CLEANING IN PLACE (CIP)

Procedures For Membrane Systems

INTRODUCTION

During normal operation of a membrane system, the membranes will eventually exhibit a loss of performance from fouling or scaling. When the normalized permeate flow has declined 10%-15%, a Clean-in-Place (CIP) should be scheduled. Review of the operating data and feed water quality will aid in determining the most effective CIP procedure. In certain situations a membrane autopsy/cleaning analysis may be considered to help define the best CIP procedure. The manufacturer of the membrane model that is to be cleaned is a valuable resource. They generally have recommended guidelines for cleaning and their specific membrane model cutsheets provide pH and temperature limits that should not be exceeded. Suppliers of specialty membrane cleaning chemicals can also provide a wealth of knowledge. In addition, the engineer or system supplier for the membrane treatment equipment can assist with site-specific knowledge. CIPs for spiral wound membrane systems – reverse osmosis (RO) and membrane softening (NF) – are usually much more infrequent and, therefore, more of a manual process compared to CIPs for low pressure membrane systems such as micro and ultrafiltration, referred to as Membrane Filtration (MF).

SAFETY CONSIDERATIONS

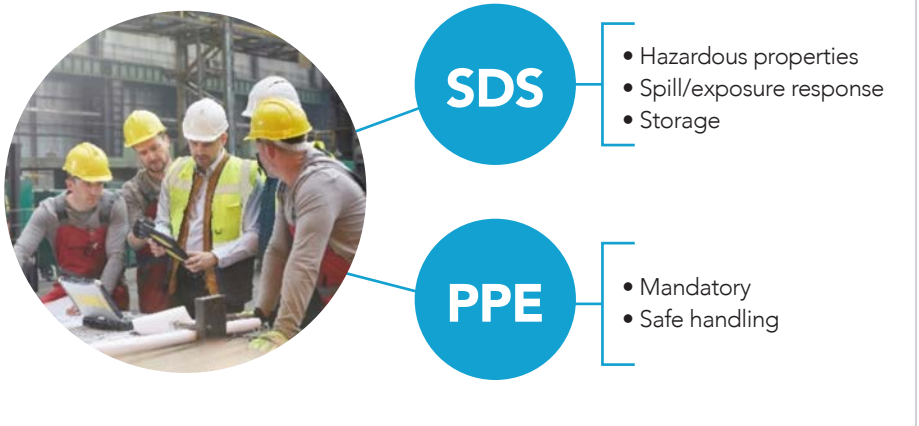
Safety is the number one concern when handling cleaning chemicals. Cleaning-in-Place chemicals should always be treated with caution. Avoid storing high and low pH cleaners next to each other as a strong reaction can occur if there is a spill. When adding the CIP chemicals, proper Personal Protective Equipment (PPE) should always be worn. This will vary depending on the chemical and the steps required to introduce them into the system. Consult the Safety Data Sheet (SDS) before first use. Special care should be taken if adding powders in an enclosed space. A well-ventilated area is optimal for handling powders.

PRE-CIP CONSIDERATIONS

There are standard CIP guidelines that are shared for cleaning either RO/NF or MF systems. A high pH clean is usually recommended before a low pH clean because salts may precipitate or re-disperse during the high pH clean. Those salts can then be removed by the subsequent low pH clean. The opposite order has a higher propensity for foulant or scale to remain in the system after the conclusion of the CIP. Finishing with a low pH cleaning can also help restore the salt rejection of the membranes, which may be negatively impacted by the high pH cleaning. The pH of the solution should be taken prior to cleaning and compared to the target pH from the CIP procedure or manufacturer. The calculation for volume of chemicals needed should include the tank volume and piping factor to get a good estimate of the required amount. The volume calculation coupled with pH measurement should guarantee that the proper amount of chemicals has been added.

It should be noted that the solution temperature tends to increase during recirculation; hence start recirculating the CIP make-up solution with the heating element on before the final temperature is achieved. Ideally, the CIP system piping is designed with a recirculation line between the discharge of the CIP pump and the CIP tank so the solution can be mixed and heated within the CIP system prior to introduction to the membrane skid to be cleaned. A final temperature of 35-40°C for cleaning is commonly recommended. Consult the membrane manufacturer temperature guidelines for cleaning. Cleanings that can be performed at an elevated temperature are typically more effective and are essential when cleaning for biofouling.

RO/NF: The initial measurements for RO/NF should include a conductivity reading of the feed, permeate and concentrate water to compare after the CIP. The CIP process begins with a flush to remove any lose particles and displace process water



in the RO system with the CIP solution. Next, configure the system to be a closed circuit to recirculate the CIP chemicals or single pass if an extreme buildup of foulant or scale has occurred. Care should be taken to ensure that the valves are in the correct positions to avoid pressure build up and to control permeation of CIP chemicals. Ensure there is a path for any permeate produced to discharge back to the CIP tank so the permeate side of the membrane does not experience back pressure. Also, ensure that spool pieces are removed, block and bleed valves are in the correct position, or any other cross-connection controls are in place.

The ideal system configuration should maximize the cross flow of the CIP solution across the membrane. If possible, the CIP loop should include cartridge filters to prevent redeposition of particulates on the membrane surface. The goals for effective cleanings are to achieve high crossflow (approximately 40-50 gpm per 8" pressure vessel) at a low pressure (<60 psi). It is important to clean each stage individually so that foulant from one stage is not introduced to another stage and so that proper hydraulics and crossflow are maintained. Also, try to orient skid cleaning connections so that the cleaning solution does not have to flow through restrictions such as control valves or booster pumps. Hard-piped cleaning connections are recommended to minimize loss of cleaning solution or exposing operators to cleaning fluid, which is possible when cleaning with mobile hoses.

MF: Foulant buildup on MF membranes can cause a significant decrease in the membrane permeability and increase in normalized trans-membrane pressure (TMP). To test the effectiveness of a CIP cycle, it is best to note the permeability before cleaning, which is commonly measured as GFD/psi. The CIP process for MF differs from RO with respect to use of halogen-based chemical oxidizers and the ability to perform a backwash (with air-scour, if available). Conduct a regular backwash with an air-scour if available to loosen particulates deposited on the outside of the membrane surface. Air-scour is only available for outside-in flow MF membranes in a vertical assembly wherein air is introduced across the outside of the fibers. Drain the module to remove the dislodged particulates and to prevent any dilution of the CIP chemical make-up solution. The MF modules are now ready for a chemical CIP.

CIP CONSIDERATIONS

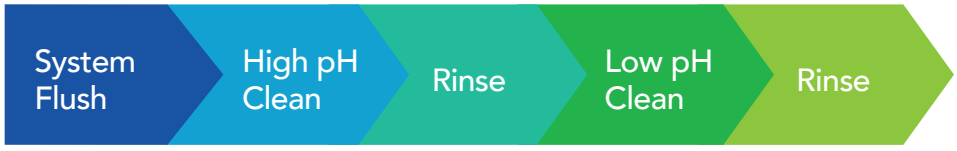
RO permeate or deionized water is preferred for the CIP make-up solution. The cleaning chemicals, especially powders, should be dissolved into the CIP solution completely before circulating through the membrane elements. This can be accomplished with a static mixer or more commonly by recirculation through the CIP pump to the tank to mix. A powdered chemical can also be premixed manually into a liquid slurry in a drum prior to introduction into the CIP system. This is especially important with powder cleaners as improper mixing could cause abrasion to the membrane surface or it may result in powder "cottage cheese" buildup that blocks the feed channels and prevents an effective cleaning.

The changes in the turbidity of a cleaning solution are good indicators of an effective CIP. Should the cleaning solution become rapidly turbid, send at least 20% of the solution to the drain and refill the tank with the CIP cleaning make-up solution. It is critical to monitor the pH and temperature of the CIP solution during the cleaning process to ensure both parameters remain at the desired levels. Strongly buffered specialty cleaning chemicals should resist pH drift whereas generic acids and caustics used for cleaning will need to be closely monitored. As a rule of thumb, pH changes of more than 1 pH unit require acid or alkali mediation.

RO/NF: The CIP solution is recycled through the RO/NF elements for 30-60 minutes. During recycle, if the system pressure is high, permeation of the CIP solution could harm the membrane. As the system is cleaned, the flows may fluctuate. It is important to prevent spikes in crossflow rates and maintain it around 40 GPM without exceeding differential pressure (ΔP) limits specified by the membrane manufacturer.

A recycle step is often followed by a soak period. Membrane soaking is important because some chemical cleaners work best in static conditions to remove foulants. A final recycle is performed followed by a drain and system flush before the RO skid is returned to service. In cases of heavier fouling, the circulation and soak steps may have to be repeated multiple times.

MF: The cleaning solution is recycled through the module using a low flow pump. Depending on the flow direction of the water through the fibers, the chemical



Photos show typical packaged CIP systems for NF/RO

solution can be recycled either outside or inside of the fibers. Cleaning solution is often recycled for 30-60 minutes.

The first recycle is often followed by a soak cycle for 60 minutes or longer depending on the extent of the fouling. If extended soak times are necessary, refresh the soak solution every 20-30 minutes at a slow recirculation rate. This will also help maintain the temperature of the soak solution inside the MF module/bank.

A final recycle step is performed for 30-60 minutes followed by an air-scour and draining the CIP solution from the modules. A backwash is performed to remove any concentrated CIP chemicals before the skid is brought online. A backwash is recommended between high pH and low pH chemical cleans.

NEUTRALIZATION: Often the spent cleaning solution cannot be directly discharged to the sewer system due to chemical contents and high/low pH. Typically, a neutralization system is installed to adjust the pH and dechlorinate (CIP) prior to sewer system discharge.

The neutralization system can be fully automated using pH, oxidation-reduction potential and /or residual chlorine analyzers.

POST-CIP CONSIDERATIONS

Before returning the system to service, a post-CIP rinse is performed. An RO system should be rinsed until the concentrate conductivity is similar to that of the feed, and no foaming is visible. This indicates that the chemicals used for the CIP have been completely flushed out of the system.

When the RO system is returned to service, compare the normalized operation data trends to assess CIP effectiveness. The pressure drop across each stage of the membrane system should also be recorded to check for removal of scale or biofilm. Comparing the pre- and post-CIP differential pressure data can illustrate the effectiveness of the cleaning. **Figure 1** shows how the normalized data helped the operator to make a decision to perform a CIP on time, and obtain an excellent result after the CIP, where differential pressures dropped significantly.

Permeability of the MF module is measured to check cleaning efficiency. Normalized TMPs should drop and an increase in flow through the MF membrane would indicate an effective CIP cycle. ■

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Photo shows a fully automated neutralization system

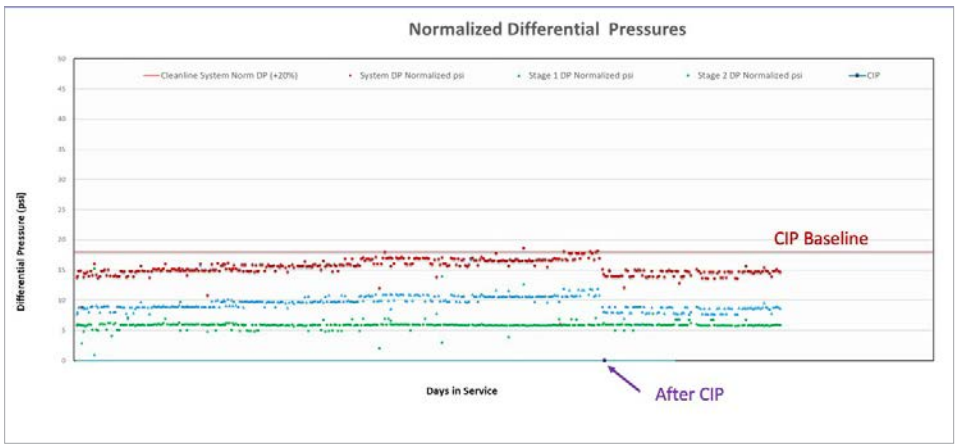

Figure 1: Graph shows normalized data and CIP event

This material has been prepared as an educational tool by the American Membrane Technology Association (AMTA). It is designed for dissemination to the public to further the understanding of the contribution that membrane water treatment technologies can make toward improving the quality of water supplies in the US and throughout the world.