MEMCOR® MBR

PROCESS DESCRIPTION

DuPont Water Solutions

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Issue 8
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MEMCOR® MEMBRANE BIOREACTOR (MBR) FILTRATION SYSTEMS

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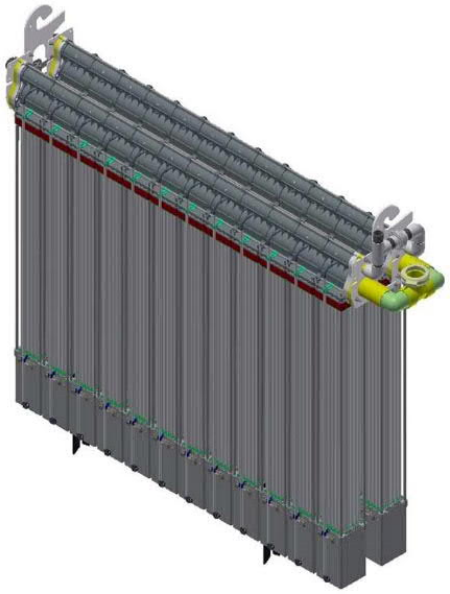
INTRODUCTION

DuPont Water Solutions has unrivalled experience in the research and development of membrane filtration products and membrane manufacturing processes. It continues to produce leading edge technology membrane filtration systems that are used around the world for a wide range of industrial and municipal filtration applications.

The MEMCOR® MBR Membrane Operating System (MOS) is an advanced wastewater treatment technology using low pressure membranes to extract liquid from a suspended growth activated sludge system.

The Memcor Membrane Bioreactor (MBR) process replaces the secondary clarifiers typically used in conventional waste treatment methods for solid/liquid separation. Unlike secondary clarifiers, however, the treated water quality is not dependent on the mixed liquor suspended solids concentration or the settling characteristics of those solids. In fact, Memcor MBR systems can operate at much higher mixed liquor suspended solids (MLSS) concentrations than conventional activated sludge systems.



MBR systems combine a biological process and a low pressure membrane filtration process, so expert knowledge in both areas is essential. The development of Memcor's MBR technology has combined the skills of Memcor's membrane specialists and the biological treatment specialists from JetTech and Envirex, all part of the global expertise available from DuPont Water Solutions. The result – the unique MemPulse® MBR system.

The membranes and process developed for Memcor MBR systems are founded on Memcor's unrivalled experience in membranes for water and wastewater treatment.

Memcor's Submerged Membrane Filtration processes leverage more than 30 years of proven low pressure membrane filtration product know-how. Over this time, Memcor membrane systems have achieved increased product scale and improved operating economies and have proven ideal for use in Membrane Bioreactor systems.

The Memcor MBR system provides high quality, highly efficient and reliable waste water processing with a small plant footprint and economic operation.

A Membrane Operating System (MOS) typically incorporates one or more Membrane Filtration Cells located adjacent to the biological treatment system. The use of a separate tank for the Membrane Filtration Modules, adjacent to the biological reactor provides a number of benefits, including:

- A controlled membrane environment;
- Positive fluid transfer of Mixed Liquor through the Membrane Filtration Modules and uniform distribution of flow and of solids (Mixed Liquor Suspended Solids or MLSS);

- Flexibility in biological process selection;
- Independent optimisation of biological and membrane processes;
- A small footprint;
- A Clean-In-Place system that allows chemical cleaning without membrane removal, providing safer operation and reduced downtime;
- Separation of biological processes from chemical cleaning systems.

Typical MOS Components

The biological section of an MBR plant typically includes:

- Primary waste water treatment, including fine screening and grit removal;
- A biological treatment system, often including anaerobic, anoxic and aerobic zones;
- Flow balancing.

Following the biological process, the Membrane Operating System (MOS) typically includes:

- A Mixed Liquor recirculation system which recirculates Mixed Liquor from the biological treatment system through the MOS. The recirculation system can be configured to be pump feed/gravity feed or gravity feed/pump return;
- One or more Memcor Membrane Filtration Cells. Each Cell is a rectangular tank in which several Racks are fitted. Each Rack holds a number of Memcor MBR Hollow Fibre Membrane Filtration Modules and has manifolds to collect filtrate and distribute low pressure air. Cells may be covered for odour control;
- An aeration system which continuously supplies low pressure air to the Filtration Modules in each Cell;
- A Filtrate Pump, which draws filtered liquid from the Membrane Filtration Modules in the Cell;
- Valves, instrumentation and controls, including a programmable automation controller (PLC/PAC) and human machine interface (HMI);
- Ancillary equipment, such as a compressed air system and chemical storage/delivery system, to provide operating and cleaning resources;
- Downstream storage and processing systems (such as disinfection or Reverse Osmosis);
- Maintenance components, such as a Rack Removal System and special tools.

MEMCOR® MBR Membrane Filtration Modules

The critical components of the Membrane Operating System are the Membrane Filtration Modules. MEMCOR® MBR Modules have the following membrane characteristics:

- Chlorine tolerant PVDF;
- Hollow fibre configuration;
- Pore size in the ultrafiltration (UF) range;
- Homogeneous asymmetric structure.

Each Memcor MBR Membrane Filtration Module contains thousands of fibres which are partitioned or “layered”, into thin fibre bundles. Fibres are sealed with polyurethane “pots” at each end of the Module and supported in a frame. The upper pot allows filtered water to pass from the hollow inner core, or lumen, of all the membrane fibres into the filtrate manifold. The lower pot seals the ends of all the fibres but allows the two-phase Mixed Liquor and low pressure process air to pass from the Air Sub-Manifold through a series of openings to the outside surfaces of the membranes within the fibre bundle.

The Membrane Filtration Modules are assembled on a Rack that manifolds the process connections and supports the Modules. O-Rings create watertight seals between the different wetted components. Tie rods hold the Rack components together.

Each Membrane Filtration Module is a serviceable filter element that may be removed from the Rack for repair or replacement.

Figure 1

LEFT – A MEMCOR® B40N MBR Membrane Filtration Module. RIGHT: – Close-up sectional view of a Memcor MBR Rack Assembly showing the Air (upper) and Filtrate (lower) Sub-Manifolds.

Figure 2

Photograph showing an MBR Rack Assembly containing sixteen MEMCOR® B40N Membrane Filtration Modules.

The MemPulse® System

During operation, Mixed Liquor is fed from the biological treatment process to the cell. The Mixed Liquor, or Sludge, is distributed throughout the cell, flowing upwards through the membrane modules before overflowing out of the cell and back to the biological treatment system.

At the base of each Memcor module is a patented MemPulse® device. MemPulse® technology uses a simple arrangement with no moving parts to achieve a significant reduction in energy consumption and lower maintenance costs. It does this by converting continuous airflow into irregular pulses of air at the base of each membrane module. Coarse bubble air scouring of the membrane fibres is thus achieved intermittently through the accumulation of air which is then released in a random plug flow, producing Memcor's proven Two-Phase Flow concept. This upward plug flow generates an "airlift effect" causing two-phase (air-liquid) fluid to flow upwards through the Membrane Filtration Modules. The cross-flow dynamics created in the fibre bundles scour the membrane surfaces to prevent accumulation and dehydration of solids.

This dynamic plug flow maximises efficiency because:

- The moving bubbles generate secondary flows behind the initial bubble that assist in breaking up the filter cake layer and promoting local mixing near membrane surfaces;
- The film around the outside of the bubble acts as a high shear region which promotes the movement of solids away from membrane surfaces;

- The moving slugs of air result in pressure pulses in the liquid around them producing agitation which scours the membrane surfaces.

At the same time, the Filtrate Pump draws filtrate from inside each membrane fibre and discharges this liquid to the next treatment process step. Virtually all solids are rejected at the membrane surface and retained in the Mixed Liquor which returns to the biological process system. Mixed Liquor is recirculated typically at between three to five times the filtrate flowrate.

The MemPulse® system is designed to minimise polarisation (concentration) of suspended solids around the membrane fibre bundles. With this system mixed liquor is pumped directly into each Membrane Module distributing mixed liquor evenly so that every Module sees the same process conditions.

Typical solids concentration, air and water velocity profiles for Memcor systems are shown in the figures below. Without the MemPulse® system, Membrane Modules at the far end of the Cell would see increased solids concentrations, causing uneven fouling of these membranes.

Additionally, Memcor systems provide an integrated cleaning solution combining efficient scouring of the membranes with chemical cleaning. The integrated cleaning system allows the Membrane Modules to be automatically cleaned in place. The Clean-In-Place procedure eliminates the need for membrane removal from the Cell, improving plant operator safety and reducing the risk of damage to membranes and other system components.

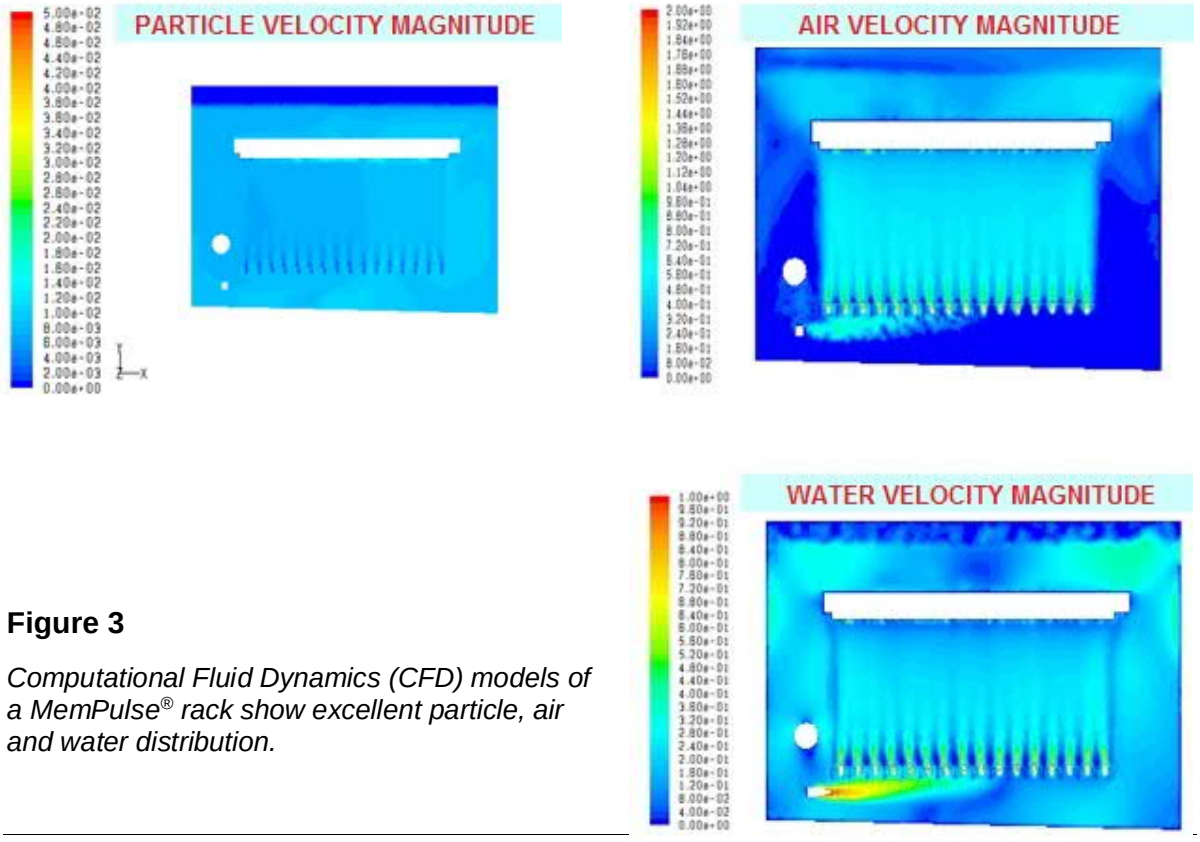


Figure 3

Computational Fluid Dynamics (CFD) models of a MemPulse® rack show excellent particle, air and water distribution.

Maintaining Membrane Performance

During membrane filtration, filtered solids tend to form a compressible filter-cake on the membrane surface. The filter cake forms a filter in itself and so adds to the filtration performance of the system, but at the same time it increases the head loss or pressure drop across the membrane, commonly referred to as the Trans-membrane Pressure (TMP). This filter cake must be controlled to maintain a reasonable pressure drop or TMP across the membranes during filtration.

The minimisation of this fouling layer or filter cake is regulated by three processes, namely:

- Relaxation;
- Maintenance Wash (MW), and;
- Clean-In-Place (CIP).

Filtration rates are principally maintained by Relaxation. However, a small residual of foulants remains on the membrane surfaces and accumulates over time. This is reflected by a slow increase in membrane resistance to flow. To remove these foulants, occasional chemical cleaning is carried out, either with a Maintenance Wash (MW) cycle or with a Clean-in-Place (CIP) cycle.

These three processes are described in more detail in the following sections.

1. Relaxation

Relaxation takes place when filtration through the membrane is stopped. This reduces the TMP to zero, allowing the filter cake to relax and expand. This improves the efficiency of the MemPulse® two-phase scrubbing action, which scours the filter cake back into the bulk solids solution. This process prevents the filter cake thickening to such an extent that filtration performance is adversely affected.

Backwash vs Relaxation

The standard operating regime for Memcor MBR Systems is to use Relaxation only. Considerable operating experience has shown that there is no significant increase in membrane performance when operating with a more complex backwash sequence as compared to a simple Relaxation step.

Therefore Memcor MBR Systems do not require a backwash as part of the standard operating regime. However, for operational flexibility, provision can be made in the Membrane Operating System design for a backwash cycle to be used if ever required.

The Relaxation Cycle

Typically, the Relaxation cycle operates as follows:

- Frequency: Every 10 to 12 minutes of filtration;
- Duration: Filtration is stopped for 60 seconds.

2. Maintenance Wash (MW)

Typical MBR operation will include a Maintenance Wash (sometimes referred to as a Chemical Backwash (CBW) or as a Maintenance Clean) every 1 to 2 weeks of operation. A Maintenance Wash is usually performed automatically after a pre-set total time in filtration.

During a Maintenance Wash, chlorinated filtrate is passed in the reverse direction through the Membrane Filtration Modules to inhibit biological growth and reduce fouling on the membranes and in filtrate pipework. During this process, membrane aeration continues and the Cell remains full of Mixed Liquor, although Mixed Liquor feed is turned off. The whole cycle typically lasts for about 30 minutes after which the Cell can be returned to service.

A typical Maintenance Wash sequence is as follows:

- Reverse flow backwash of clean water dosed with chlorine (typically sodium hypochlorite) normally at a concentration of about 200 mg/L (ppm);
- Relaxation for 5 to 10 minutes;
- Repeat of reverse flow backwash with chlorine solution and Relaxation steps usually up to 3 times;
- Resume Mixed Liquor recirculation with aeration for 5 minutes;
- Start filtration, returning the first few minutes of filtrate production to the Cell, that is, to the Mixed Liquor recirculation system. Rinse effectiveness can be determined by measuring the pH of the filtrate;
- Return Cell to normal operation.

During a Maintenance Wash the membranes remain fully submerged in Mixed Liquor. No neutralisation is required as the small amount of chlorine used in the MW is consumed by the Mixed Liquor.

3. Clean in Place (CIP)

The Memcor MBR process is designed so that a CIP cycle is required only once every 3 to 6 months of operation. During a CIP cycle, the Mixed Liquor is drained from the Cell and the Cell is flushed with filtrate before being filled again with dilute cleaning solution made up with clean water, such as town water or RO (Reverse Osmosis) permeate.

For biological systems using coagulant for phosphorus removal, both acid and chlorine cleaning solutions are typically used. In these systems, the Acid CIP cycle typically uses a blend of Citric Acid (0.5 %) and Sulphuric Acid (~0.1 %) or other mineral acid. The Chlorine CIP cleaning solution is often made to an initial concentration of up to 1,000 mg/L of free chlorine.

A CIP cycle will usually be initiated when:

- the filtration TMP reaches a pre-set maximum value;
- the total filtration time reaches a pre-set value, or;
- an operator starts the CIP cycle manually, for example, if Cell maintenance is required.

Usually only one Cell in a system is cleaned at a time with the others remaining in service.

A CIP sequence generally takes up to 6 hours to complete and typically includes the following steps:

- Drain Mixed Liquor from the Cell;
- Fill the Cell with filtrate from the Filtrate Storage Tank in Backwash;
- Soak with aeration on;
- Drain the Cell again;
- Backwash the Cell with clean water and add the cleaning solution concentrate for 60 – 120 seconds per step;
- Soak in cleaning solution for 285 seconds;
- Repeat the two steps above until it's reached 1/8th of the CIP level tank and desired concentration of chemical solution (typically 8 – 10 times);
- Fill the Cell with clean water from the Filtrate Storage Tank;
- Aeration – For an Acid CIP, the membranes continue to soak for about 5 minutes with aeration on. For a Chlorine CIP, this step is skipped;
- Repeat the soak and aeration (for Acid CIP) steps for the pre-set number of times (typically a total of 8 times for a total soak period of 3 hours);
- Drain the used cleaning solution from the Cell and the Membrane Modules to the CIP Waste Disposal or Neutralisation system;
- If a dual (Acid followed by Chlorine) clean is in progress, refill the Cell with clean water and chlorine concentrate and repeat relevant steps as described above;
- After cleaning solution has been drained, reverse flush the filtrate pipework and Membrane Modules with filtered water for 5 mins;
- Fill the Cell with Mixed Liquor then start Mixed Liquor aeration for 20 minutes;
- Start filtration;
- Return Cell to normal operation.

During the CIP cycle the Membrane Modules are fully submerged in the cleaning solution. This process is performed in the Cell, providing operational simplicity by eliminating the need to remove membranes to a separate location for cleaning.

Some Advantages of Memcor MBR Systems

The MEMCOR® MBR Membrane Operating System offers a number of important advantages over competitive systems:

Efficient Membrane Scouring	Two Phase flow created by MemPulse® device under each module. Plug flow of membrane scour air provides more vigorous and efficient cleaning. Elastic fibres that move freely with minimal aeration.

Simplicity	Unique MemPulse® cleaning action has no moving parts or valves.
Reduced Process Complexity	Larger bubble size created by MemPulse® system does not significantly increase Dissolved Oxygen (typically only 1 – 2 mg/L).
Highly Efficient Mixed Liquor distribution	Memcor systems are designed to ensure even distribution of Mixed Liquor to each Membrane Module. The MemPulse® device under each Membrane Module in the Cell directs Mixed Liquor evenly into each module, ensuring that all modules see the same process conditions. Memcor systems ensure even solids concentration profiles across the filter Cell. Other systems have uneven distribution with some membranes seeing very high sludge concentrations resulting in uneven performance and fouling of membranes.
Ease of Maintenance	Memcor's Membrane Filtration Modules are easily handled. Modules are self-supporting and light weight (a B40N Module weighs less than 20 kg). Competitive membrane systems don't have these characteristics and are often difficult to handle, increasing the risk of injury to personnel and of damage to membranes during maintenance.
Ease of Repair	Memcor Membrane Filtration Modules are easily repaired with Memcor's proven pin repair process. Fibre damage is easily located and can be mechanically repaired in only a few minutes – with the positive effect of the repair immediately evident. Competitive membrane systems can be difficult to repair for two reasons: • Locating the damaged area of the membrane can be very difficult (especially in flat sheet systems); • Repairs typically involve the use of adhesives which are both time consuming and sometimes unsuccessful.
Homogeneous Membrane Structure	Memcor's MBR membranes are manufactured from a homogeneous material. The membrane material is the same from the inside to the outside surfaces of the fibre. Many competitor membranes rely on a composite structure that uses a very thin layer of membrane glued or cast onto a coarse support structure for strength. The weakness of this approach is in the bond between the membrane and the support. Delamination (the process of the thin membrane surface being removed from the support structure) is a significant problem for some suppliers.
Durability	Memcor hollow fibre tensile elongation is typically greater than 200 %.
Continuous Quality	High quality filtrate is provided by the Memcor membrane system, an advantage particularly for reuse applications. There is a much lower bypass risk because fibre inside diameter is smaller than many competitor membranes.

In situ Membrane cleaning	Memcor's Membrane Operating Systems are designed for automatic membrane cleaning in the filter Cell. There is no need for membranes to be removed from the Cell for cleaning. Some competitive systems, particularly those with membranes located in the activated sludge bioreactor, have limited *in situ* cleaning efficiency and require removal for efficient cleaning.

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