Membrane Clean-in-Place (CIP) Guide for Industrial Aquaporin Inside® RO Membrane Elements

Introduction

The surface of an RO membrane is subject to fouling by suspended solids, colloids, precipitates, organics, and biological matter. Pre-treatment of feed water prior to the RO process is required to prevent fouling as much as possible. The nature and intensity of fouling depends on several factors, such as the quality of the feedwater, the system recovery rate, and operating conditions.

To ensure long membrane lifetime and optimal membrane performance, periodic membrane cleaning is required. Membrane clean-in-place (CIP) should be performed when the RO membranes show evidence of fouling, prior to a long-term shutdown, or as scheduled routine maintenance. Fouling of membrane elements is indicated by performance decline, i.e. decreasing permeate flowrate and/or higher solute passage. Another side effect of fouling is an increased pressure drop between the feed and concentrate side. To avoid permanent performance loss and membrane damage, membrane CIP should be performed at the latest when one or more of the following occur:

- Normalized permeate flow has decreased 10% since startup or last cleaning
- Normalized salt passage has increased 10% since startup or last cleaning
- Normalized pressure drop from feed to concentrate has increased 15% since startup or last cleaning.

Membrane CIP can be accomplished very effectively due to high pH stability and temperature tolerance of the industrial Aquaporin Inside® RO membrane elements. The choice of membrane CIP protocol and CIP chemicals needs to be tailored to the specific fouling problem. Note that a wrong choice can make a situation worse. Therefore, the type of foulants on the membrane surface should be determined prior to cleaning, e.g. through analysis of performance data, analysis of feedwater characteristics and foulants, reference to previous cleanings, etc.

Recommended Membrane CIP Protocol

The RO membrane elements can be cleaned-in-place in the pressure vessels by soaking and circulating the cleaning solution across the high-pressure side of the membrane. RO cleaning procedures may vary depending on application and situation. The recommended standard membrane CIP consists of an alkaline cleaning followed by an acidic cleaning. Below CIP protocol should be followed for each cleaning solution.

1. Prior to introducing any cleaning solutions, it is recommended to flush the elements with clean water to displace any feed/brine solution. Flush water should be RO permeate or deionized water. Flushing flow rates should be half of the cleaning flow rates listed in **Table 1**.
2. Prepare the cleaning solution and adjust the temperature and pH to the target values. Temperature and pH limits are shown in **Table 2**. Recommended generic cleaning solutions are shown in **Table 3**.
3. Pump the cleaning solution into the pressure vessel at low feed flow rates and pressures. The flow rate should be half of the cleaning flow rates listed in **Table 1**. The pressure should be low enough that ideally no permeate is produced. Discard the concentrate, as necessary, to prevent dilution of the cleaning solution or readjust the pH and temperature to the targets.
4. After the clean water or process water has been displaced, circulate the cleaning solution at feed flow rates and pressures according to **Table 1**. If required, readjust the pH and temperature to the target values. pH and temperature of the cleaning solution should be monitored, controlled, and kept below the maximum allowable values during the whole cleaning cycle (**Table 2**). A standard cleaning consists of 30 minutes circulation.
5. After circulation, it is recommended to stop the pump and allow the membrane to soak in the cleaning solution. The soak time can vary from 30 minutes to 8 hours. A standard cleaning consists of 30 minutes soaking. An extended soak period is beneficial for difficult or excessive fouling. During long soak periods, circulate the cleaning solution slowly at ca. 1/10 of the flow rates stated in **Table 1** or in intervals to monitor and control the target temperature and pH.
6. After soaking, it is recommended to circulate for another 30 minutes. Temperature and pH should be monitored and controlled.
7. After the cleaning cycle, RO permeate or deionized water at minimum 20 °C is recommended for flushing out the cleaning solution and remaining foulants.
8. A second cleaning with a different cleaning solution can be started at this point, if required. Otherwise, flush membrane elements for at least 30 minutes with permeate directed to drain or until the permeate is clear and permeate pH has normalized.

Table 1: Cleaning feed flow rates during circulation.

Element Diameter	Feed pressure	Feed flow rate per pressure vessel	
[inches]	[bar]	[GPM]	[LPM]
4	1-4	9-12	34-45
8	1-4	36-48	136-182

Table 2: Temperature ranges and pH limits during cleaning.

Temperature Range	> 45 °C	>35 - 45 °C	>25 - 35 °C	≤ 25 °C
pH limit for CIP	Contact Aquaporin for assistance	pH 2.0 - 10.5	pH 1.0 – 11.0	pH 1.0 – 12.0

Cleaning Chemicals

Choosing the right cleaning chemicals is important since harsh and frequent membrane cleaning will shorten the membrane life, and sometimes a wrong choice of cleaning chemicals can worsen the fouling situation. The membrane cleaning will be more effective if it is tailored to the specific fouling problem. Therefore, the type of foulants should be determined prior to cleaning. **Table 3** lists the recommended simple cleaning chemicals depending on the type of foulants.

Generally, alkaline cleaners are used to remove organic fouling including biological matter, while acidic cleaners are used to remove inorganic precipitates including iron. If the elements suffer from inorganic precipitation and organic fouling, it is highly recommended to start with the alkaline cleaning. The acidic cleaning should only be performed once all organic, colloidal and biofouling has been removed, as acid cleaners can react with organic material and worsen the fouling problem. Sulfuric acid should not be used for cleaning because of the risk of calcium sulfate precipitation. RO permeate or deionized water should be used for the preparation of cleaning solutions.

Specialty cleaning chemicals are frequently used in the industry. Most of them are compatible with Aquaporin membranes in short term tests. For long term compatibility, please contact the cleaning chemical provider and Aquaporin for assistance. In any case, make sure that the given temperature and pH limits are not exceeded.

Table 3: Recommended cleaning solutions and alternatives.

Foulant	Cleaning solution	Alternative 1	Alternative 2
Carbonate scale	0.2 wt% HCl pH 1-2, max. 35 °C	2.0 wt% citric acid	0.5% wt% H_3PO_4 pH 1-2, max. 25 °C
Iron fouling	1.0 wt% $Na_2S_2O_4$ pH 5, max. 30 °C	2.0 wt% citric acid	0.5% wt% H_3PO_4 pH 1-2, max. 25 °C
Sulfate scale	0.1 wt% NaOH + 1.0 wt% Na_4EDTA pH 12, max. 25 °C	-	-
Biofouling	0.1 wt% NaOH pH 12, max. 25 °C	0.1 wt% NaOH + 1.0 wt% Na_4EDTA pH 12, max. 25 °C	-
Silica fouling	0.1 wt% NaOH pH 12, max. 25 °C	-	-
Organic fouling	Step 1: 0.1 wt% NaOH pH 12, max. 25 °C Step 2: 0.2 wt% HCl pH 2, max. 45 °C	Step 1: 0.1 wt% NaOH + 1.0 wt% Na_4EDTA pH 12, max. 25 °C Step 2: 0.2 wt% HCl pH 2, max. 45 °C	-

Safety Precautions During the Cleaning Procedure

When using cleaning chemicals, follow accepted safety practices. Consult the chemical manufacturer for detailed information about safety, handling, and disposal.

Respect the temperature and pH limits stated in **Table 2**. For cleanings that require conditions exceeding these limits, please contact Aquaporin for assistance.
Use the least harsh cleaning conditions possible. This includes the cleaning parameters of pH, temperature, and contact time. This will optimize the lifetime of the membrane.

Thoroughly rinse the first cleaning solution from the element before introducing the next solution.
After cleaning, the elements should be flushed with preferably permeate or deionized water and at reduced flow and pressure to flush the bulk of the cleaning solution from the elements before resuming to normal operating pressures and flows. Further, the permeate must be directed to drain for at least 30 minutes or until the water is clear as cleaning chemicals will be present on the permeate side.

Cleaning and flushing flows should usually be in the same direction as the normal feed flow to avoid potential element telescoping and element damage.

Aquaporin A/S
Nymøllevej 78
2800 Kongens Lyngby
Denmark

Phone: +45 8230 3082
sales@aquaporin.com
aquaporin.com

Aquaporin Inside®