7 Chemical Clean-In-Place (CIP)

7.1 General Overview

The pressurized UF In-Out process is designed to maintain clean membrane state throughout the entire operation by both, hydraulic cleaning steps (backwash) and chemical cleaning steps (CEBs). The feed water can, however, contain contaminants (natural or introduced), which cannot be adequately removed by CEB.

A Clean-In-Place (CIP) procedure has been designed to restore membrane productivity for difficult to remove fouling and scaling. There are several different CIP chemicals and procedures available, depending on the nature of the foulant or scale. CIP is typically performed as a manual procedure; however, full automation of the CIP procedure(s) is also possible.

A CIP is performed by introducing a chemical solution into the modules and shutting down the individual UF-rack for a longer period of time than is required for conventional cleaning methods. One of the major differences to a CEB is that a CIP is characterized with the recirculation of different chemicals using a forward flush through the membranes back into a CIP tank followed by an extended soaking time (in some cases the feed tank can also be used as a CIP tank).

NOTE	
	**ATTENTION!** Observe the following guidelines!

- A CIP should be performed if the permeability of the system falls below 100 –150 L/(m²h)/bar (4 – 6 GFD/psi) and if this drop cannot be reversed by performing a CEB. A CIP is rated as successful if the permeability of the system subsequent to the CIP is restored to a value of at least 70 – 80% of the reference value* recorded after the commissioning of the ultrafiltration system.
- Only those chemicals specified in the section "Using Chemicals for CEB/CIP" may be used for a CIP, and only in conformance with the concentrations and soaking times specified. No other chemical(s) may be used unless prior written approval has been obtained from DuPont™ specifically agreeing to its use and stating the permissible concentration.
- The water used to prepare the CIP cleaning solution should be at least of drinking water quality. If reverse osmosis permeate is available, this should be used for the alkaline CIP. Please note that precipitation may occur in the CIP water, particularly if UF filtrate or water of drinking water quality is used for the alkaline CIP. An alkaline CIP must therefore always be followed by an acid CIP or alternatively by a standard acid CEB.
- The overall duration of the recirculation and soaking time of a CIP depends on the effectiveness of its cleaning results, though it should not exceed 12 hours.
- A conventional backwash should be performed prior to a CIP to ensure that the membrane surface is as clean as possible and to rinse out any foreign particles that may be contained in the piping of the modules or racks.
- When performing a CIP, ensure that the modules and racks being cleaned are disconnected from the rest of the main system.
- The CIP solution must be fed into the rack from the feed side of the modules/rack. This prevents any damaging substances which could cause fouling or scaling from entering through the filtrate side of the membranes during CIP recirculation.

---

* Experience has shown that permeability falls during the initial running-in phase of a membrane, which generally lasts around one week, dropping from its initial level to a lower yet stable level of permeability which depends on a number of factors including the quality of the source-water. It is this subsequent, stable level that is classified as the reference value. The initial permeability of PES-UF modules lies somewhere in the range of approximately 700 L/(m²h)/bar (28.4 GFD/psi), while the reference permeability lies between 300 and 600 L/(m²h)/bar (12.2 – 24.4 GFD/psi) depending on the source-water quality.

- In some applications it may be possible to improve the effectiveness of the cleaning process and reduce the soaking time by heating the CIP solution. If a system is available to heat the CIP solution, this system must observe the maximum permitted temperature of 40 °C and the maximum permitted rate of temperature change of 5 °C/min. A significant amount of energy is required to heat the solution and the process of ensuring compliance with the maximum 5°C/min temperature change rate can be relatively complicated. Heating of the CIP solution is not necessary in the vast majority of application and is therefore not recommended when using PES-UF modules.
- Ensure adequate ventilation of the area before and while using cleaning chemicals.
- When preparing the chemical solution in a CIP tank (mixing together the cleaning chemical and water), the chemicals must always be added to the tank of water, not the other way around. Adding water to concentrated chemicals could cause a violent reaction.
- It is important to ensure that the CIP chemicals are recirculated in the system for a long enough period of time to ensure that they are distributed evenly and homogeneously throughout the entire rack in the concentration required in each case. If the concentration falls below the required value, more of the chemical must be added.
- Note that the concentration of the CIP solution will be diluted by the water stored in the rack including the manifold (known as the "hold-up volume") and that this hold-up volume may lead to precipitation in the case of an alkaline CIP. When performing a CIP using reverse osmosis permeate, it may therefore be a sensible idea to empty the rack including the manifold before injecting the CIP solution.
- To increase the efficiency of a CIP cleaning, DuPont™ recommends performing multiple successive cleaning steps using different chemicals.
- If using a coagulant in the pretreatment stage, or if there are concerns that metals may have accumulated on the membrane surface, it is essential to perform an acid CIP before any CIP or disinfection process that involves oxidants in order to optimize the cleaning efficiency and to prevent coagulant from being deposited on the membrane. Ensure that the acid CIP solution has been completely rinsed out of the system before performing the oxidant CIP or disinfection process.
- Chlorine-containing CIP solutions should under no circumstances be mixed with acid CIP solutions (e.g. in a neutralization tank), since this could lead to the formation of toxic chlorine gas.

7.2 Establishing CIP Recirculation

The CIP tank must be designed large enough to ensure that the minimum level of water delivers sufficient initial pressure to the intake side of the CIP pump and that the previously empty pipes of the recirculation system can be filled. The total volume of the CIP tank is therefore obtained by adding together the following partial volumes:

- Empty volume of the piping from the top feed to the module/rack incl. manifold (V1)
- Empty volume of the filtrate piping (V2)
- Empty volume of the piping from the bottom feed to the module/rack incl. manifold (V3)
- Volume required to protect the CIP pump from running dry (V4)
- In seawater applications the UF rack has to be drained prior to CIP!

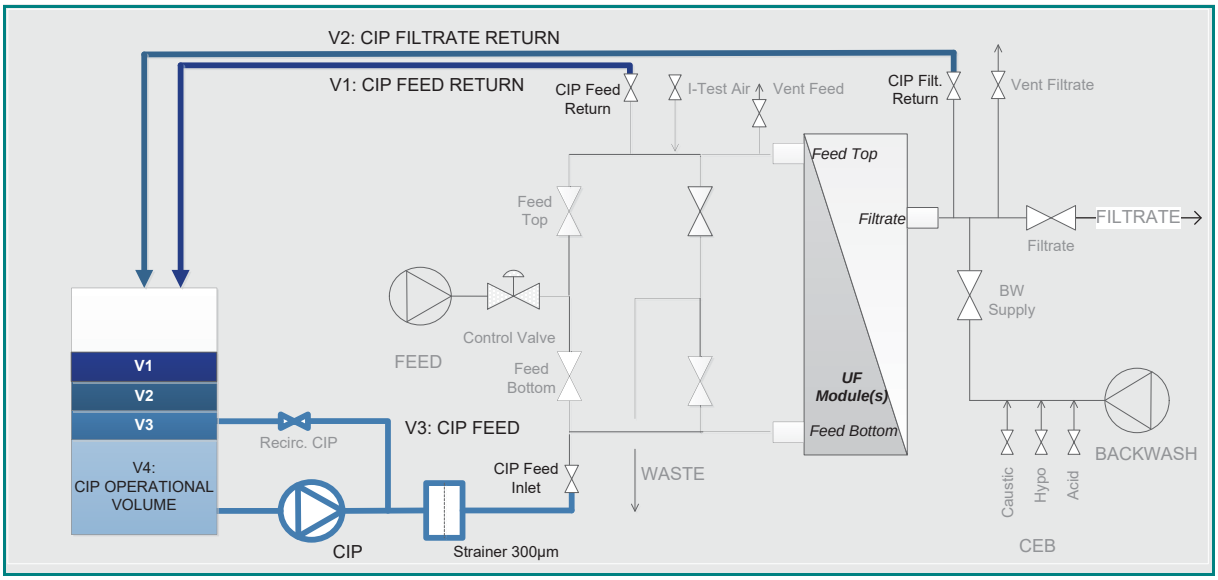

Figure 7.2-1 - Partial volumes for determining the size of the CIP tank

To protect the membranes from damaging particles, it is important to install a screen filter with a minimum cut-off of 300 µm in the recirculation system or at the point where the CIP solution is fed into the system. The recommended volume flow rate for cleaning all PES-UF modules is at least 25 L/(m²h) (12 GFD), the maximum hydraulic pressure loss 1 bar /14.5 psi).

[Design recommendation for the CIP cleaning pump capacity:

Nb of modules x surface area / module x 25 L/(m²h) (12 GFD) = volume flow rate @ minimum 1 bar]

7.3 How a CIP is Performed

7.3.1 Preparing the Chemical Solution for a CIP

1. The CIP tank (or feed tank) is filled with UF filtrate, reverse osmosis (RO) permeate or drinking water. If available, RO permeate should be used for the alkaline CIP.
2. The cleaning chemicals are added to the water-filled CIP tank, not the other way around.
3. The chemical solution is mixed using a mixer or a special recirculation system.

   After mixing, check that the pH value and concentration of the solution correspond to the target values. It is important to ensure that the concentrations do not exceed the maximum concentrations specified in DuPont™ IntegraTec™ P Series | PES In-Out specific product documentation.
4. (In seawater systems, there must be a rack draining step at this point).
5. If a heating system is to be used to heat the chemical solution, the heating process may not commence until the chemical solution has begun recirculating through the modules. Significant differences in temperature between the chemical solution and the water inside the modules could lead to stress cracks in the module and should therefore be avoided. Do not exceed the maximum permitted rate of temperature change or the maximum permitted operating temperature for the modules.

7.3.2 Preparing for a CIP Process

1. For a manual CIP, ensure that the valves are in the correct positions and that the connections are set properly for the cleaning cycle:
   - Cleaning solution inflow = feed bottom header connection
   - Cleaning solution outflow = feed top header connection
   - Filtrate outflow = filtrate

2. The cleaning solution may be pumped either in forward flush mode or in filtration mode. However, the CIP method described should under NO circumstances be used in the backwash direction since this could cause large-scale irreversible contamination or bacterial growth on the filtrate side.

7.3.3 Recirculation and Soaking time

1. In the first stage, recirculation should only take place via the feed side for at least 60 minutes in order to perform initial cleaning of just the fiber lumen. The filtrate valve is closed during this procedure.
2. Injection of the chemical solution into the fiber lumen on the feed side is triggered by starting the CIP cleaning pump (Figure 7.3-1). Set the minimum volume flow rate in accordance with the section "Establishing CIP Recirculation". It is important to ensure a feed side venting.

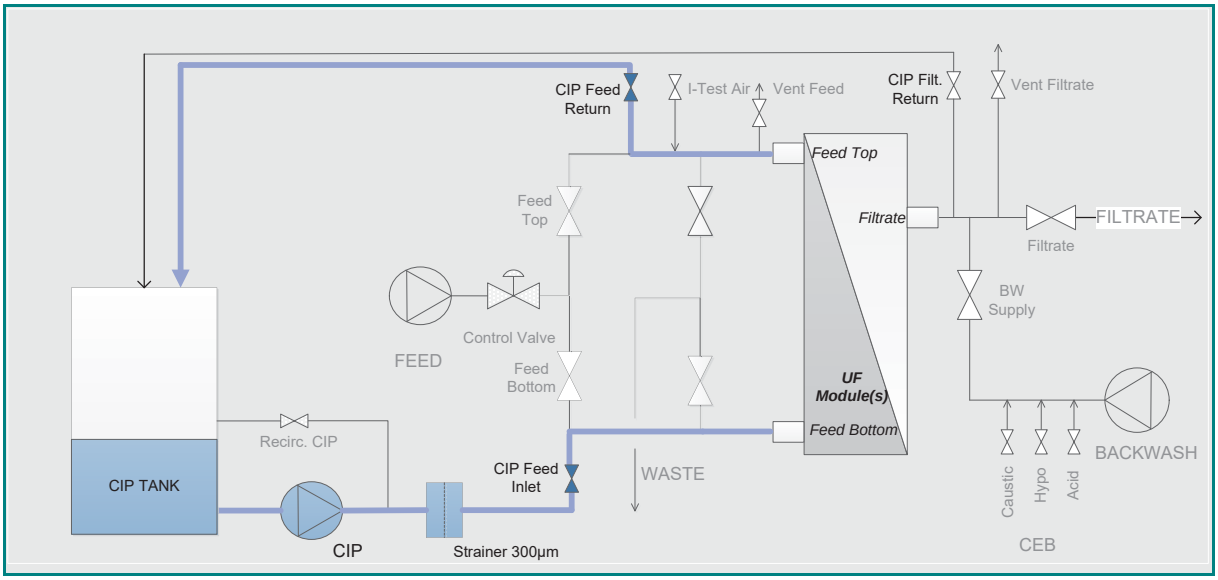

Figure 7.3-1 - Recirculation on the feed side

3. If the chemical solution is to be heated, it should be slowly heated to 30-35°C while it is recirculating through the system. Do not exceed the maximum permitted rate of temperature change or the maximum permitted operating temperature for the modules.
4. The readings of the temperature, pH value and concentration of the cleaning solution are to be continuously monitored and documented to ensure that they remain within the required range and within the scope of the permissible operating conditions. Long periods of recirculation could potentially heat the solution to a level above the maximum permitted temperature due to waste heat from the pump entering the equation. If the temperature exceeds the required level, this must be countered by adding fresh UF filtrate, RO permeate or drinking water. The pH value and chemical concentration should be adjusted to meet requirements.
5. Once at least 60 minutes have passed with the solution recirculating exclusively through the feed side, the process moves on to a second stage in which the filtrate side is incorporated in the recirculation process. The filtrate valve is now opened, and CIP fluid is allowed to recycle through the feed top port and through the filtrate port simultaneously. Normally, the flow rates should be of similar dimension which is acceptable for the CIP process. Recycle flow rates should nevertheless be verified for similarity during the first CIP. Flow rate ratios are allowed to differ as much as 20%-80% for compliance with this CIP procedure.

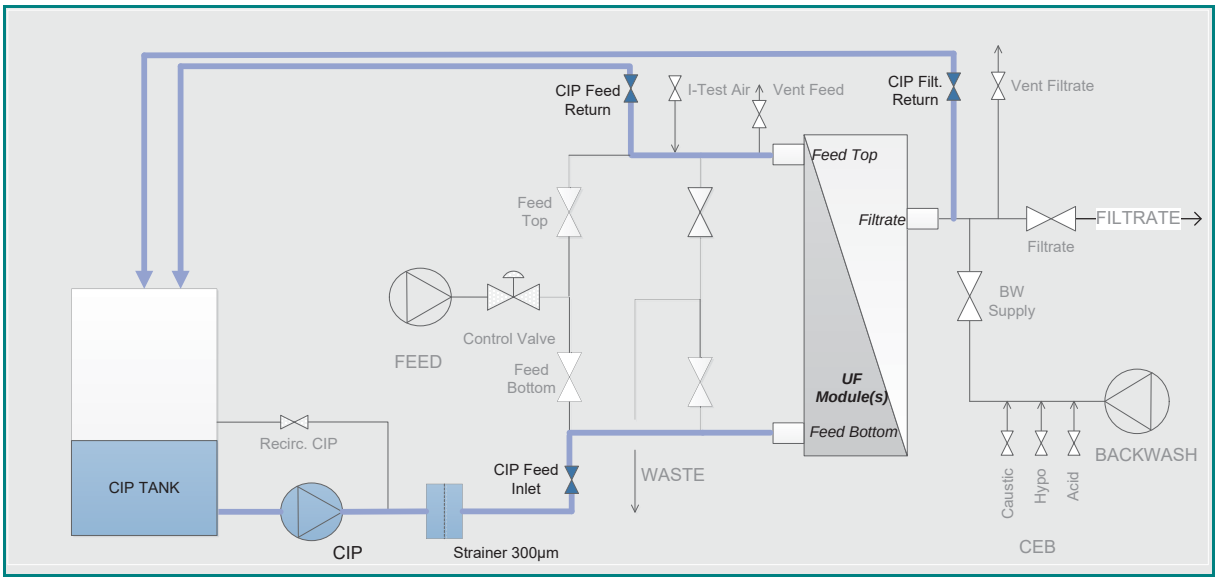

Figure 7.3-2 - Recirculation on feed and filtrate sides

6. During the entire recirculation process, which should last for at least a further 60 minutes, it is important to ensure that the chemical solution recirculates through both - the feed and filtrate - sides.
7. Once the chemical solution has been recirculating through the system for approximately 2 hours, the process moves on to a third stage which alternates between soaking periods and recirculation through the feed and filtrate sides. In this third stage, the cleaning pump is stopped, the heating element is switched off, and the feed side valves are closed (ensure venting all the time).
8. As a rule of thumb, 60 minutes is sufficient for the soaking time prior to the next recirculation, though longer soaking times may be necessary in the case of stubborn fouling or scaling. To maintain a high temperature during lengthy soaking times, a brief recirculation process lasting approximately 5 minutes should be conducted midway through the soaking time.
9. The next steps involve alternating between recirculation through the feed and filtrate sides and soaking times. Note that the duration of a recirculation period should not exceed 60 minutes and the overall duration of recirculation and soaking time should not exceed 12 hours.

7.4 Preparing to Rinse out the Rack/System

1. Once the recirculation process has been completed, the chemical solution is drained from the CIP tank. Where required, the solution should be neutralized before being discharged. Ensure that the discharged solution complies with all the local regulations regarding discharges into the sewage system. Before emptying the CIP tank, ensure that the feed side valves of the modules/racks are closed.
2. Once the CIP tank is empty, it can then be refilled with UF filtrate, RO permeate or drinking water ready for the next rinsing process. It is not necessary to use RO permeate to rinse out the system even if this is available.

7.5 Rinsing out the Rack/System

After completion of the soaking period, the standard CEB rinsing procedure is used to rinse out the remaining chemicals.

The following diagrams show the two rinsing operating modes "Rinsing Drain Bottom" and "Rinsing Drain Top". Figure 7.5-1 shows a Rinsing Drain Bottom (RDB) step in which the backwash water (filtrate) exits the module at the bottom feed/drain port, while Figure 7.5-2 shows a Rinsing Drain Top (RDT) step in which the backwash water exits the module at the top feed/drain port.

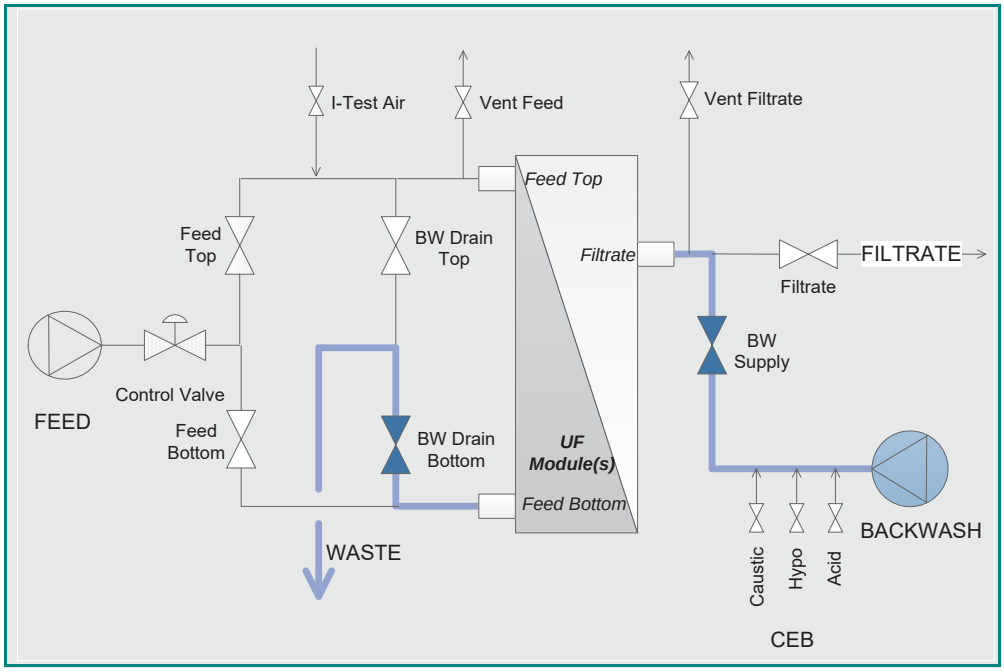

Figure 7.5-1: Rinsing of CIP chemicals in Drain Bottom mode

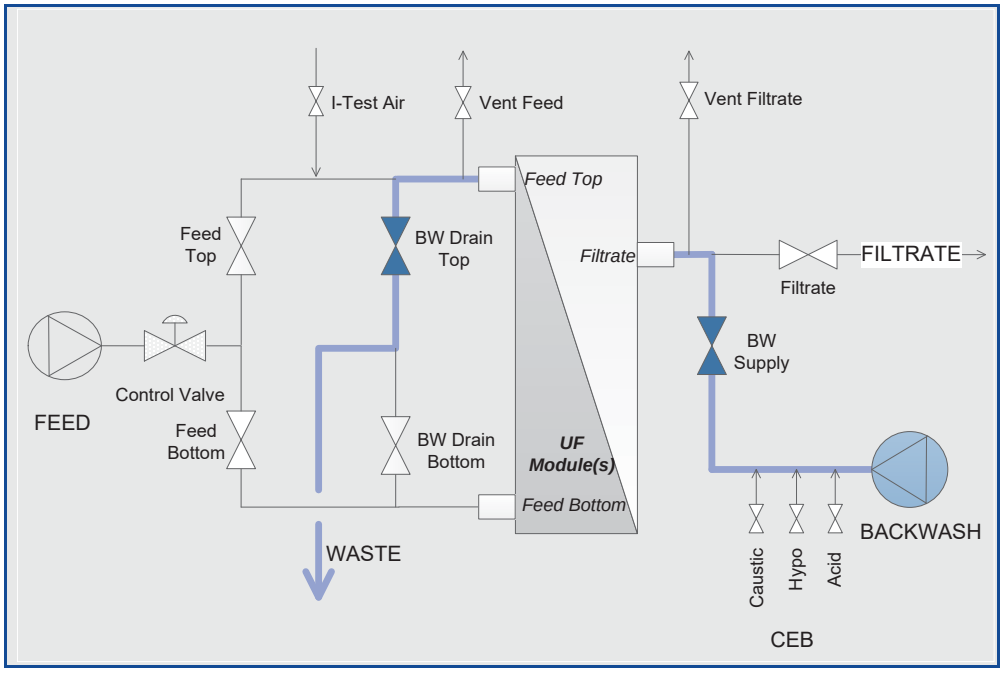

Figure 7.5-2: Rinsing of CIP chemicals in Drain Top mode

If the chemical solution has previously been heated, the first step before beginning the rinsing process is to equalize the respective temperatures of the rinsing water and the chemical solution contained within the module/rack by stopping the CIP pump and waiting for the temperature inside the UF rack to return to ambient conditions. Alternatively, colder water can be added at slow rate to the CIP tank towards the end of the CIP recirculation. Significant differences in temperature between the rinsing water and the chemical solution inside the modules/rack could lead to stress cracks in the module and should therefore be avoided. Do not exceed the maximum permitted rate of temperature change or the maximum permitted operating temperature for the modules

Required duration of the CIP rinsing procedure must be determined by sampling of discharge water for residual chemicals (e.g. pH or free chlorine) and evaluated based on project specific permissible contaminant concentration.

During the rinsing process, the flow rate (flux rate), the temperature and the TMP (transmembrane pressure) should be monitored and documented in order to calculate the permeability and check the cleaning efficiency of the preceding cleaning process.

Once the rinsing process has been completed, the permeability should be monitored and documented in filtration mode in order to check the efficiency of the CIP. This should be conducted after every CIP, even if two CIPs are performed in succession.