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Issue 1
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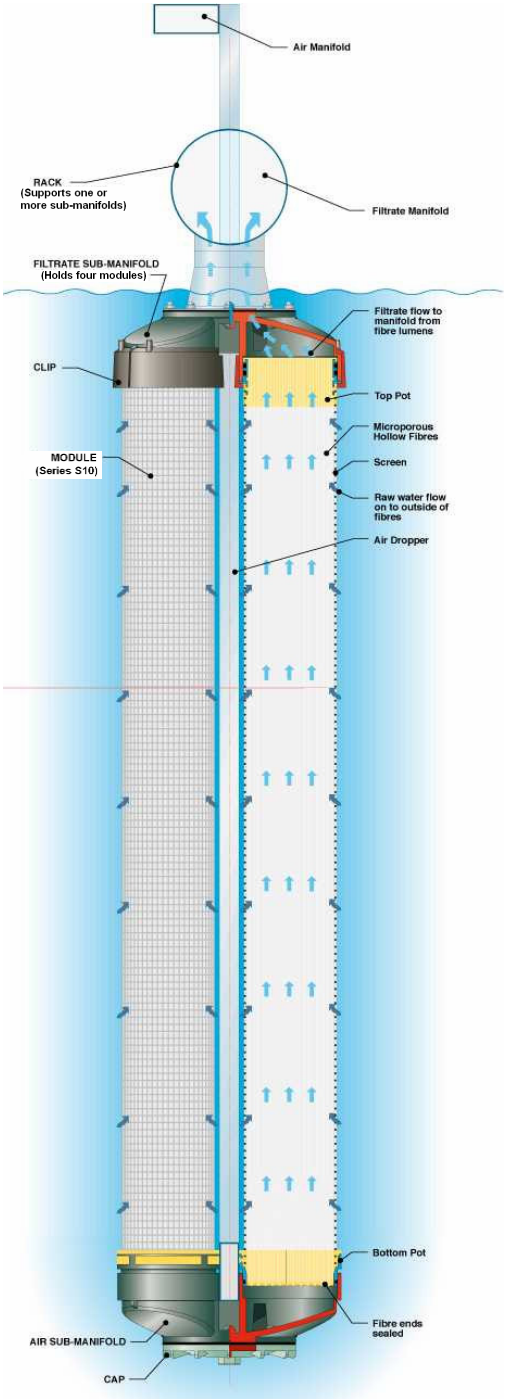
MEMCOR® XS AND CS SUBMERGED MEMBRANE FILTRATION SYSTEMS



MEMCOR® XS AND CS

PROCESS DESCRIPTION

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INTRODUCTION

Memcor's unrivalled experience in the research and development of membrane filtration and membrane manufacturing processes continues to produce leading edge technology membrane filtration systems that are used all around the world.

MEMCOR® XS Submerged Membrane Filtration Units are pre-packaged and factory tested, ready for site installation. MEMCOR® CS Submerged Membrane Filtration Units are engineered and built to project specific requirements. These Units provide high quality, highly efficient and reliable water filtration with a small plant footprint and economic operation.

A MEMCOR® XS or CS Submerged Membrane Filtration Unit typically includes:

- Hollow Fibre Membrane Filtration Modules (typically S10 type with PVdF homogeneous asymmetric ultrafiltration membrane – other membrane options are available);
- Filtrate Sub-Manifolds and Air Sub-Manifolds (Top and Bottom Clovers), moulded Nylon components which hold the Membrane Filtration Modules in groups of four;
- One or more stainless steel Racks, which collect filtrate and distribute low pressure air, on which the Clovers and Modules are mounted (see Figure 1 below);
- The Cell, the open top tank in which the Racks fitted with Modules are installed;
- A Filtrate Pump which draws water from the Cell through the Membrane Filtration Modules;
- Valves, instrumentation and controls;
- A frame or skid on which the core equipment is mounted.

Each Hollow Fibre Membrane Filtration Module contains thousands of fibres surrounded by a protective plastic mesh screen and sealed with polyurethane "pots" at each end. The upper pot allows filtered water to pass from the hollow inner core, or lumen, of all the membrane fibres to the filtrate manifold. The lower pot seals the ends of all the fibres but allows low pressure process air to pass from the Air Sub-Manifold through a series of holes to the outside surface of the membranes within the fibre bundle during backwashing. Each Membrane Filtration Module is a serviceable filter element that is easily removed from the Unit for repair or replacement.

Figure 1

A photograph showing a stainless steel Rack removed from the Cell and showing Filtrate Sub-Manifolds (Top Clovers – blue in colour) fitted with Hollow Fibre Membrane Filtration Modules.

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TYPICAL SYSTEM COMPONENTS

The MEMCOR® XS or CS Submerged Membrane Filtration Unit forms the core equipment necessary for an operational membrane filtration plant. Once a Unit is installed on site, external equipment is connected to it by means of appropriate termination points on the Unit.

Figure 2 shows the equipment in a typical Submerged Membrane Filtration process. Each part of the system is described in the following section.

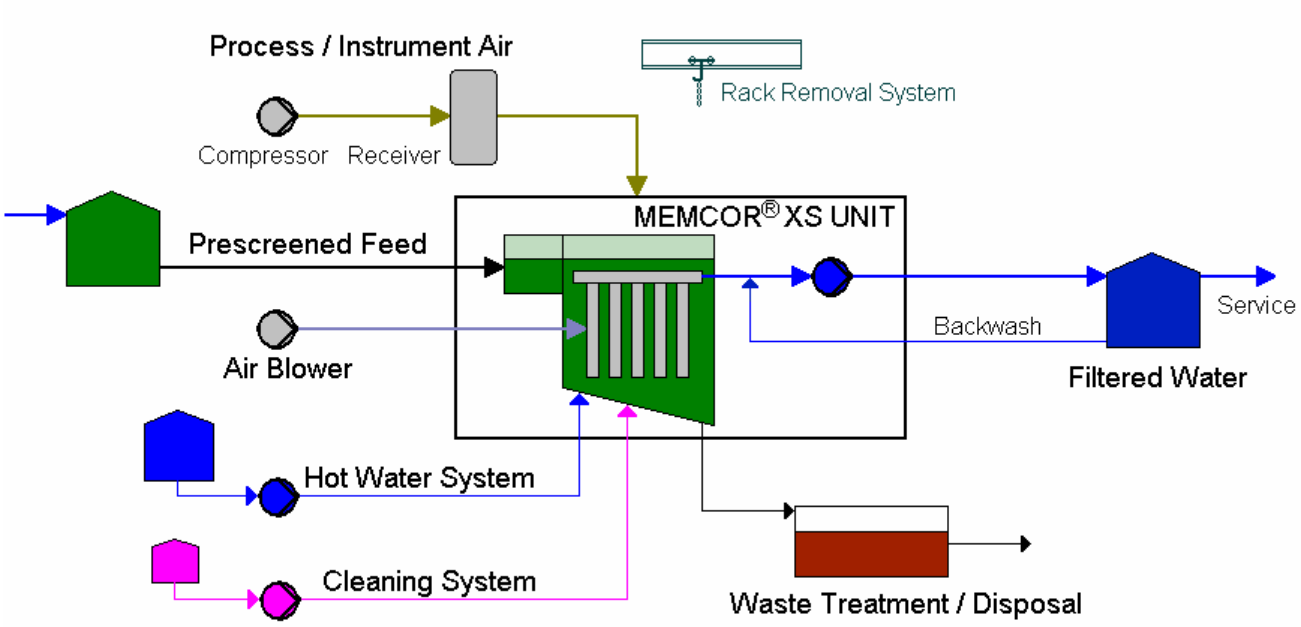

Figure 2

Typical MEMCOR® XS Submerged Membrane Filtration System Components

FEED SYSTEM

Raw water must be screened to remove large solids before it enters the Cell. Some systems include other raw water pre-treatment, such as coagulant dosing or pH correction.

Typically, a Feed Tank holds raw water that is then either pumped or flows by gravity to the Cell. Flow into the Cell is usually controlled by a positioning valve in the Feed line, which regulates the level in the Cell. A level switch or level transmitter is used to monitor the level in the Feed Tank.

Typical limitations on feed quality include a feed temperature of greater than 0 degrees Celsius (non-freezing) and less than 40 degrees Celsius, turbidity of less than 150 NTU (although higher turbidities may be handled for short periods) and pH between 5.5 pH and 8.5 pH. Other membrane specific limitations may also apply. Please consult Memcor for further details.

FILTRATE SYSTEM

Filtrate from the MEMCOR® XS or CS Submerged Membrane Filtration Unit usually flows to a local Filtered Water Tank or direct to a service outlet pipe. Available filtrate discharge pressure from the Unit is typically limited to around 50 kPa (5 metres) maximum.

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Provision must be made close to the Unit to store filtrate that is used during the backwash process. During backwashing, filtrate is pumped for a short time in the reverse direction to flush solids from the Membrane Filtration Modules. Filtrate Backwash may be drawn from the Filtered Water Tank or from a separate Filtrate Backwash Tank.

COMPRESSED AIR SYSTEM

Clean, dry compressed air is required for the operation of pneumatically actuated valves and for draining filtrate from the inside of the Membrane Filtration Modules. Process air that enters the Membrane Filtration Modules must be oil free.

Memcor recommends the use of quality compressed air filters, typically cartridge type filter/coalescer units. On larger systems, refrigerated air dryers are recommended. Air lubricators are not necessary. Air receivers should be fitted with automatic drains to remove condensate.

In smaller MEMCOR® XS Submerged Membrane Filtration Units (typically fewer than about twelve Membrane Filtration Modules) the compressed air supply may also be used to provide the air for aeration in the backwash process. Above this number of Membrane Filtration Modules, it may be more economical to provide a separate air blower system for the aeration air supply.

AIR BLOWER SYSTEM

In the backwash process, low pressure air is blown down through the Rack and distributed into the Air Sub-Manifolds (or Bottom Clovers) then up into the fibre bundle of each Membrane Filtration Module. This is the Aeration step of the backwash sequence.

The blower system must be able to deliver air at the required flow rate, at a pressure that can displace water from the Rack so that it reaches the bottom of the Membrane Filtration Modules (blower discharge pressure of about 20 – 25 kPa typically required). Delivery line losses must also be taken into account, so blowers should be located as close as possible to the Membrane Filtration Unit.

Typically, the air for this purpose is supplied by a blower system of one or more air blowers (typically rotary lobe (Roots) type oil-free positive displacement blowers). Usually where multiple blowers are installed, each blower provides the necessary flow for a single backwash and duty is rotated to the next blower after each backwash.

The air blower system should be fitted with appropriate air inlet filter(s) and discharge relief valve(s). In some plants variable speed drives on air blowers are used to regulate flow and reduce running costs. A blower exhaust valve may also be fitted to prevent blower discharge against a closed head.

BACKWASH WASTE DISPOSAL SYSTEM

When the Filtrate Backwash and Aeration steps of the backwash sequence have been performed, the solids that have been loosened from the Membrane Filtration Modules need to be drained from the Cell. This “high solids” Backwash Waste usually drains by gravity to a low tank or sump near the Unit. The draining process should be quite rapid since the longer it takes, the longer the Unit is off-line and not producing filtered water.

Depending on local requirements, Backwash Waste usually needs further treatment before disposal or re-processing.

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CLEANING SYSTEM

Before using cleaning system equipment, operators should be provided with safety equipment and trained in its use. This includes Personal Protective Equipment (PPE) such as overalls, aprons, gloves and face-shields and should include an eye bath and safety shower near chemical handling areas. Material Safety Data Sheets for all chemicals used should be kept nearby.

The cleaning system typically includes a concentrate storage container and a concentrate transfer pump for each cleaning chemical. Container and pump sizes may vary depending on the volume of each concentrate type to be transferred. Each pump should have some means of calibration or flow measuring instrumentation to ensure accurate control of cleaning solution concentration. If concentrations are too low, cleaning will be less effective. If concentrations are too high, concentrate is wasted and equipment may be damaged.

The cleaning system may include bunded areas for this equipment, and possibly a delivery area set aside for transfer of concentrate from delivery vehicles to concentrate storage containers.

During a cleaning cycle, the concentrate transfer pump draws the required volume of cleaning solution concentrate from storage and injects it into water that is recirculated through the Membrane Filtration Modules by the Filtrate Pump on the Unit. The Membrane Filtration Unit is usually fitted with instrumentation on the discharge of the Filtrate Pump that may be used to monitor the concentration of the recirculating solution and verify that it is within the required range.

Most MEMCOR® XS and CS Submerged Membrane Filtration Units use a cleaning regime that uses cleaning solution once only. This prevents the build-up of contaminants that can occur in cleaning solutions if they are used more than once.

CLEANING SOLUTION WASTE DISPOSAL SYSTEM

On completion of the MEMCOR® XS or CS Submerged Membrane Filtration Unit cleaning cycle, the used cleaning solution is typically drained by gravity from the Unit to a waste disposal system. In many cases, this is the same disposal system that collects Backwash Waste. In some systems, a separate cleaning solution waste disposal system is required.

The cleaning solution waste disposal system typically provides a means to neutralise the cleaning solution prior to further treatment or disposal. Additional chemical concentrate storage and transfer equipment may be necessary for this. Appropriate instrumentation is usually also required to monitor and control the neutralisation process.

HOT WATER SYSTEM

Heated cleaning solution has been found to provide improved cleaning effectiveness for MEMCOR® XS and CS Submerged Membrane Filtration systems.

Where cleaning solution temperature is likely to be much below 20 degrees Celsius, a hot water system is recommended. This is usually in the form of a Hot Water Tank with electric heating, that stores and heats clean water that is used for the Membrane Filtration Unit cleaning cycle. Tank insulation and pipe lagging can reduce energy costs in these systems.

Another option is the use of heat tracing on insulated recirculation piping to provide in-line heating during cleaning solution recirculation.

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The water used in the hot water system can be Membrane Filtration System filtered water, town water or, where available, Reverse Osmosis permeate.

Appropriate instrumentation and controls should be fitted to the hot water system to regulate heating and to prevent high temperature water coming into contact with the Membrane Filtration Modules (water in contact with the membranes should never exceed 40 degrees Celsius).

INSTRUMENTATION AND CONTROL SYSTEM

Standard MEMCOR® XS and CS Submerged Membrane Filtration Units are supplied with pressure, flow, temperature, level sensing and other instruments which are used to monitor operation of the Unit. Some provision also exists for connection of external instrumentation to the Unit.

A Programmable Logic Controller (PLC) controls all Membrane Filtration Unit functions and may provide limited control for typical external system components. An operator interface provides operators with the means to monitor and control the system.

The Membrane Filtration Unit PLC and operator interface are usually loaded with standard operating software and configured for the Unit during factory testing. Further adjustments can be made to configuration settings once the Unit has been installed on site.

The standard system software uses process validation to ensure that the Membrane Filtration Unit is operating within recommended guidelines. If the Unit operates outside normal limits, a warning is typically generated. Operation outside wider limits can generate a shutdown alarm, which stops the Unit reducing the risk of damage to system components. A detailed troubleshooting guide helps operators pinpoint problems within the system.

Memcor also produces its proprietary MEMLOG® data logger that can be fitted to any of its Membrane Filtration Units. The MEMLOG® data logger collects detailed Unit operating data in a standard format that can be quickly and easily collected, either locally or remotely, using Memcor's MEMANLY® software. The data can be displayed and analysed in MEMANLY® to assess Unit condition and operating performance and to confirm operation of mechanical components in the system.

MODULE MAINTENANCE EQUIPMENT

MEMCOR® XS and CS Submerged Membrane Filtration Units have built-in Integrity Test routines that can be initiated either manually or automatically. If system integrity loss is detected, Module Racks can be removed, usually one at a time, from the Unit. Hollow Fibre Membrane Filtration Modules may then be removed from the Rack in groups of four, by removing the Bottom Cap and Air Sub-Manifold (or Bottom Clover), then removing the Clips (around the Top Clover) to release each Module in turn.

Most installations are fitted with equipment that can be used to remove a Rack from the Unit and to hold the Rack while individual Membrane Filtration Modules are removed. On smaller Units, a Rack Removal mechanism is usually supplied. On larger Units, an overhead crane or pulley system is usually required to lift Racks out of the Cell and move them to a location where Membrane Filtration Modules can be accessed.

Membrane Filtration Modules that have been removed from the Rack may then be integrity tested one at a time in a Test Vessel that Memcor can supply. The Test Vessel allows Membrane Filtration Modules to be repaired if necessary, prior to return to service.

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Please consult Memcor for details of recommended Module Maintenance Equipment (such as standard tools, Test Vessels and pin repair kits).

MEMCOR® XS AND CS UNIT OPERATION

A MEMCOR® XS or CS Submerged Membrane Filtration Unit operates automatically to produce high quality treated water and at the same time, concentrates removed solids for further processing or disposal. The main operating states or sequences of the Unit are described below.

SHUTDOWN

Shutdown is the normal power-up state of the Unit and the state entered when the Unit is stopped and alarms are cleared. In Shutdown, the Unit is ready to start.

STARTUP

When the Unit is started from Shutdown, and feed is available, the inlet valve opens to allow screened feed to enter the bottom of the Cell. When the Cell is full and the Filtration Modules are covered with water, the Vacuum Priming system uses a compressed air powered Air Ejector to prime the Membrane Modules, Racks and filtrate pipework in preparation for the Filtrate Pump to operate. A Filtrate Manifold Level High Switch is used to monitor liquid level during priming.

FILTRATION

Once the system has been primed, the Filtrate Pump operates to draw water through the Hollow Fibre Membranes, discharging filtrate to service. Filtration flow rate is measured by a flowmeter on the Unit and controlled by means of a variable speed drive on the Filtrate Pump. The feed inlet valve modulates to maintain the level in the Cell. Filtration performance is monitored by the control system, which uses Unit instrumentation to calculate the Trans-Membrane Pressure (the TMP, or pressure difference across the membrane required to produce filtrate flow) and Resistance to flow. It then triggers Backwash requests and Cleaning Cycle requests as required based on these calculations.

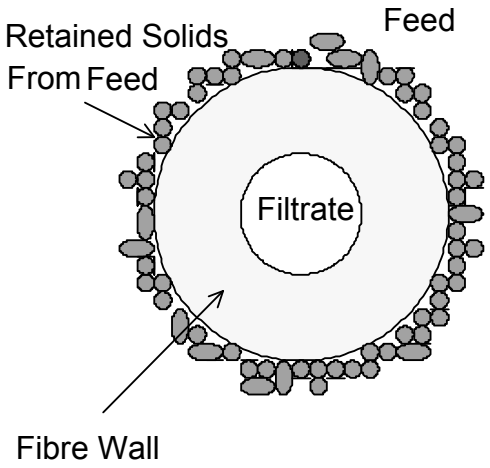

Figure 3

A section through a single Hollow Fibre Membrane during Filtration.

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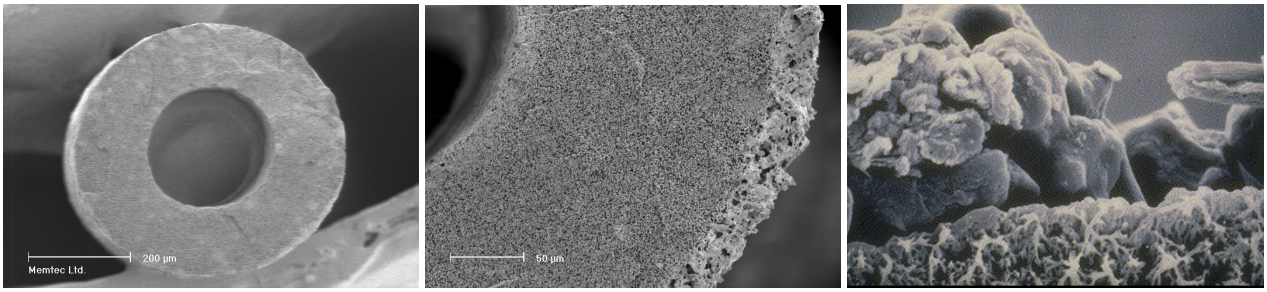

(a) *(b)* *(c)*

Figure 4

Electron micrographs of a typical Memcor hollow fibre membrane: (a) sectional view enlarged about 200 times, (b) close-up of membrane cross-section with outer fouling layer visible, (c) enlargement of interface between fouling layer and membrane.

STANDBY

If feed water is not available or if treated water storage level is high, the Unit can be configured to enter the Standby state automatically. In Standby, the Unit waits for the feed supply to return or the treated water storage level to drop. When this happens, the Unit can usually return directly to filtration without the need for a Startup sequence.

BACKWASH

As feed passes through the membrane barrier, a filter cake builds up on the membrane surface, increasing the resistance to flow. The key to the efficient operation of the Submerged Membrane Filtration Unit is Memcor's patented Backwash process. This process uses low pressure aeration to scour and agitate the Hollow Fibre Membranes and, when combined with a short reverse flow of filtrate, removes the retained solids from the membrane fibre bundle. Liquid backwash waste is then drained by gravity from the Cell to the Backwash Waste Disposal System. The Cell is then refilled with feed and the Unit returns to service.

The control system typically initiates an automatic Backwash every 20 to 60 minutes of filtration (depending on feed quality). The Backwash cycle takes about two and a half minutes to complete.

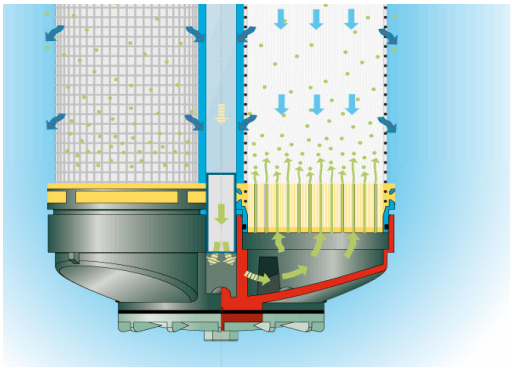

Figure 5

Cutaway view through a Membrane Module showing the path of air from the Rack through the Air Sub-Manifold and upwards into the fibre bundle during Backwash aeration.

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MAINTENANCE WASH (MW)

A MEMCOR® XS or CS Unit's Backwash process is very efficient at keeping the Membrane Modules clean. However, depending on raw water quality, a small residual of organic and inorganic foulants tends to build up on the membrane, increasing the resistance to flow over time.

The rate of this build up can be reduced by Memcor's short duration Maintenance Wash or MW process. In this process, a low concentration of cleaning solution makes contact with the Membrane Modules for a short time. This reduces resistance to flow, decreasing operating energy requirements and greatly extending the operating interval between Clean-In-Place cycles.

A Maintenance Wash is usually initiated automatically after the Unit has operated for a preset time interval or after a preset number of Backwash cycles. The Unit is typically off-line for less than 30 minutes while a Maintenance Wash and rinsing takes place, after which, the Unit returns to service.

CLEAN-IN-PLACE (CIP)

When the build up of foulants on the Membrane Modules increases the resistance to flow to an unacceptable level, a cleaning cycle is required. The MEMCOR® XS and CS Units use a Clean-in-Place or CIP cycle for cleaning. The Clean-in-Place process allows the system to be cleaned without the need to remove or disassemble equipment.

MEMCOR® XS or CS Units fitted with standard PVdF (polyvinylidene fluoride) Membrane Modules (usually S10V type), are cleaned using sodium hypochlorite solution as the primary cleaning regime and acid as the secondary regime. Depending on the type of acid used in the application, an additive such as EDTA (ethylenediaminetetraacetic acid, a chelating agent) may also need to be added during an acid clean.

Cleaning cycles using the primary cleaning regime are most commonly performed. After a preset number of primary cleaning cycles have taken place, the control system is configured to perform the next cleaning cycle using the secondary regime. This cleaning cycle will be immediately followed by a cleaning cycle using the primary regime. This is referred to as a **Dual** cleaning cycle.

Depending on the equipment fitted in the system and on local requirements, the CIP cycle can be configured to be initiated manually or automatically.

The CIP cycle typically uses the following sequence of steps:

1. **Backwash**

   The Cell is initially backwashed to remove excess solids and maximise cleaning efficiency. This initial backwash cycle is terminated when the Cell has drained.

2. **Water Fill and Cleaning Concentrate Addition**

   The cell is then filled with hot and/or cold water as required. Water used is typically from filtered water storage but, depending on site and process requirements, may be from another source, such as town water or Reverse Osmosis (R.O.) permeate.

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The water is then circulated around the Unit by the Filtrate Pump while cleaning solution concentrate is added. One or more concentrates may be added during a cleaning cycle, depending on the membrane type and the type of cleaning cycle being performed. Concentrate addition continues until the target cleaning solution concentration is reached.

3. Cleaning Solution Recirculation

Recirculation of the cleaning solution continues for the preset time to ensure that it makes contact with all parts of the Unit, particularly the Membrane Modules and the filtrate pipework.

4. Cleaning Solution Soak

Recirculation then stops and the Unit is left to soak in the cleaning solution for the preset time.

5. Repeat Recirculation and Soak

The previous two cleaning cycle steps are repeated for the preset number of times (typically up to four times). This can enhance the effectiveness of the cleaning process.

6. Cleaning Solution Drain

The used cleaning solution is then drained to the cleaning solution waste outlet for further processing and disposal.

7. Rinse Backwash

The Unit then performs one or more Backwash cycles to rinse cleaning solution from the system. Depending on site requirements and system configuration, Rinse Backwash waste water may be directed to either the Backwash Waste Disposal system or to the Cleaning Solution Waste Disposal system as appropriate.

8. Rinse To Waste

After completing the Rinse Backwashes, the Unit then filters to waste for the preset time. Instrumentation on the filtrate discharge can be monitored at this time to ensure that filtrate quality meets site requirements before the Unit is returned to service.

9. Return To Service

On completion of the cleaning cycle, the Unit is able to return to normal service. Depending on the equipment fitted in the system and on local requirements, return to service can be configured to occur manually or automatically. If manual restart is required, the Unit enters Shutdown on completion of the cleaning cycle. If automatic restart is enabled, the Unit enters Startup, then resumes filtration and normal service.

Where a secondary regime cleaning cycle has been performed as the first stage of a **Dual** cleaning cycle, the cleaning cycle is restarted at this time, using the primary cleaning regime.

A cleaning cycle generally takes about two and a half hours to perform. A Dual cleaning cycle typically takes just under twice that duration.

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INTEGRITY TESTS

Integrity testing may be used to validate the membrane filtration barrier to ensure consistent treated water quality and maximum availability for the MEMCOR® XS or CS Submerged Membrane Filtration Unit.

All MEMCOR® XS and CS Units have a built-in integrity testing sequence, called a Pressure Decay Test, which can be configured for automatic initiation at preset operating intervals. The Unit is off-line for about five minutes while this test takes place before automatically returning to service.

In a Pressure Decay Test, air is used to drain filtrate from the Membrane Filtration Modules and Racks and the filtrate side of the system is pressurised with low pressure air, typically to around 100 kPa. The low pressure air supply is then turned off and the rate of decay of filtrate side air pressure is monitored by the control system. System integrity can be related to the rate of pressure decay measured during this test.

If a higher than normal pressure decay rate is measured, a Leak Test can then be performed to determine the location of any integrity loss. The Leak Test is manually initiated, and helps to localise a problem Membrane Module, or leaking seal, valve, pipe or fitting, by the appearance of bubbles. If necessary, where Filtrate Isolation Valves are fitted, the Filtrate Sub-Manifold containing a damaged or leaking component may be isolated so that the Unit may be returned to service with improved integrity. The Rack containing the damaged component can then be removed at some later time for inspection and testing.

Important features of the MEMCOR® XS and CS Unit Pressure Decay Test include:

- that it is sensitive to greater than LRV4 (Log Reduction Value) particle removal;
- that it measures actual filter performance, which is critical for control of chlorine tolerant pathogens;
- that it is independent of feed quality, including feed water particle count or turbidity challenge;
- that it provides a more sensitive integrity monitoring method than filtrate particle counting. In combination with filtrate particle counting, it provides for redundant testing;
- that the efficiency and accuracy of the test reduces the need for operator involvement and maximises membrane life.