MAINTENANCE

MEMBRANE CLEANING: THE ADVANTAGES OF OFF-SITE CLEANING OF RO MEMBRANES

Even with excellent pretreatment, reverse osmosis (RO) membranes can become fouled during service by a number of contaminants in water. These include (see Table A) metal oxides, scaling salts, colloids, organics, and biological matter. They need to be effectively removed to ensure the quantity and quality of water required. Without proper cleaning, the foulants can eventually accumulate and cause reduced productivity, increased feed pressure requirements, and/or decreased salt rejection. Ultimately, ineffective membrane cleanings can lead to permanent damage to the membrane and/or shortened membrane life.

Today's manufacturers and plant maintenance personnel operate under increasingly tight schedules that allow little room for unplanned or unexpected interruptions in their day-to-day operations. Contributing to these tight schedules are the complexities of RO pretreatment and reduced labor resources. When all factors are combined, off-site RO membrane cleaning becomes an economic necessity, since it is convenient and frees up plant personnel for other tasks. Off-site cleaning ensures that the RO system will continue to operate at peak performance. This article will discuss the advantages and benefits of off-site membrane cleaning.

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Advantages of Off-Site Membrane Cleaning

Every plant operates under strict production requirements. Usually, plant personnel are responsible for the operation of the water treatment system and are also responsible for a number of other areas within the plant. Time is at a premium and plants must balance their limited financial and manpower resources, while trying to maintain optimum production from their equipment.

For plant personnel, the primary advantages of off-site cleaning are:

1. Elimination of clean-in-place (CIP) equipment.
2. No handling and storage of potentially hazardous chemicals.
3. No need to manage the waste discharge of spent cleaning chemicals and the associated permitting and documentation requirements.
4. Minimal system downtime.
5. Maximum control of cleaning parameters.
6. The ability to pre- and post-test individual membranes, and generate reports.
7. The ability to selectively re-clean the membranes.

The secondary advantages of off-site cleaning by a qualified membrane cleaning facility are:

- Long-term tracking of individual membrane performance and cleaning efficacy.
- Performance tests that can be used to assess and project membrane life.
- Selective replacement of membranes, based upon the performance tests.
- The ability to perform laboratory studies, autopsies and other support services.

By design, an RO system is built to produce high-purity water, not to clean membranes. Individual membrane housings generally range in size from 4 to 8 membranes per housing. On-site cleanings are usually performed by stage. With multiple housings per stage, the number of membranes that need to be cleaned is multiplied (*# of membranes X # of housings X # of stages)*. Based on design limitations, all stages may require cleaning at one time. The foulants need to be displaced from the feed end of the first membrane through the concentrate end of the last membrane within the same housing. Likewise, depending on system design, the foulants may need to be moved through the system in total. With off-site membrane cleaning, generally a maximum of 3 membranes are placed into each housing within the cleaning equipment, which provides for more efficient cleaning.

Benefits

There are a number of benefits to a plant when cleaning off-site that are related to the advantages cited earlier. The plant

TABLE A
Typical RO Membrane Foulants

Metal Oxides
- iron
- manganese
- aluminum

Scaling Salts
- calcium carbonate
- calcium sulfate
- barium sulfate
- strontium sulfate
- calcium fluoride
- silica

Colloids
- silica
- clay
- silt

Organics
- humic acids and other natural organics
- coagulants
- incompatible pretreatment chemicals

Biological Materials
- organics slimes
- bacteria
- algae

no longer needs a CIP system or the resulting maintenance of this equipment. Floor space is gained and can be used for other operations. For a newly acquired RO system, a CIP system will not need to be purchased. Plant personnel would not require knowledge of the membrane cleaning process, or need to be trained in the operation of the CIP system. Exposure to potentially hazardous situations is avoided. Chemical storage and the danger of chemical spills are eliminated, as well as the need to maintain the paperwork, inventory, and special storage requirements (depending upon regulations) for the chemicals. Because chemicals no longer need to be mixed, neutralized and discharged, the associated environmental issues are avoided.

Finally, depending on the off-site cleaning service provider, replacement or "float" membranes can be used in the RO system, while the plant's RO membranes are being cleaned. This reduces any downtime due to cleaning. Qualified off-site cleaning facilities can provide support services, such as unloading/loading, packaging, and shipping of the membranes.

There are also benefits directly related to the cleaning process. Pressure, recirculation, and temperature conditions can all be accurately controlled, providing uniform cleaning conditions. Additionally, qualified off-site cleaning facilities can use optional cleaning methods, such as soaking, reverse flow, and air scour to address heavily fouled membranes. Off-site cleaning facilities typically stock a wide variety of chemical cleaners. Thus, if one cleaning chemical is not successful, another one can be used. Personnel at qualified off-site cleaning facilities are well trained and technically proficient in the area of membrane cleaning.

During off-site membrane cleaning, system operators can test individual membranes before and after cleaning to provide a more complete analysis of the membranes' condition. The performance tests are run according to the conditions recommended by the membrane manufacturer, and then normalized. The pre-test indicates the level at which the membrane is fouled, while the post-test provides the results of the cleaning. Together, the pre- and post-performance tests help determine the resulting efficacy of a particular cleaning. Using the performance test results, one can choose to re-clean an entire set of membranes or selectively choose individual membranes to be cleaned. If re-cleaning is required, there is no additional downtime, provided a set of replacement/float membranes have been installed in the plant's RO system.

Other advantages may not be as obvious, but are still important. Because qualified off-site cleaning facilities can performance test individual membranes, the membrane cleanings and performance tests can be entered into a database. Thus, a history of the membrane, its cleaning record, and performance results can be maintained. Other benefits of individual membrane performance testing include the ability to project expected membrane life and the selective replacement of membranes. By reviewing the performance data, a plant can selectively choose which membranes to keep or discard. This reduces capital expenditures because the entire set of membranes is not discarded. Finally, membranes that are difficult to clean can be autopsied to determine the nature of the foulants. Individual cleaning trials can then be performed on sections of the membrane to determine the best cleaning procedures to remove the foulants. The autopsy can also reveal possible deficiencies in the RO pretreatment process that, once addressed, can lead to fewer cleanings and better system performance.

The next section highlights three case studies of successful off-site cleanings as reported by independent facilities.

Case Study 1

The manufacturing division of a leading pharmaceutical company operates a 12-year-old RO system that consists of three parallel trains for producing make-up water for a distillate column. Each RO train is composed of a 2:1:1 array with each housing consisting of 5 membranes for a total of 20 membranes per train and a system total of 60 membranes. Each train is operated at a system recovery of 75% and is capable of producing 60-gallons per minute (gpm) permeate. The feedwater source to the system is a blending of municipal and on-site well water, with the blend ratio fluctuating with seasonal water supply availability. The system is operated by adjusting the feed pressure to maintain a 60-gpm permeate flowrate. The operating temperature is not controlled and varies between 45°F and 65°F. Pretreatment to the RO system consists of multimedia filters, softeners, caustic injection, bisulfite injection, and pre-filters.

Cleaning of the membranes by the facility is triggered by an increase in differential pressure drop across the system. Cleaning efficacy is determined by a "clean" membrane baseline that has been established for the RO system. The facility has cleaned the membranes both on-site, using a CIP system, and off-site. The company recently modified their CIP system to allow for heating the cleaning solution.

Even with the modification, a senior manufacturing facilitator utility engineer noted that the off-site cleanings have provided better cleanings than what the plant could achieve on site. "This has extended our membrane run times between cleanings and should also extend the life of our membranes. The off-site cleaning technology allows for better control of the cleaning process parameters and the ability to introduce special cleaning techniques," he said. The site engineer said that the service company can provide a report that supplies the cleaning and performance results of the individual membranes.

Case Study 2

U.S. Agri-Chemicals Corp., a phosphate producer in Florida, operates an 8-year-old, five-train RO system for producing boiler feedwater. Each RO train is composed of a 2:1 array, with each housing consisting of 7 membranes for a total of 21 membranes per train and a system total of 105 membranes. Each train is operated at a system recovery of 75% and is capable of producing 100-gpm of permeate. The feedwater source for the system is well water that contains high levels of hydrogen sulfide. The system is operated by adjusting feed pressure to maintain the permeate flowrate at 100-gpm per train. The system operates between 70°F and 80°F. Pretreatment to the RO system consists of sulfuric acid injection, 5-micron (µm) bag filters and 1-µm cartridge filters. Cleaning of the membranes by the facility is triggered by a loss in permeate flowrate and salt rejection. Cleaning efficacy of the membranes is directly determined by the operating performance of the system.

For several years, the facility had been cleaning their membranes on-site with a CIP system; however, they began using the service company for off-site membrane cleaning approximately 6 months ago.

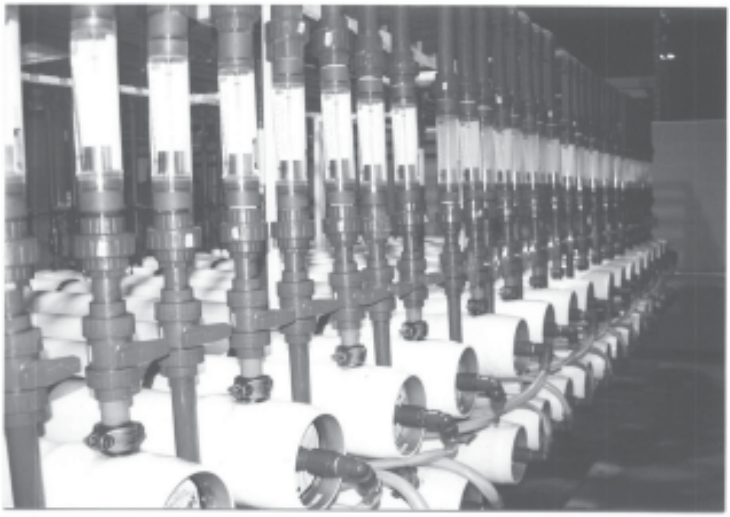

Figure 1. Off-site cleaning skid.

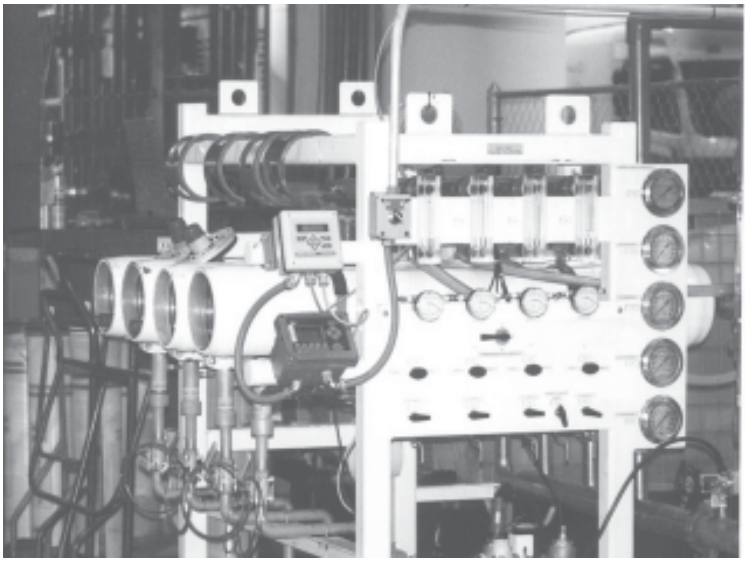

Figure 2. Performance test skid.

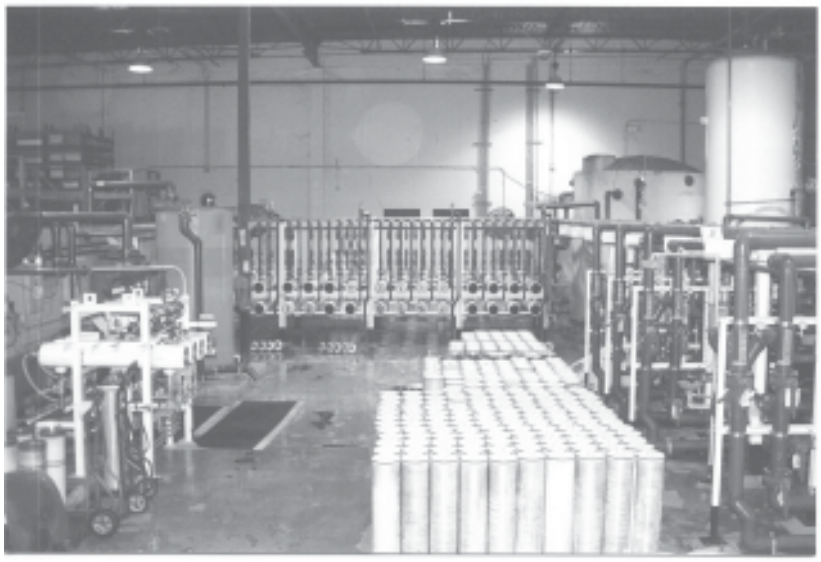

Figure 3. Off-site cleaning operation.

Charles Turvin, U.S. Agri-Chemicals' production coordinator, stated, "When cleaning on-site with our CIP system, the facility realized a 10% to 15% improvement in the operational parameters; however, recent cleanings of the membranes off-site by the service company have shown an increase of over 40% in the operational parameters." He continued, "The off-site cleanings have also minimized our system downtime. Prior to the off-site cleanings, a day or more was required to complete the cleanings and get our system back into operation. Our system can be unloaded/loaded in a couple of hours and placed back into operation. While our membranes are being cleaned off-site, a float set of membranes is placed into our system, allowing for minimal production downtime."

Case Study 3

Brazos Valley Energy LP, a power generating facility in Texas, operates a year-old RO system that consists of two parallel trains for producing boiler feedwater. Each RO train is composed of a double-pass RO system with a 2:1 array, followed by a 1:1 array with each housing consisting of 6 membranes, for a total of 30 membranes per train and a system total of 60 membranes. Each train is operated at a system recovery of 75% and is capable of producing 60-gpm of permeate. The feedwater source for the system is river water. The system is operated by adjusting feed pressure to maintain the permeate flowrate at 60-gpm per train. The operating temperature of the system ranges from 40°F to 90°F. Pretreatment prior to the RO system consists of a clarifier, multimedia filters and 5-µm pre-filters. Cleaning of the membranes by the facility is triggered by an increase in differential pressure drop across the system.

Jay Winters of Brazos Valley Energy stated, "We have incurred significant pressure drops across our system during operation, at which time we perform on-site CIP membrane cleanings. But, our capabilities and resources for cleaning are limited. And, while we find that our initial cleanings return the membranes' operational parameters to within our specifications, the production time between cleanings is successively reduced. We eventually reach a point where the cleaning does not return the operational parameters to within our specifications, and if we were to continue cleaning the membranes, we would

TABLE B
Customer Advantages for Off-Site Membrane Cleaning by a Qualified Service Provider

Primary Advantages	*Primary Benefits*
Clean-in-Place (CIP) equipment is not needed (storage and maintenance are eliminated)	Floor space is gained and can be used for other operations Capital expenditures are eliminated (for new systems) Maintenance is reduced or eliminated On-site personnel can be used for other responsibilities
Handling and storage of potentially hazardous chemicals is no longer needed	Exposure to hazardous situations is avoided Storage space is no longer needed Possibility for chemical spills is eliminated Associated paperwork, inventory (purchasing, receiving, etc.) and special storage requirements are eliminated
Managing of spent cleaning chemical waste discharge and permitting and documentation are eliminated	Chemicals do not need to be mixed, neutralized and discharged Associated environmental issues are avoided
System downtime is reduced or eliminated	Replacement or "float" membranes can be placed into the RO systems Support services (loading, unloading, packaging, etc.) can be provided to further eliminate time-consuming plant duties Operational personnel can attend to other responsibilities
Ability to control cleaning parameters is maximized	Pressure, recirculation, temperature, etc. can be easily controlled to provide uniform cleaning conditions Optional cleaning methods (soaking, reverse flow, air scour, etc.) can be used for difficult to clean membranes An array of cleaning chemicals can be used
Off-site cleaning technicians with specialized training perform the cleaning	Personnel receive specialized training in a variety of cleaning techniques, operation of the equipment and the mixing, handling and neutralizing of chemicals
Individual membranes can be pre- and post-tested, and reports generated .	Pre- and post-tests provide a more complete analysis of the condition of the membranes on an individual basis Pre-test provides insight into the level of fouling Post-test provides the results of the cleaning
Membranes can be selectively re-cleaned, if needed prior to being returned and placed into operation	Pre- and post-testing can determine the efficacy of a particular cleaning, and plant personnel can then selectively choose individual membranes to be re-cleaned Further downtime is eliminated for the second cleaning, if replacement or float membranes have been installed
Secondary Advantages	*Secondary Benefits*
Individual membrane performance and cleaning efficacy can be tracked long-term	A history of the membrane, its cleaning record and performance results are maintained in a database
Performance test results can be used to assess and project membrane life	Scheduling and budgeting for replacement membranes can be better controlled
Membranes can be discarded/replaced based upon the performance tests	Membranes can be individually selected versus discarding a whole set of membranes when poor system performance is observed Capital savings can be realized because "good" membranes are not discarded
Laboratory studies, autopsies, trial cleanings and other key support services can be provided	The nature of the foulants can be determined Proper cleaning procedures can be implemented Deficiencies in pretreatment can be determined and corrected

waste chemicals, production time and manpower." As a result. the enduser has decided on an off-site membrane cleaning service.

Summary
The advantages and the resultant benefits of cleaning membranes off-site have been presented in order to allow the operators of RO systems to consider off-site cleaning as an effective alternative for their facility. Advantages and benefits that an owner/operator of a RO system can receive from off-site membrane cleaning are summarized in Table B. Three case studies of successful off-site cleanings were presented to demonstrate how customers are successfully using this service to clean their membranes. Because each facility's operating situation and manpower requirements are unique, plant personnel must carefully weigh the advantages and benefits to determine if off-site cleaning is the right choice for their plant.■

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Endnote
USFilter is the service company referred to in the text.

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