could help increase the run time between the biocide cleanings.

Low pH. If scale is a problem, the CIP could be used to soak the membranes in a low-pH cleaning solution between uses.

High pH. The CIP could be used to introduce a high-pH cleaning solution to the RO membranes for organic and microbiological fouling conditions. Added care and consideration should be given if the CIP is used for high-pH cleaning so that solubilities of scale-forming inorganics are not exceeded at the higher pH. In a full-blown RO cleaning, high-pH cleanings typically follow a low-pH cleaning if mineral salts are potential foulants to avoid exceeding solubilities that cause membrane scaling.

Table A provides some examples of cleaning solutions.

Case Study

An industrial plant recycles treated oily wastewater through a two-stage RO machine. The RO membranes required cleaning every 4 to 8 weeks to remove mostly organic and microbiological foulants, consisting of oils, surfactants, and bacteria.

The wastewater reuse system has the capacity to recycle more than 200 gpm by using the following treatment strategy:

1. Equalization.
2. Coagulant addition prior to an inclined plate clarifier.
3. Sand filtration.
4. Activated carbon to remove the oils, surfactants, and residual metals in the RO feedwater stream.
5. Sodium zeolite water softening.
6. Intermittent feed of DBNPA to reduce microbiological fouling.
7. RO machine.

CIPs were conducted by first using a low-pH citric-acid-based cleaning solution to separately clean each of the two stages of the RO machine. High-pH cleanings of each individual stage followed the low-pH cleanings.

Declines in permeate quality and increased differential pressures required that a membrane replacement be conducted after approximately 2 years of service. After the membranes were replaced, the machine was operated in the permeate lay-up mode described here, and utility plant operators began adding approximately 1 gallon of 50% sodium hydroxide to the 800-gallon CIP tank once per month. As a result, foulants were visually removed, and the CIP frequency has been reduced to once or twice per year.

Conclusion

A well-maintained RO system can be a real asset; a poorly maintained RO system can be your worst headache. When properly operated, RO systems can save money, time and energy, increase equipment life cycles and efficiency, improve product quality, and recover wastewaters. Prematurely replacing RO membranes can be a costly endeavor and can be avoided, or at least delayed, by properly monitoring and maintaining the RO system. Good CIP procedures and integrating the CIP system to place the RO in wet lay-up with RO permeate or abbreviated cleanings is one more tool to ensure a properly managed integrated water treatment system.

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