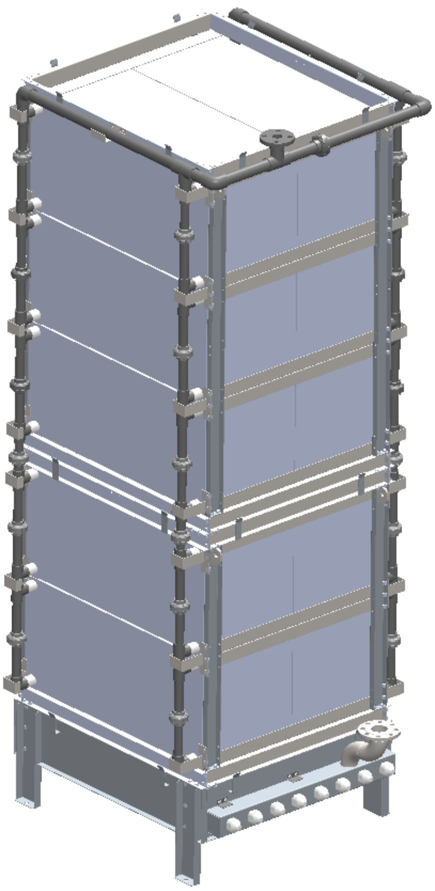
MYT U1L MBR User Manual

Submerged MBR Membrane Modules



UNISOL MEMBRANE TECHNOLOGY

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1 About this Document

Thank you for choosing MYTEX submerged membrane filtration modules!

This manual provides detailed information about how to handle, store, install, operate, and maintain the membrane modules as well as general information about necessary system and process design for systems using MYTEX membrane modules.

The target groups for this manual are system planner, system integrators as well as system operators. For operators, please consult your engineering company in case of lack of detail in this manual and when noticing abnormalities during operation, even when following the instructions properly.

First of all, please read and understand the safety information and warnings in chapter 2, which explains general safety guidelines as well as membrane specific guidelines that prevent danger to users and the equipment. Please read this manual carefully to use this product safely and properly. Failure to follow the guidelines in the manual may result in damaged or destroyed equipment.

The intended use of MYTEX membrane filtration modules as described in this manual is submerged filtration (pumped vacuum filtration or gravity filtration) for the treatment of municipal or industrial wastewater or process water. The major application is for biomass separation within a membrane bioreactor (MBR) system for wastewater treatment. But also the sequential use as polishing step e.g. in tertiary treatment or as sludge thickening in aerobic digestion or direct filtration of e.g. river water for process water treatment are possible fields of application.

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This product manual is provided to each user without any warranty or liability. Project specific warranty information is detailed in the UNISOL MEMBRANE TECHNOLOGY Terms and Conditions of Sale or in a project specific sales and warranty contract or in separate warranty terms.

2 Safety Information and Warning

The user of this manual is responsible for ensuring that their own safety program and operation and maintenance procedures comply with all applicable safety rules, regulations, and standards in accordance with prudent industry standards. General safety comments in this manual are not meant to circumvent any existing safety policies, procedures, or programs. The purpose is to supplement these and include safety information that may be unique to this type of membrane system that the user may not be aware of.

Failure to follow these safety guidelines, local safety rules, regulations and standards may result in a potentially hazardous situation. Potentially hazardous situations highlighted in this manual have been indicated using the symbols listed below.

Safety Symbols (Dangers, Warnings & Cautions)

⚠ DANGER	DANGER indicates an imminently hazardous situation. If not avoided, it may result in death, serious injury, or equipment damage.

DANGER - PRESSURIZED ANDS HEAVY DEVICE: Improper installation, operation or maintenance of the equipment, including but not limited to the membrane units, electrical system and piping may result in loss of life, severe bodily injury and/or property damage. Please read and understand all equipment guidelines provided before attempting to open, operate or service the equipment. Failure to follow these instructions and observe precautions may result in malfunction and catastrophic failure. Misuse, incorrect assembly or use of damaged or corroded components may result in serious injury.

⚠ WARNING	WARNING indicates a potentially hazardous situation. If not avoided, it may result in death, serious injury, or equipment damage.

WARNING: Certain operating situations require the use of chemicals and other hazardous substances. Material safety data sheets (MSDS) should be provided by chemical suppliers and all instructions therein should be adhered to. Safety briefings for the operating personnel should be carried out by plant health and safety personnel. Always use caution and wear the correct personal protective equipment (PPE) when handling chemicals.

WARNING: Comply with all pressure, temperature and pH limits specified in the technical data for the operation of the module.

WARNING: The use of chemicals that are not approved or in concentrations higher than those specified, may cause premature failure of the membranes and maybe other equipment.

WARNING: Do not perform any equipment or membrane maintenance unless the system control power is OFF, the pump starters are OFF, lock out/tag out procedures have been followed and internal pressure has been relieved from the equipment. Failure to do so may result in serious injury or death.

⚠ CAUTION	CAUTION indicates a potentially hazardous situation. If not avoided, may result in injury or equipment damage.

CAUTION: Except otherwise stated in the project specific technical product the membranes must not be allowed to dry out. The membranes must remain wet at all times including when the equipment is shut down or for maintenance. Dried out membrane may result in irreversible membrane damage.

CAUTION: No anti-foam agents of any kind are to be added into the equipment, without prior review and written approval from UNISOL.

CAUTION: Silicone-based materials, such as waterproofing sprays, lubricating or cutting fluids, or greases, should not be used in or around the equipment. Using these materials may result in complete and irreversible membrane fouling.

The above list of warnings and cautions not comprehensive. Other important points can be found in the corresponding chapters of the document. **Please read the entire document before using the product.**

3 Glossary (In Progress)

4 MYTEX Technology, Components and Technical Data

4.1 MYTEX Laminate Technology

The MYTEX laminate is a patented, textile based multilayer laminate. The flat sheet type membrane is fully connected with the drainage layer on both sides of the laminate ensuring a semi-flexible design and a fully backwashable membrane. These technological aspects utilize the benefits of both hollow fibers and flat sheet membranes, while overcoming the challenges identified with these products.

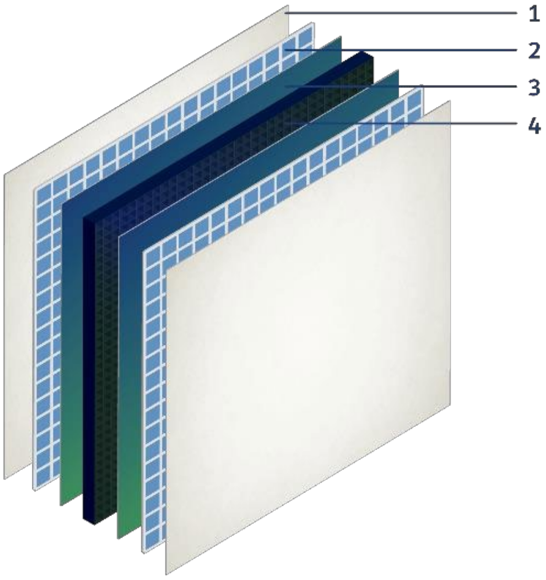


Figure 1: Principle design of MYTEX laminate

Flat Sheet Membrane (1+2)

The flat sheet membrane consists of two main components:

a. The actual selective barrier with the tiny pores, that are responsible for retention of solids, bacteria, and viruses. Both material and pore sizes depend on the actually used membrane. Ultrafiltration membrane are usually made of PVDF or PES with nominal pore sizes in the range of 0.03 to 0.04 µm. For Microfiltration membranes nominal pore sizes are about 0.1 µm or even higher.

b. The membrane support or carrying layer. To provide sufficient mechanical stability the selective layer is coated on a typically non-woven based support material made of polyester or polypropylene.

Adhesive Fabric (3)

The adhesive fabric is used to connect the back side of the flat sheet membrane (membrane support layer) with the drainage layer in the middle of the laminate.

Drainage layer (4)
The drainage layer is made of a high strength polyester based non-woven material, specially post-treated by UNISOL to provide excellent mechanical strength and minimal pressure drop for filtrate transport.

4.2 MYTEX Membrane Sheets & Blocks

The MYTEX laminate is cut into the corresponding membrane sheet shape and size and prepared with four permeate outlets, one outlet per corner. The edge sealing process is based on two steps, an ultrasonic welding step followed by a high-tech glue step to ensure a 100% long-term leakproof joint and increased mechanical robustness against accidental events e.g. during installation.

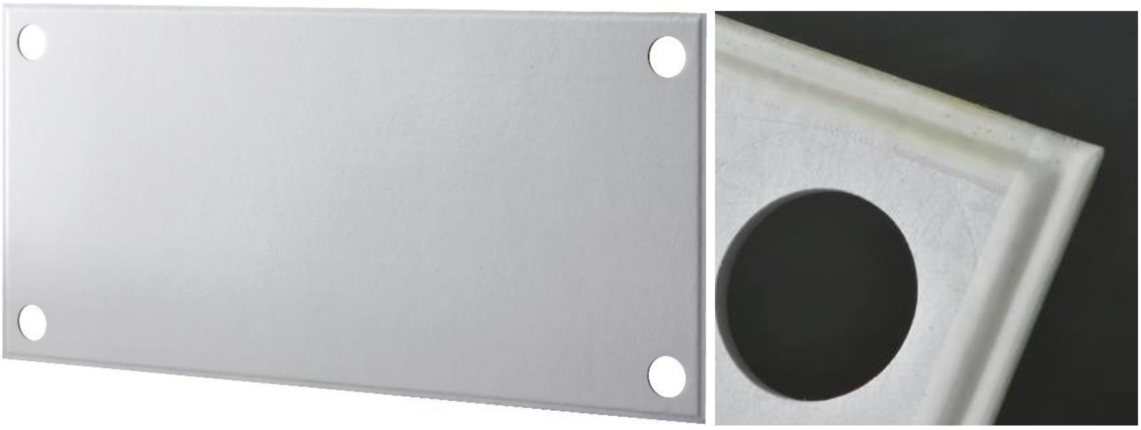


Figure 2: MYTEX membrane sheet (left) with 2-step (weld&glue) edge sealing process (right)

The MYTEX membrane sheets are glued in self-supporting membrane block with a permeate header in each corner (row of blue corner pieces), see Figure 3. These fully automatically manufactured membrane blocks are arranged side by side and stacked on top of each other in a module.

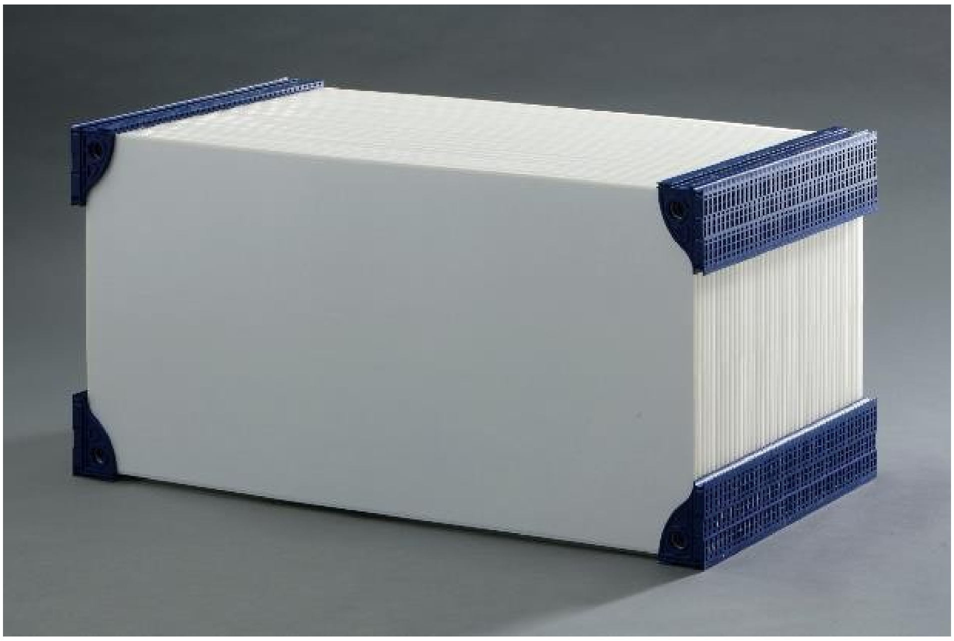


Figure 3: MYTEX membrane block with about 50 m² of membrane area

4.3 The MYTEX U1L Module Assembly

Within the U1L membrane modules several MYTEX membrane blocks are assembled in a double permeate header module. Compared to all other suppliers the U1L does not need a support frame or cassette to hold the membrane blocks. The self-supporting membrane blocks are just sitting on a base rack that provides the necessary ground clearance and includes the aeration system. The following figure shows the basic components of a U1L module:

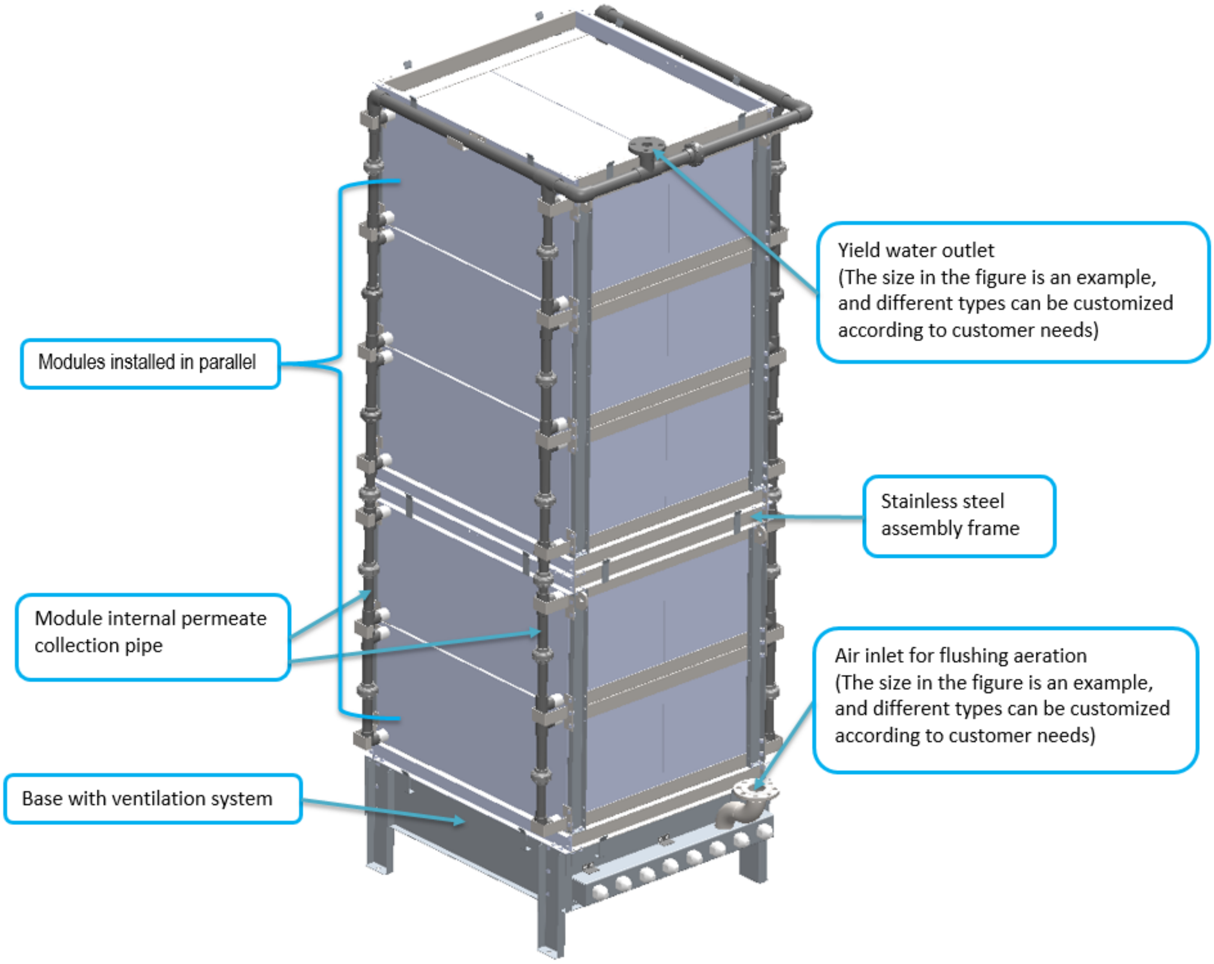


Figure 4: Basic configuration of U1L membrane module with 5-layer modules (modules have been simplified, the same below)

4.4 Models and Identifications

Various models are available in different sizes and for a wide range of applications and installation conditions. The different models can be identified by the code described below.

4.4.1 Identifications for Complete Membrane Modules (base rack, blocks, etc.)

The following code is valid for standard U1L type modules with a membrane sheet height of 500 mm.

U1L	5	--	1	35	800	--	2	50	1060
A	B		C	D	E		F	G	H

With

A…states the development stage of MYTEX submerged membranes; thsi
B…number of levels per module: 5 means 5 levels or 5 membrane blocks stacked on each other.
C…number of small membrane blocks with side outlet (see Figure 5 left) per level.
D…number of membrane sheets in the small membrane block with side outlets.
E…sheet length of the small membrane block.
F…number of big membrane blocks with front outlet (see Figure 5 right) per level.
G…number of membrane sheets in the big membrane block.

H…sheet length of the big membrane block.

The example codes “U1L5-135800-2501060” identifies a module that looks like the one in Figure 4. The product identification number can be found on the base rack and the top assembly frame (see Figure 4).

The U1L module illustrated in Figure 6 would be identified with the code “U1L3-000000-1501060”.

4.4.2 Identifications for Single Membrane Blocks

The following code is valid for standard MYTEX blocks with a membrane sheet height of 500 mm.

MYTB	--	0	00	000	--	0	50	1060
A		C	D	E		F	G	H

With
- A…general product code: MYTB for all single MYTEX membrane blocks
- C…not used for MYTB, always 0
- D…number of membrane sheets in the membrane block with side outlet (see Figure 5 left)
- E…sheet length of the membrane block with side outlet
- F…not used, always 0
- G…number of membrane sheets per membrane block with front outlet (see Figure 5 right)
- H…sheet length of the membrane block with front outlet

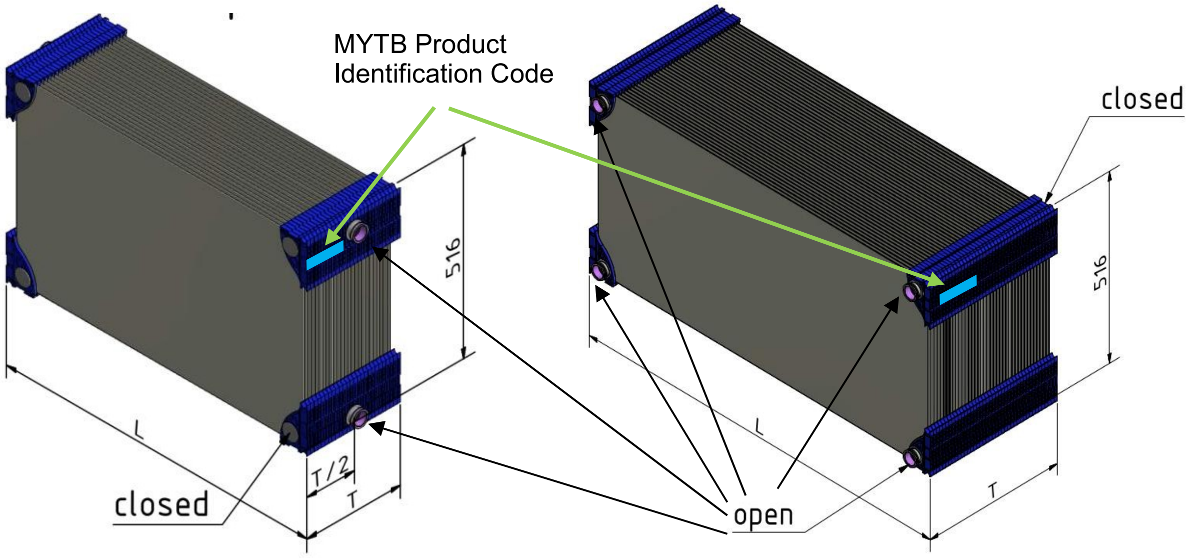


Figure 5: Standard MYTEX membrane blocks with side outlet (left) and with front outlet (right

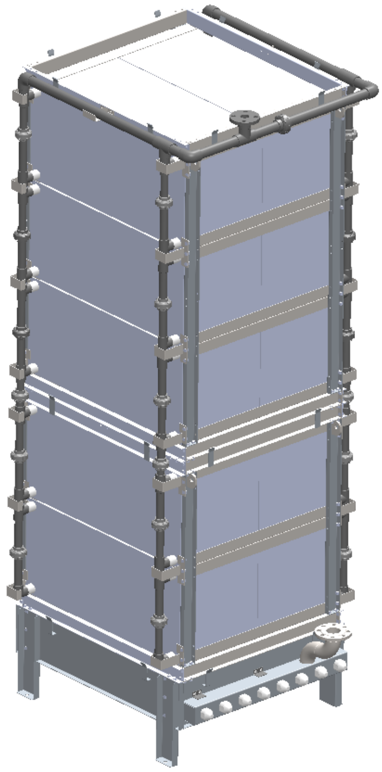


Figure 6: U1L module with three levels and one membrane block per level

4.5 Technical Specifications and Performance

4.5.1 Project Specific Membrane Characteristics and Module Specification

All MYTEX modules are project specific regarding type of membrane, membrane area, air scour rate, overall dimensions, weights, air inlet, filtrate outlet port configuration etc. For information about these specific parameters please check the project specific technical data sheet and technical proposal.

4.5.2 General Module Operating Specification and Requirements

The following Table 1 summarizes the general operating specifications and requirements for all MYTEX products with focus on but not limited to MBR operation with municipal wastewater. Most parameters are also valid for other applications. For more details about the specific parameters please check the corresponding sections in this manual or get in contact with your UNISOL representative.

Table 1. MYTEX module operating specification and requirements

Parameter	Value	Comments	More details
TMP during filtration (suction)	no limit	more than 600 mbar is not needed	Section 0
TMP during backwash/backpulse	≤ 300 mbar		Section 0
MLSS for MBR operation	≤ 20 g/l ≤ 15 g/l	for short-term operation or low flux for continuous operation	Section 8.1.6
Storage temperature	-5°C … 50°C	freezing allowed only with dry/preserved membranes	Section 6.2
Operating/Cleaning temperature	< 50°C	no freezing allowed	-

Parameter	Value	Comments	More details
pH range for chemical cleaning	2 … 11		Section 8.4
Total active chlorine resistance	≥ 500 000 ppm*hrs		Section 8.4
Diffusor inflow air temperature	≤ 60°C ≤ 90°C	in case of PVC piping in case of PP or SS piping	Section 8.1.3
Chloride concentration	≤ 1000 mg/l no limit	for 1.4571/SS316TI steel grade for versions without steel parts	-
Tank coverage	≤ 60 %	based on outer leg to outer leg dimensions and min. 300 mm top clearance	Section 5.6.1
Integrity testing pressure	membrane specific, usually 80 - 100 mbar in water		Section 7.3.3
Mechanical pre-treatment			
Trash content	Mixed Liquor Sieve testing: < 1 mg/L of material greater than 3 mm < 10 mg/L of material greater than 2 mm		Section 5.2.4
Particle size in MLSS	≤ 4 mm		Section 5.2.4
Oil and grease	≤ 10 mg/l	in membrane tank	Section 5.2.3
Biochemical pre-treatment			
Soluble BOD5	≤ 5 mg/l	in feed to membrane tank	Section 5.3.2
Soluble COD	≤ 50 mg/l	in feed to membrane tank	Section 5.3.2
Soluble ammonia	≤ 2 mg/l	in feed to membrane tank	Section 5.3.2
Surfactants sum of non-/ anionic	≤ 5 ppm	in membrane tank	Section 5.3.2
Surfactants cationic	≤ 0.5 mg/l	in membrane tank	Section 5.3.2
Dissolved oxygen level	≥ 1.0 mg/l	in aerated zone of the biol. stage	Section 5.3.2
For **chemical compatibility, antifoam product** use or **flocculants** please check section 10.4.			

4.5.3 Module Performance – Achievable Permeate Quality

All flat sheet membranes used with MYTEX membrane modules are a physical barrier, which stops the passage of all particles that are larger than the membrane pores. In this solids/liquid separation step the membrane retains particulate material in the mixed liquor, leaving only high quality permeate to pass through the membrane pores. However, the removal of dissolved and soluble materials such as dissolved organics (BOD/COD), dissolved phosphorous or nitrates are part of a biological treatment process or part of a separate precipitation step and dependent on a proper treatment step design and operation.

The following table summarizes the permeate quality that can be achieved when using MYTEX membrane modules considering that the systems are designed, built, and operated in accordance with UNISOL guidelines.

Table 2. Achievable Permeate Quality

Effluent Quality Parameter	Expected Permeate Quality
TSS	< 5 mg/L
Turbidity	< 0.5 NTU
SDI	< 5
BOD5	Equal to soluble BOD5 concentration in mixed liquor
COD	Equal to soluble COD concentration in mixed liquor
Total Phosphorous	Equal to total phosphorous concentration in mixed liquor
Ammonia	Equal to soluble ammonia concentration in mixed liquor
Total Nitrogen	Equal to soluble TN concentration in mixed liquor

Notes:

a. BOD_5, ammonia, total nitrogen, total phosphorous level is achievable only with appropriate biological system design, temperature, and/or appropriate coagulant addition.
b. To achieve the lowest quality values sanitary like permeate piping design and regular chemical cleaning/disinfection is necessary.

5 Process Description for Systems using MYTEX

5.1 General MBR Process Overview

As shown in Figure 7, the pretreatment process is generally the same for MBR systems as it is for CAS. However, an additional fine screening process is required to remove particles that may potentially block or damage the membrane. In general, there are two options for MBR integration in wastewater treatment plants: submerged directly into the aeration tank (internal configuration) or submerged in a separate membrane tank (external configuration).

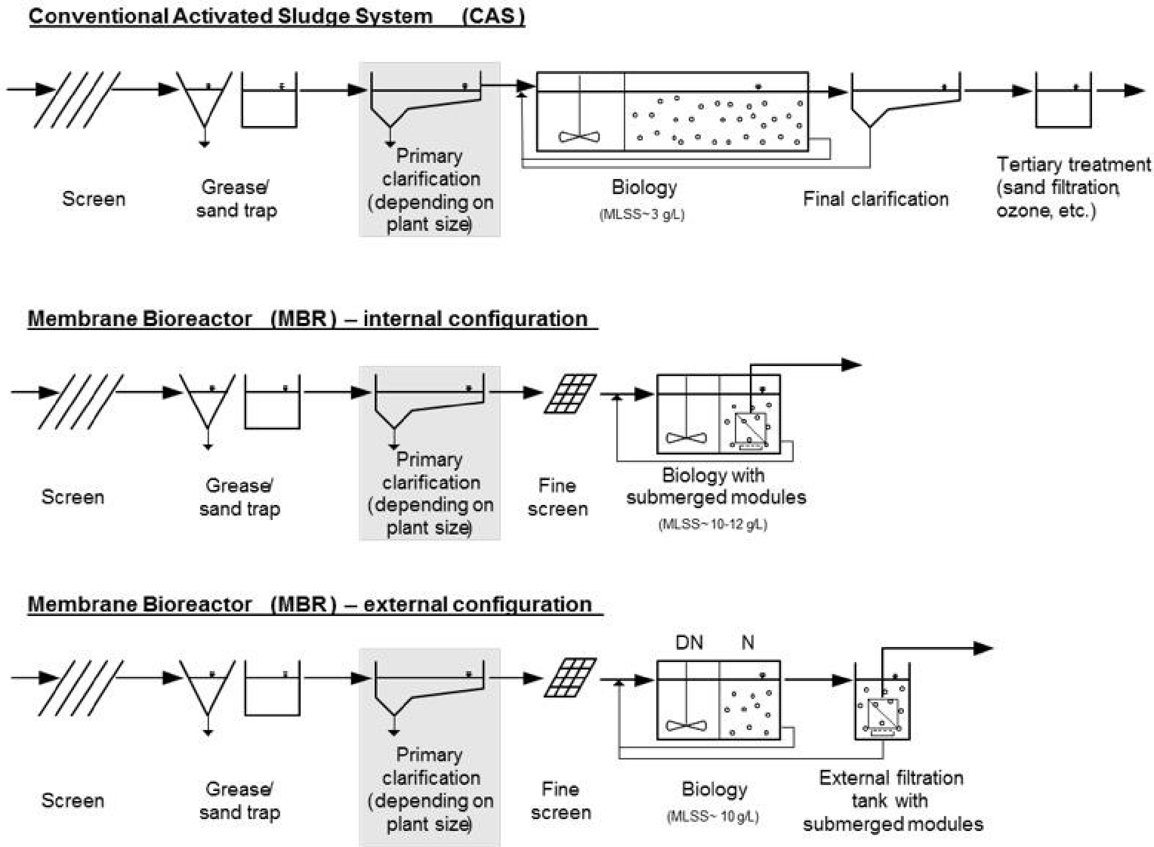


Figure 7: Process configuration for CAS, internal and external MBR

MBR systems utilizing the internal configuration can operate at highest overall MLSS levels and require simpler pumping and piping schemes. The union of the filtration process with the biological treatment also allows for more efficient oxygen transfer, and consequently, lower energy demand. The tanks where the membrane modules are installed, may have to be drained for maintenance requirements. This makes the membrane cleaning and maintenance for this configuration more complex, as this means the aeration tank must be drained or the membranes have to be lifted out to be cleaned in a separate cleaning chamber.

In case of an external configuration recirculation of mixed liquor between the membrane tank and the aerobic segment of the bioreactor is necessary. Because of this, plumbing systems for external configuration systems are slightly more complex than for internal configuration systems. However, the separation of the filtration process from the biology allows greater flexibility for cleaning and maintenance operations.

5.2 Mechanical Pretreatment

The selection of an appropriate pretreatment process is essential for the efficient operation of the downstream processes in any wastewater treatment plant.

Specific site parameters, such as size of plant, wastewater characteristics and variations in wastewater flow, determine the type and amount of pretreatment necessary for successful operation of the MBR. The complexity associated with additional pretreatment processes should be weighed against the advantages and possible disadvantages for the downstream processes, especially with respect to membrane fouling and maximizing membrane life.

Typical pretreatment processes include coarse screening, grit removal, fat, oil & grease (FOG) removal and fine screening.

5.2.1 Coarse Screening

Coarse screening refers to screens of an opening size of 6 mm or larger and are available in different types and configurations. Systems using MYTEX modules do not have specific requirements for coarse screening. However, most fine screen suppliers require coarse screening ahead of their fine screen to minimize the risk of blinding or overloading the fine screens. The use of coarse screens may also allow the usage of smaller and less expensive fine screens.

5.2.2 Grit Removal

Grit and sand are inert material and are removed using physical processes such as aerated grit chambers. The need for grit removal and its design is based on assessment made by engineers for the entire wastewater treatment plant.

However, fine screen suppliers may require grit removal ahead of their fine screens to minimize wear and tear. This should be discussed with fine screen supplier.

5.2.3 Fat, Oil & Grease (FOG) Removal

Wastewater may contain a certain amount of FOG and most municipalities have discharge limits for FOG. Systems using MYTEX modules may handle the typical FOG content found in municipal wastewater. However, significantly higher amounts of free oil may be fouling to membranes and should be removed prior to membrane filtration stage. The limit for FOG entering the MBR modules is <10 mg/L of soluble oil.

5.2.4 Fine Screening for MBR

The purpose of fine screening is to remove the trash and other material that may accumulate within the membranes and on membrane aeration system causing severe solid build up and potential damages. A proper pretreatment ensures longer membrane life and less need for membrane maintenance. The fine screening recommendations for systems using MYTEX modules are as follows:

Minimum specification: screens with ≤ 3 mm square shape mesh or round-hole openings. Bar screens are possible but may cause a much higher mechanical or recovery cleaning frequency.

Preferred specification: screens with ≤ 2 mm square shape mesh or round hole openings.

Notes:

a. The screen design, installation and operation should not allow overflow or bypass of unscreened wastewater to the MBR system in any circumstances. If such a case has occurred, an inspection of the membrane modules and, if necessary, mechanical cleaning must be carried out promptly.
b. Fine screen maintenance is very important. Frequent replacement of worn seals to close gaps is important for low maintenance membrane operation
c. It is recommended to install enough screens where maximum wet weather influent wastewater flow can be treated with at least one screen out of service.
d. The screening requirements for industrial applications may be different from those for municipal applications depending on the nature of solids in wastewater and what needs to be removed prior to membranes.
e. The trash content in the mixed liquor entering the membrane stage/tanks should be tested monthly as per Mixed Liquor Sieve Test instructions (see section 10.6.2)

5.3 Biological Treatment

5.3.1 Basic Biological Processes

The main biological processes used in MBR systems are based on an **anoxic zone** and an **aerobic zone**. The primary function of the anoxic process is denitrification. In the absence of dissolved oxygen, the biomass oxidizes organics using available oxygen molecules from nitrate. The reaction reduces nitrate to nitrogen gas which is stripped out in the subsequent aerobic processes under aeration.。

A mixer is installed in the anoxic tank to mix incoming screened wastewater with the mixed liquor returned from the aerobic tank at a predetermined recycle rate. This recycle rate is chosen to achieve an optimal bioreaction within the anoxic zone.

After the anoxic zone, the denitrified wastewater enters the aerobic tank. Typically, fine bubble diffusors are used to provide oxygen for biomass in the aerobic zone (1mg/L < DO < 3 mg/L). Air is dissolved and used by biomass for aerobic reactions. In this oxygen-rich environment, organic materials (as measured by BOD and COD testing) and ammonia are biologically oxidized to carbon dioxide, nitrate and water.

In case of the external configuration wastewater is pumped or fed under gravity from the aerobic zone to the membrane tanks to separate water from biomass. Return activated sludge (RAS) overflows or is pumped from the membrane tanks into the biological zone. This circulation flow is used to maintain a moderate level of mixed liquor suspended solid (MLSS) concentration in the membrane tanks.

While in some cases, the biological process includes an **anaerobic zone** for biological phosphorous removal, phosphorous removal can also be achieved by adding coagulants. There are different coagulants and they are dosed based on phosphorous content and desired removal rate.

5.3.2 Biological Design Requirements

For optimal membrane performance and low chemical cleaning demand mixed liquor suspended solids that are filtered by MYTEX membranes must meet the criteria included in Table 3. The MBR system performance is dependent on the design and operation of the whole MBR system, including the pretreatment and biological treatment processes. The criteria in Table 3 are developed for municipal wastewater treatment applications. Other or additional criteria may apply to industrial wastewater treatment applications.

Operating the membranes outside of these parameters can result in decreased capacity, high chemical cleaning demand or even damage to the membrane modules. Sludge filterability testing is required for monitoring the condition of sludge. Poor filterability may indicate high fouling potential and may lead to low filtration performance. A detailed description of sludge filterability monitoring parameters is provided in section 10.6.

Table 3. Mixed liquor parameters for a well working biological process

Parameter	Acceptable range	Comments
Temperature	10 - 40ºC	Low temperatures will inhibit the bacteria and cause insufficient BOD/COD removal
pH	6 - 8	
MLSS Biology	< 15 g/L	For economical oxygen transfer ≤ 12 g/L
Sludge Loading Rate (F/M Ratio)	0.1 - 0.22 kg COD/ (kg MLSS·d)	This assumes the sludge has a typical MLVSS/MLSS ratio of 0.75-0.8. In case of high inert content, the lower F/M-ratio should be used.
Dissolved Oxygen (DO)	> 1.0 mg/L	Relevant for the mixed liquor that goes into the membrane filtration tanks
Alkalinity	Not scaling	Important during NaOCl addition due to the pH shift
Sludge Colloidal TOC	< 20 mg/L	
Sludge Time to Filter (TTF)	< 200 s	
Sludge Volume Index (SVI)	< 200 ml/g	Values higher than 200 ml/g will require biological optimization.
Sludge Retention Time (SRT)	> 15 d	A sludge age of 10 days is acceptable for permanently high temperatures with complete nitrification and denitrification.
Hydraulic Retention Time	> 6 h	> 4 h acceptable for PHF and PDF operation

(HRT)		
Soluble BOD5	< 5 mg/L	< 1 mg/l preferred
Soluble COD	< 50 mg/L	
Soluble ammonia	< 2 mg/L	< 1 mg/l preferred, must be < 2mg/L at 100% of the time

Notes:

a. The sludge must be aerobically biodegraded until all residual BOD is removed and only a residual COD is present as hard COD (non-biodegradable).
b. While complete nitrification and denitrification processes are not required for membrane operation, better membrane performance is seen in systems with complete nitrification and denitrification.
c. Soluble COD for industrial applications may be higher. These limits are for municipal wastewater treatment and required permeate quality.
d. For optimal membrane performance, shorter sludge Time-to-Filter is desired. Other sludge characteristics such as colloidal TOC may also be measured and monitored as part of mixed liquor management and achieving best membrane performance.
e. For MLSS control in the membrane filtration tanks the flow of recirculated activated sludge (RAS) may be between 3 to 5 times that of the membrane permeate flow depending on the MLSS difference to the biological tank and the used configuration (pumped-to or pumped-from).
f. Solvent and other chemicals like ether (e.g. THF); ester (e.g. EtOAc)); aldehydes (e.g. formaldehyde); ketones (e.g. acetone); hydrocarbons; aprotic, polar organic solvents (e.g. NMP, DMSO, DMF) are not compatible with the membrane but usually easily biodegradable. Please find more information about chemical compatibility in section 10.4.

5.4 Filtration Stage Requirements

As already mentioned, there is an internal and an external configuration for MBR integration in wastewater treatment plants: submerged directly into the aeration tank (internal configuration) or submerged in a separate membrane tank (external configuration), see Figure 7. For both options, the needs regarding module installation, access for maintenance etc. are different.

5.4.1 Internal Configuration with Module inside the Biological Tank

With the internal configuration the membrane modules are installed inside the aeration tank. For this option, the overall plant design should consider a possibility to access the membranes in case of recovery cleaning or membrane module inspecting at least on a yearly basis. This can be ensured by draining the tank or installing the modules in way that they can be removed without draining the tank. For the second option an overhead crane and an external recovery cleaning tank will be necessary.

5.4.2 External Configurations with Modules in separate Membrane Tanks

With the external configuration the membrane modules are installed in separate membrane filtration tanks. Depending on the flow conditions and redundancy requirements several membrane filtration trains (or tanks) are used to make sure there is always enough treatment capacity available if one train is out of service due to chemical cleaning or other maintenance. In case of external configuration, the membrane tanks are often used for recovery cleaning so no overhead crane or separate recovery cleaning tank is needed for standard operation.

Typically, the transfer of mixed liquor between the biological tanks and the membrane tanks is achieved by pumping in one direction and flowing by gravity in the other direction. In the so called “Pump-To” case the mixed liquor is pumped to the membrane tanks, in the “Pumped-From” case the mixed liquor is pumped from the membrane tanks back to the biological tank.

5.4.3 Pumped or Gravity Filtration Options

Independent from the external or internal configuration the filtration stage can be operated by pump or by gravity. Figure 8 till Figure 10 show few of many possible filtration options. Depending on the local restrictions and degree of automation many other combinations are possible. For more detailed information or consulting please get in contact with your UNISOL representative. No matter which type of setup is used a proper control of permeate flow, TMP, air flow, chemical addition, mixed liquor concentration and mixed liquor levels needs to be ensured.

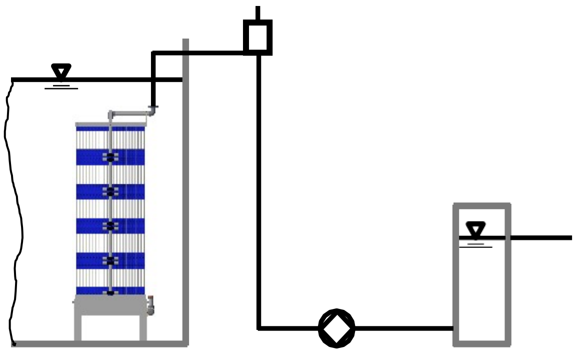


Figure 8: Filtration Stage Design with Reversible Pump

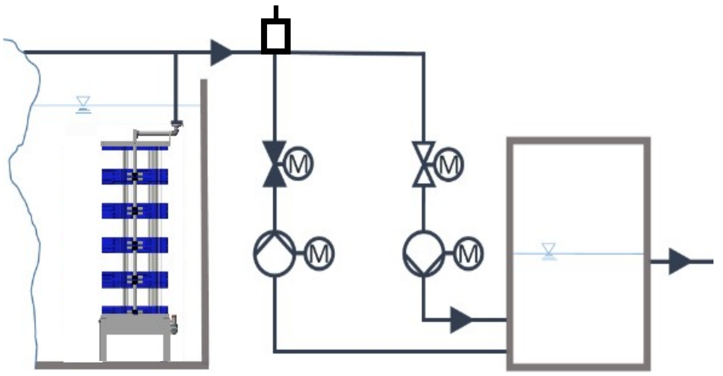


Figure 9:Filtration Stage Design with Dedicated Filtration and Backwash Pumps

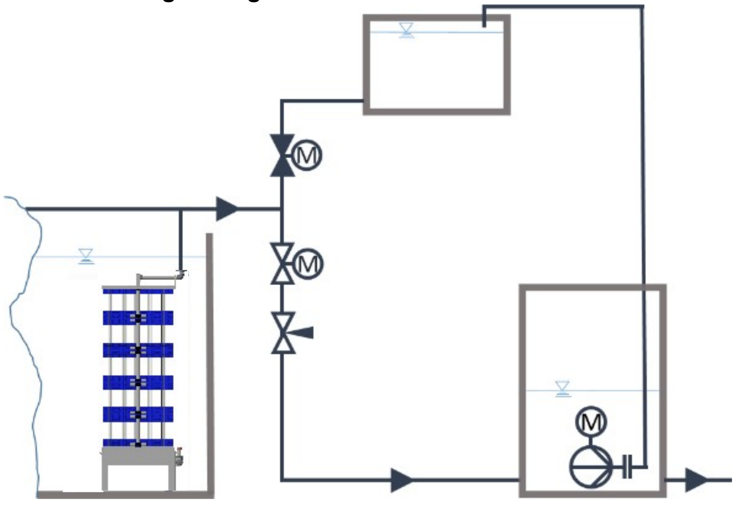


Figure 10: Filtration Stage Design with Gravity Filtration and Gravity Backwash

5.4.4 Permeate Pump

Once the permeate is physically separated from the sludge in the membrane tank, the permeate collection system transfers the clean water from the membrane tank to a permeate storage tank.

A typical setup is based on permeate pumps that are reversible in their flow direction and have a pressure range of -500 to +500 mbar (e.g. an eccentric screw pump or a rotary piston pump). It is important that the pump has the described qualities to ensure that the pump can both extract permeate from the sludge during filtration (through the permeate channel) and conduct the reverse module backwashing.

Each individual filtration line should be assigned to a separate permeate pump. The pump is sized based on the maximum gross flux. Additionally, it is suggested that the pumping system is designed, in coordination with piping and valve schemes, with redundancy so that multiple pumps have the capability to provide adequate power to multiple lines, or that spare pumps are stored on site to ensure minimal downtime in the event of unexpected failure.

5.4.5 Permeate Pipes, Valves, Venting

A series of pipes, valves and fittings connect the permeate pump (and the permeate tank) to the modules. A clever plumbing system configuration is imperative to ensure that the entire membrane system operates properly. A short permeate piping system also helps minimize the overall pressure drop. The diameter of the connection between the module and the main permeate header should follow or be bigger than the flange size of the module. Spiral supported flexible hoses may be used to connect the module with the main header.

Small amounts of air are carried through the pipes along with the permeate as a result of the slight vacuum needed to facilitate filtration. The captured air will accumulate at high points along the piping system and form air pockets which will interfere with the pressure measurement in the system. To counteract formation of air pockets, the piping system should only have one high point with a venting system mounted in this position. Additionally, the pipes should be sized so that the permeate velocity is between 0.5 – 1.2 m/s throughout the system. The maximum recommended flow velocity during peak flow events is 2 m/s. Higher flow rates will cause significant pressure drop causing wrong TMP values or even unequal flux distribution over the membrane modules.

Systems operating with gravity flow should not exceed 1 m/s for permeate velocity, otherwise part of the driving head will be lost because of pipe losses.

The venting system is not needed if the only high point of the piping system is the permeate tank at the end of the permeate extraction system. All air will be exhausted in the permeate tank and does not cause any misreading of the TMP sensor.

5.4.6 Permeate Tank

Another important component of the permeate collection system is the permeate tank. Once the clean water is separated from the sludge by the membranes the permeate pump transfers permeate through the piping system to the permeate tank. It is important that the tank is sized so that it contains enough clean water for a chemical backwash at any time. If the system is configured with multiple filtration lines or trains, the volume of the permeate tank may be smaller. This is because as one permeate line is cleaned, the other lines will continue to supply permeate. It is very important to cover the permeate tank

and to disinfect it regularly to avoid the formation of a biofilm. Please also avoid direct sunlight since both issues lead to an algae growth in the tank.

The tank should be operated in overflow mode so that once an adequate amount of permeate is stored for backwashing, the excess is discharged or reused.

5.5 Membrane Aeration Requirements and Equipment

During membrane aeration air bubbles remove the solids accumulated on membrane surface and prevent membrane fouling. The amount of delivered air should match the prescribed design values in the project specific technical data sheet and technical design proposal. Insufficient air may result in membrane fouling, too much air may cause damage to the membranes.

5.5.1 Crossflow Blowers

Generally, one blower is recommended per filtration line, but it is suggested that either reserve blowers are stored in case of failure or the system is designed with redundancy so that adequate air can be supplied at all times. Additionally, pressure losses associated with piping, water level differences and pressure loss from the diffusers should be considered when designing the aeration system.

The air delivered by the blower must be free of oil, dust, condensate and solvents. Dust filters in the inlet port of the blower are required. Dust filters for environmental dust with a separating efficiency of at least 90% in accordance with EN 779 (BS 6540, Ashrae 52-76) filter grade G4 or higher may be used.

With deep tanks and high blower intake temperatures, measures must be taken to ensure that the maximum diffuser inlet air temperatures are not exceeded. For proper aeration and to prevent damage to the modules the air scour rate, pressure and temperature need to be monitored for each line.

5.5.2 Crossflow Air Pipes & Valves

The pipes connecting the crossflow blower with the aerators below the modules should be as short and direct as possible. The diameter of the connection between the module and the main air header should follow or be bigger than the flange size of the module.

To ensure an equal air distribution between the modules properly sized main and sub header piping is mandatory. As a rule of thumb, the air flow velocity in the pipes should be lower than 10 m/s.

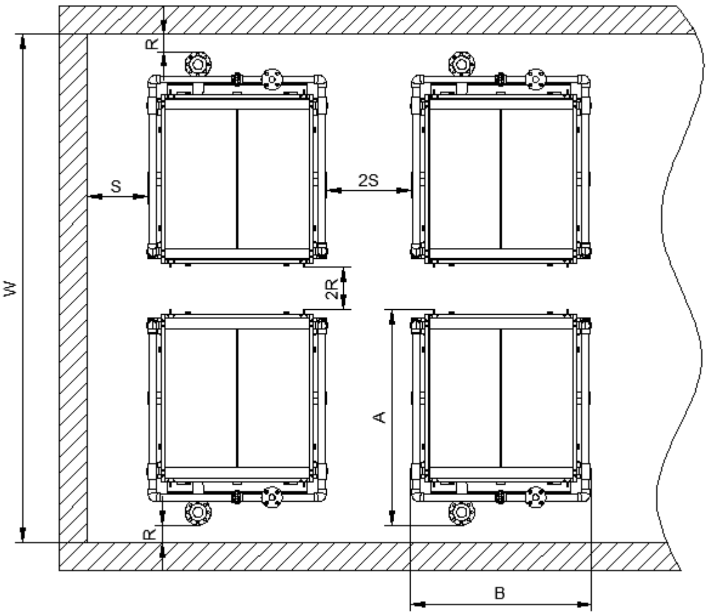
5.6 Filtration Tank & Train Requirements

5.6.1 Membrane Tank Sizes & Module spacing

To ensure proper aeration and mixing of sludge within the tank with proper flow pattern, the membrane tank should be designed with certain limitations. As a rule of thumb, the tank coverage of the membrane modules should not exceed 60% of the total membrane tank floor, based on the outer leg dimensions (air scour header not included).

The clearances between modules and between modules and walls are described in Figure 11 with rule of thumb values for R = 50…100 mm and S = 150…400 mm. The minimum free water level above the top of the membrane blocks (top clearance) is 300 mm. For detailed information about these specific

parameters please check the project specific technical design proposal or get in contact with our UNISOL representative.



General comments

a. Too low top clearance may cause sludge accumulation inside the module; high top clearance increases pressure loss for aeration and thus increases energy demand.
b. High ground clearances (in case of hanging modules) and high side clearances may cause sedimentation issues.
c. Tank coverage is the module footprint (based on leg dimensions) divided by the tank footprint.

5.6.2 Mixed Liquor Entrance & Recirculation Outlet

The membrane tank should include features designed to prevent damage to the membranes when filling or feeding the tank with mixed liquor. The liquid must not directly impact the membrane or module frame both in operation but also during filling of an empty filtration tank. Instead, the liquid must first impact a tank wall, tank floor or a deflector plate in order to absorb the kinetic energy prior to contacting the membranes or modules.

It is important to prevent a short circuit flow from the mixed liquor entry point to the recirculation outlet point. In order to achieve this, the two should always be on opposite ends of the tank.

5.6.3 Membrane Tank Cover

Foliage or other materials entering the system may block the space between the membrane sheets. Sludge circulation, crossflow and oxygen supply will be inhibited due to the blocked channels. The blocked membrane surface will become inactive and will not be available for filtration. Additionally, permanently blocked channels may lead to structural damage to the membrane sheet.

In order to avoid this potential damage, all tanks (not only the membrane tanks) and channels should be covered to prevent entry of foliage or other materials that may block the crossflow channels or damage the membranes. Any materials from the plant assembly (e.g. cable clips) and sharp particles which could block the crossflow channels or damage the membranes must be removed.

6 Module Handling and Storage

6.1 Packaging

For lowest transport and storage cost the MYTEX membrane module system is available in single parts for assembly on-site. As an alternative, modules are also available pre-assembled or fully assembled, depending on module size.

All packing units are provided with a parts list. According to this list the completeness of the delivery must be checked when unpacking.

6.1.1 Standard Packaging for Single Parts

The MYTEX system is packed and transported in stackable corrugated cardboard boxes on standard euro pallets. Each box contains one or two MYTEX blocks as well as various small parts for the entire system.

To protect the MYTEX blocks from humidity due to changing climatic zones, the blocks are protected by a plastic bag inside the cardboard packaging. If necessary, drying agents are used to prevent mould growth.

The base frame represents a further cardboard packaging unit and contains in addition to the pre-assembled aeration unit, all other individual parts necessary to complete the MYTEX system.

6.1.2 Packing of Pre-Assembled Modules

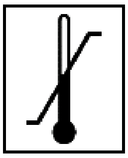
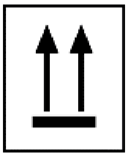
For long distance truck or container transport of pre-assembled MYTEX membrane modules a set of wooden crates and corrugated cardboard boxes is used. The boxes are equipped with drying agent to prevent mould growth.

6.2 Transport and Storage

The membrane modules have a shelf life of 12 months when stored according to the following conditions.

⚠ Caution
INSTALL THE MEMBRANE MODULE INTO THE TANK DIRECTLY PRIOR TO WATER COMMISSIONING.

Symbol	Instruction
	Do not place the product under direct sunlight.

	**Do not exceed a humidity of 70 % during storage.** Do not place the product in rain. The packaging is not rainproof and will be deformed. The membrane is preserved and after the preservative is washed out, the membrane module must be kept wet at all times to prevent irreversible damage from drying out.
	Store the preserved module within the following temperature range only: -5 to 50°C. If the product has been stored at low temperatures it is important that the module is thawed completely (T > 5°C) before moving it. Moving the module in a frozen state may cause membrane damage! Note that this product is not frost-resistant after the preservative is washed out. Storage temperature for water filled modules is 5 to 50°C.
	Always place the product upright unless stated differently in a specific instruction document.
	Handle the product with care. No shock loads of the packed equipment. Ensure that no damage occurs to the membrane during transport, assembly and installation.
	The fully or partly assembled module is top heavy. Be careful during transport and lifting.

6.3 Module Handling by Forklift or Crane

Lifting and transport of the fully assembled membrane system can be done by means of a forklift truck. To transfer the module into or from a tank the module can only be lifted by using steel ropes. These ropes need to be attached to the corresponding lifting eye bolts at the base rack and need to be attached to the top of the module to prevent rolling of the units during lifting. Please find details about correct rope assembly and connection in the assembly instruction in section 6.4. The lifting ropes are not part of the standard scope of supply but available as an accessory, see section 10.

The module must be lifted with a special traverse (see Figure 13) to keep the steel ropes in the correct position.

⚠ **Caution**
ALWAYS CHECK ALL LIFTING DEVICES FOR DAMAGE AND STRENGTH OF CONNECTIONS GEFORE LIFTING.

When installing the MYTEX module the tanks, it is essential to ensure that it is correctly seated and positioned on the intended installation surfaces (see Figure 12).

In case of lifting a module out of or putting it back into a full tank, lifting speed needs to be limited to 0.5 m per minute to let the water flow out of or into the membrane.

Figure 13: Lifting Tool for MYTEX U1L Modules

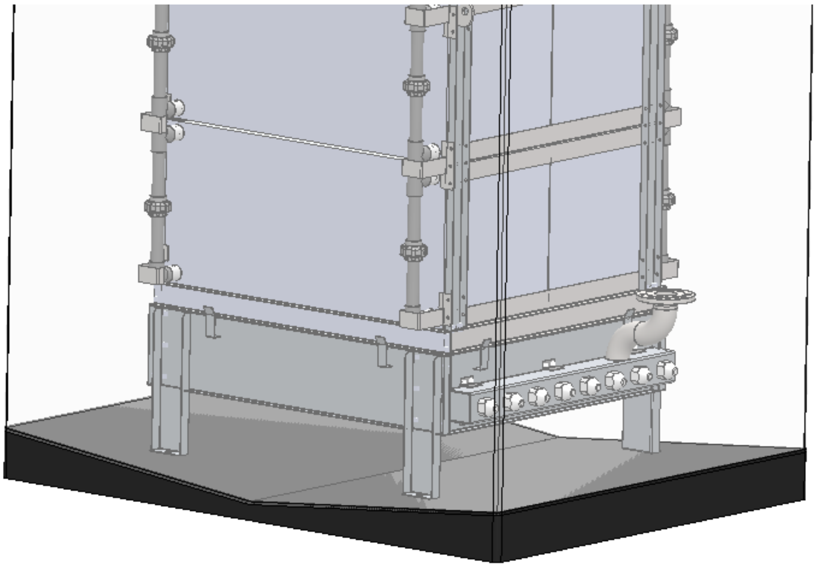


Figure 12: Wrong installation with bad leveling

6.4 General Assembly Instruction based on a MYTEX U1L Double Stack configuration (delivered in single parts)

Before starting to the module, please read this section carefully. Depending on the space in the installation location you may need vary the assembly step sequence.

All packing units are provided with a parts list. According to this list the completeness of the delivery must be checked when unpacking. Do not start assembly if any of the parts is missing or damaged.

6.4.1. Necessary Tools for Assembly

The assembly space needs to be clean dry and flat. You need to be at least 2 persons for the assembly. For module handling after assembly a forklift or crane with an appropriate lifting tool is needed. Make sure this is available (see section 6.3).

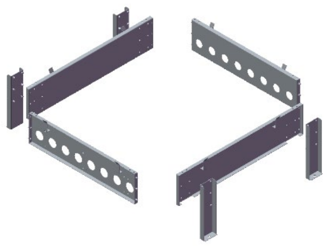
The following tools are needed or recommended for safe assembly:

- set of combination/open-end wrenches,torque wrench nuts:10 mm,13 mm
- Torx screw drivers

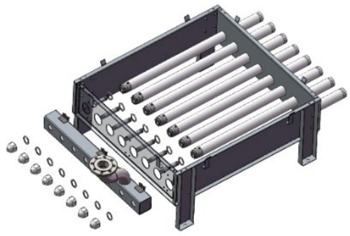
- Hexagon socket for cylinder head bolts
- torque wrench to tighten all bolts and nuts with the specified torque
- rubber hammer
- In case of modules with more than two levels of membrane blocks:
  - o Forklift or crane
  - o Membrane block lifting tool or two 15 – 22 mm (outer diameter) steel tubes
  - o Lifting devices like robe, chain, round slings
- Stable ladder or stable/mobile scaffold

Please consider all safety instructions listed on the packaging and make sure all local safety regulations are observed.

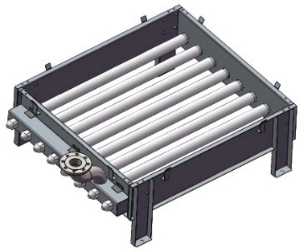
6.4.2. Assembly of base



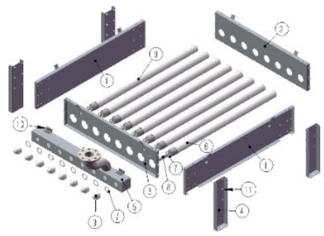
--- First find out the four support sheet metals and side plates, refer to the figure below, and fix them with M8*20 outer hexagon bolts



--- After the outer frame is assembled, refer to the explosion diagram shown in the figure and assemble all parts related to the aeration pipe
--- Note that the square tube weldment and side plate are fixed by M6*16 bolts
--- The top of the aeration pipe shall be sleeved with a sealing ring, which shall be fixed together with the threaded pipe, and then pass through the square pipe hole
--- The aerator pipe plug also needs to be sleeved with a sealing ring, and then fixed with the protruding threaded pipe

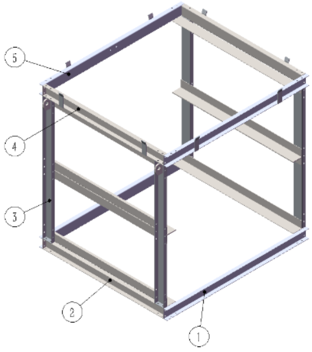


--- Complete base after assembly, as shown in the figure

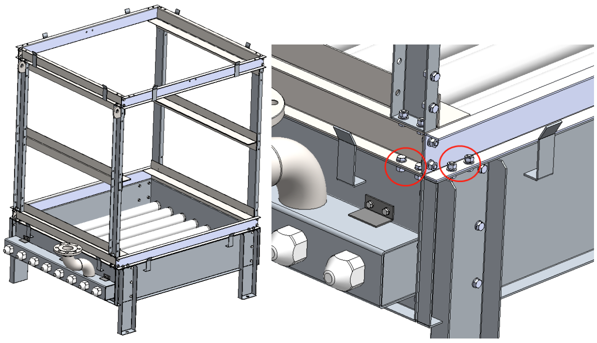


--- Exploded view of complete base is shown in the figure below

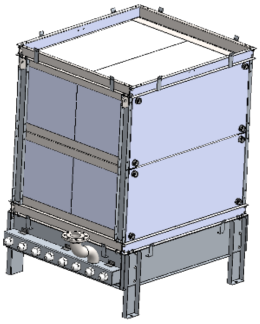
6.4.3. Add a two-layer module to the base



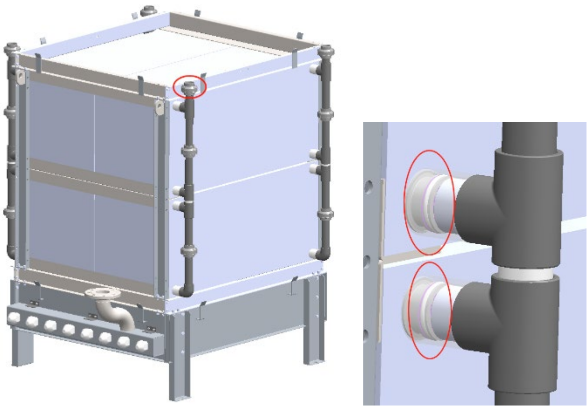
---As shown in the figure below, assemble the double-layer sheet metal frame, and connect the sheet metal parts with M8*20 bolts



---Fix the assembled double-layer outer frame with the base, and hoist it through the lifting lugs on both sides of the frame, as shown in the figure below



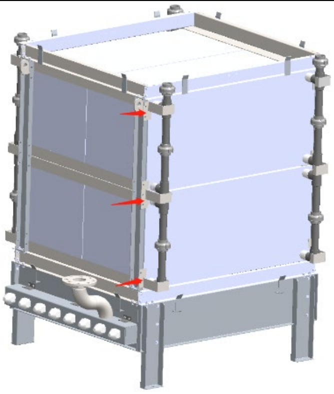
---Then install the MBR module horizontally along the reserved space. There are two modules on each floor, two floors in total. Note that the water outlets on both sides face outward (the module in the figure has been simplified, the same below)



---After the module is installed, assemble the water production pipe according to the actual object. As shown in the figure, the four sections of pipes have the same size, and the red circle above should be fixed with the three-layer module components, and then determined according to the actual size；

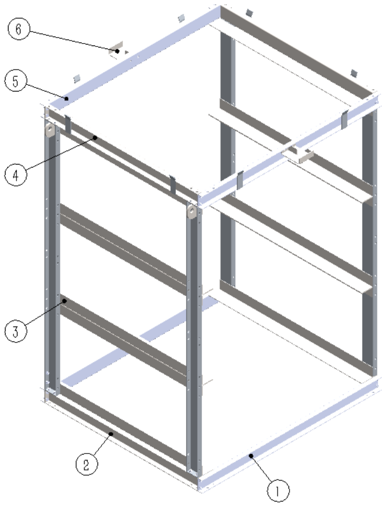
---When piping, pay attention to protect the sealing ring at the module water outlet to prevent damage；

---After the water production pipe is prepared, it needs to be disassembled for leakage test and reinstalled after confirming that there is no problem

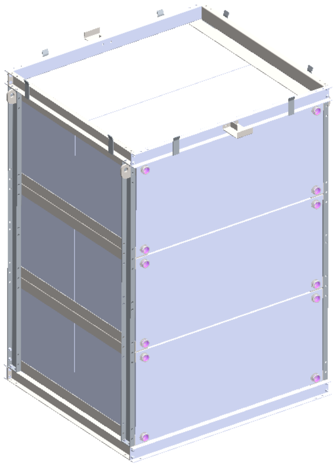


---Finally, fix the anti falling stop on the frame to prevent the water pipe from falling off

6.4.4. Assemble three-layer module assembly

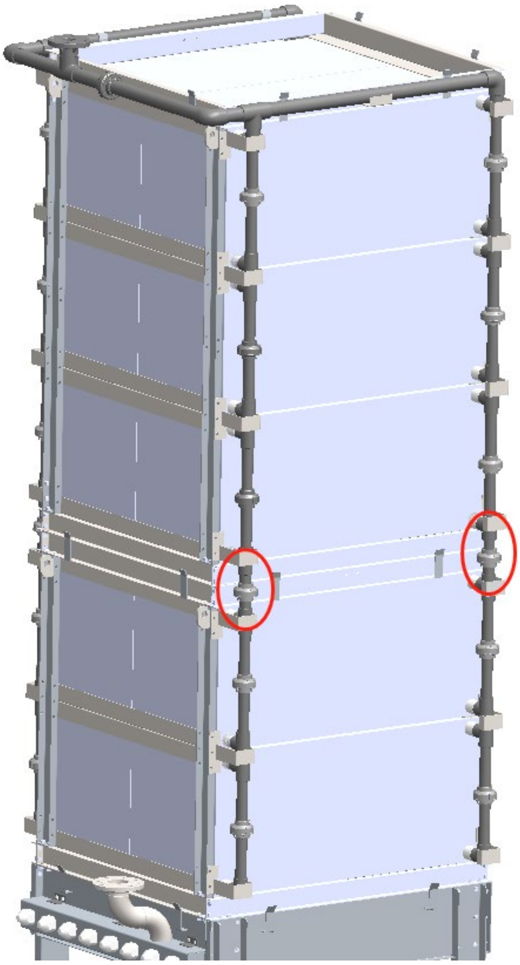


---As shown in the figure, first find out the components shown in the figure to assemble the three-layer sheet metal outer frame, and connect the sheet metal parts with M8*20 outer hexagon bolts

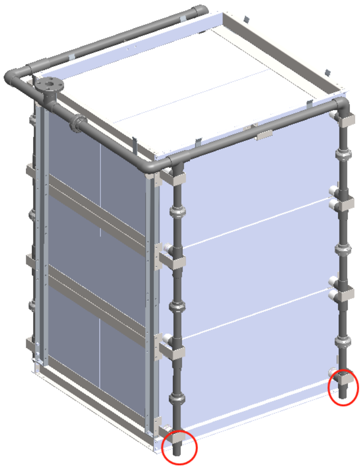


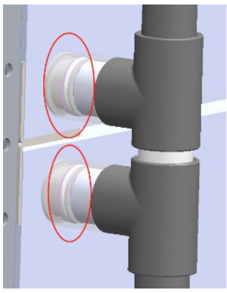
---After the sheet metal outer frame is installed, the MBR module shall be installed horizontally along the reserved space, with two modules on each layer, three layers in total;

---Note that the water outlets on both sides face outward

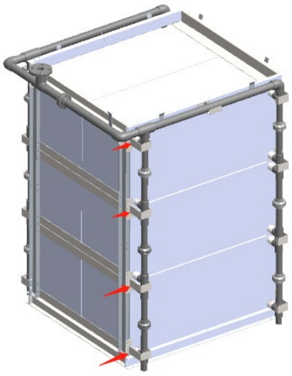


--- Then, according to the assembled three-layer assembly parts, the production water pipe is now configured. The process is similar to that of the previous step, as shown in the figure below;
--- The four connections in the red circle shall be hoisted above the double-layer assembly. After being fixed, they shall be assembled according to the actual size. After being assembled, the three-layer assembly shall be unloaded and placed separately;
--- When piping, pay attention to protect the sealing ring at the module water outlet to prevent damage;

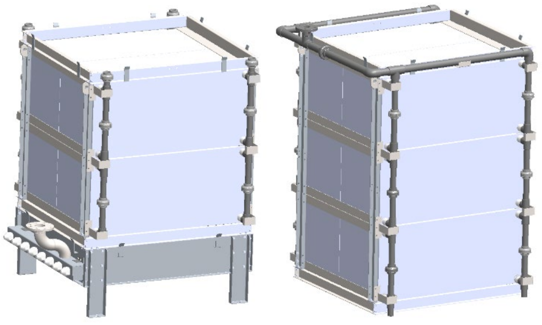




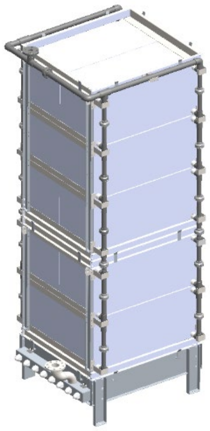
--- After the water production pipe is prepared, it needs to be disassembled for leakage test and reinstalled after confirming that there is no problem



--- After the water production pipe is installed again after leakage test, the anti tripping at each interface shall be fixed on the sheet metal frame, as shown in the following figure

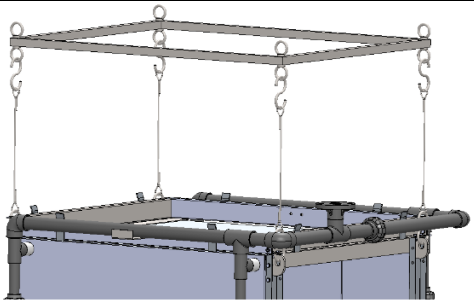


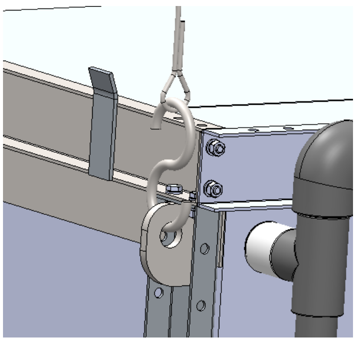
--- After assembly, it is divided into two parts as shown in the figure, and then lifted into a whole after arriving at the customer's site



The figure shows the complete assembly

6.4.5. Hoisting of equipment





--- The hoisting can be carried out in the way shown in the figure. Before hoisting, pay attention to check whether the relevant conditions of the hoisting equipment can meet the requirements and whether the steel wire rope is firmly installed. The hoisting process should be kept as horizontal as possible to avoid excessive deflection and damage to the equipment.

⚠ Caution
ALWAYS CHECK ALL LIFTING DEVICES FOR DAMAGE AND STRENGTH OF CONNECTIONS GEFORE LIFTING.

6.5 Decommissioning and Storage of Used/Wetted Membranes

When MYTEX membrane modules are not operating, they may be left submerged in biomass and aerated regularly.

⚠ Caution
WET MEMBRANES MUST BE KEPT WET AT ALL TIMES TO PREVENT IRREVERSIBLE DAMAGE FROM DRYING OUT. WET MEMBRANES SHOULD NOT BE EXPOSED TO TEMPERATURES BELOW 5°C.

6.5.1 Storage of Wetted Membranes During Maintenance

After soaking the membrane modules in water or biomass, the membranes become susceptible to drying. The membranes should not be allowed to dry out as drying may result in irreversible damage to the membranes. MYTEX membrane modules may be left in open air for a maximum of 12 hours **out of direct sunlight and wind**. After that time or in case of strong winds, membranes should be immersed in water or mixed liquor or sprayed repeatedly.

If membranes are fully wetted with water or mixed liquor frequently from the time they have been taken out of water, they may be left in open air for a maximum of 3 days.

If it is not feasible to immerse or repeatedly spray the membrane, the membrane should be cleaned and preserved according to membrane preservation procedure.

6.5.2 Storage of Immersed Modules out of Operation

For storage periods up to several weeks, the modules may be submerged in clean water containing sodium hypochlorite (NaOCl) of a maximum residual concentration of 10 mg/L. Residual concentration should be monitored each week. If the residual drops to less than 1 mg/L, add additional sodium hypochlorite.

Recovery cleaning of the membrane prior to storage is strongly recommended. Periodic aeration may also be necessary to prevent anoxic or anaerobic conditions from developing in the tank. In such cases, frequent testing of the water to ensure acceptable residual chlorine concentration is required. A simple swimming pool chlorine test kit is acceptable. A logbook should be maintained to record NaOCl concentration and water temperature.

6.5.3 Long-Term Removal & Storage

If membranes are to be out of service for a longer period, membrane modules should be cleaned, preserved and stored under conditions described in section 6.2.

Please follow the recommendations for long-term storage below. The membrane modules may be stored for up to 6 months. After this period, the long-term preservation procedure should be repeated.

Table 4. Procedure for long-term storage of MYTEX membrane modules

Step	Procedure
1	Perform a recovery cleaning with sodium hypochlorite and citric acid and make sure that the membranes are clean and free of any debris or sludge.
2	Prepare a preservative solution consisting of 20% glycerin and 3% sodium benzoate or sodium metabisulfite. This batch can be either prepared in the membrane tank or in an external tank. Membranes modules should be totally immersed in this preservative for at least 30 min. The permeate line or venting valves should be open to make sure the preservative can go into the membrane sheet.
3	Pack the membrane modules for storage and follow the interim storage conditions described in section 6.2.

7 Initial Start-up procedures

7.1 Unloading, Checking and Final Module Assembly

7.1.1 Requirements and Site Preparation

An overhead crane must be available and must also have proper strapping and connections for module and parts lifting (see sections 6.3 & 10.1). A flat area between storage place and point of installation (membrane tank) is needed for final assembly. Ensure all tools and installation hardware are available.

7.1.2 Module Inspection

For detailed information about packaging please check section 6.1.

All packing units are provided with a parts list. According to this list the completeness of the delivery must be checked when unpacking. All membrane modules are inspected before shipping to site. However, an inspection must be performed before installation in case shipping conditions affected the membrane modules. After unpacking check that all assembly bolts are tight and that no physical damage occurred to any part of the membrane system.

7.1.3 Final Module Assembly

Also, in case of pre-assembled equipment, MYTEX modules may be too tall to ship fully assembled due to shipping height restrictions, so some assembly may be required. When modules need to be finally assembled, follow assembly instructions in section 10.1.

7.2 Module Installation

Once the module is unpacked, inspected, and fully assembled, it is ready to be installed in the membrane tank. During initial start-up, the membrane modules should be installed into an empty tank.

There are several options for actual module fixation in the tank. In all cases the modules must be fastened in a way that they cannot move and that the minimum and maximum clearances below, on top and between the modules meet the project specific technical guidelines (see section 5.6.1).

7.2.1 Lateral Pressure / Application of Force on Frame & Piping

All lateral pressure on the air and permeate piping of the module is to be avoided. The piping is not intended to be load bearing. Lateral pressure on the connections or the associated pipe can cause breaches which will result in contamination of the membrane or diffuser unit and the permeate liquid.

The installation of the membrane equipment must be completed without any uneven lateral force on single parts of the modules or membrane blocks. For more information or support, please get in contact with you UNISOL representative.

The installed equipment must rest comfortably within the basin, and all attachments must be accurately aligned, avoiding pressure on the equipment.

7.2.2 Leveling the Modules

For all installation options, a proper leveling of the module is mandatory. For all MYTEX modules a maximum horizontal deviation of 5 mm per meter (≤ 5 mm / 1000 mm; ≤ 0.5%) module length and width is allowed. The correct leveling specifications may be met by leveling the tank floor or leveling the modules with additional leveling feet at the module legs.

Additionally, all membrane modules per train (per main header pipe) need to be on the same level. The maximum allowed deviation from minimum to maximum is 10 mm. Higher deviations will automatically cause uneven air distribution from module to module.

7.2.3 Connecting the Air Supply and Permeate Extraction

As last step during installation the air supply and permeate extraction piping should be connected. The air supply system must be flushed with air (20% higher flow rate as in operation) before connecting the modules. The permeate extraction piping must be flushed with water before connecting the modules.

⚠ Waring

MAKE SURE THE AIR AND PERMEATE PIPING IS FLUSHED AND FREE OF DEBRIS BEFORE CONNECTING THE MEMBRANE MODULES. ANY DEBRIS FROM THE CONSTRUCTION PROCESS MAY CAUSE IRREVERSIBLE DAMAGE TO THE DIFFUSOR OR MEMBRANE MATERIAL.

⚠ Waring

MAKE SURE ALL CONNECTIONS ARE DOUBLE CHECKED ON TIGHTNESS BEFORE FILLING THE TANK WITH WATER OR MIXED LIQUOR. SLUDGE INTRUSION INTO THE AIR SUPPLY PIPING MAY CAUSE DAMAGE TO DIFFUSERS.

The preferred type of connection is a hose connection since this can compensate for slight misalignments and this limit the forces on the module and system piping.

7.3 Clean Water Test Procedures

7.3.1 General Clean Water Testing

After completed module installation fill the membrane tank with clean water. Make sure there is enough water to fill minimum 10 cm over the top of the membrane sheets.

⚠ Waring

BEFORE FILLING THE TANKS WITH CLEAN WATER MAKE SURE THE TANKS HAVE BEEN CLEAN FROM DEBRIS CORRECTLY. BIG OR SHARP PARTICLES CAN CAUSE DAMAGE TO THE MEMBRANES.

⚠ Waring

WET MEMBRANES MUST BE KEPT WET AT ALL TIMES TO PREVENT IRREVERSIBLE DAMAGE FROM DRYING OUT. WET MEMBRANES SHOULD NOT BE EXPOSED TO TEMPERATURES BELOW 5°C.

Basic test steps:

1) Turn membrane aeration blower on and check for even aeration across the train of modules and the modules itself.
2) Turn off the blower and check for sections with large bubbles coming up. Large bubbles that rise after the blower is switched off are a sign of leakage.
3) If there are more air bubbles coming up from one side of the module the diffusors and the leveling need to be checked.
4) To keep a constant water level in the membrane tank put the permeate pump in recirculation mode so that the permeate re-enters the membrane tank.
5) Initiate a Prime mode or use air ejector system to prime the permeate system and remove air.
6) Turn permeate pump on at a flux no greater than 10 LMH.
7) Run 3-4 permeation cycles, allowing enough time to check all connection points for leaks and run through clean water test checklist. Do not run a backwash cycle unless all air has been purged from the permeate piping and membrane modules.
8) Turn permeate pump off
9) Turn aeration off
10) Leave clean water in membrane tank above the membranes to keep them wet until normal operation is to be started.

7.3.2 Pipe Pressure Loss Measurement Procedure

The following procedure is not mandatory. Properly designed piping does not need extra pressure loss correction. The procedure may be needed in case of undersized piping and high peak fluxes causing high flow rates and thus significant pressure drops in the system.

Table 5. Pressure loss measurement procedure

Step	Procedure
1	Disconnect the permeate piping from the membrane module.
2	Submerge the permeate hoses into clean particle free water. The water level is set at the operational water level planned for operation the membranes.
3	A venting of the system should be conducted. Pressure needs to stabilize and make sure that the measured values are comprehensible.
4	Measure the pressure loss at certain flows covering the average and peak flow conditions. Always note the TMPstart and TMPend (pressure loss) and the water level when pressure is stabilized. Either the water level is stabilized by recirculating water or it needs to be considered in the calculation.
5	Implement the measured piping pressure losses in the PLC programming
6	When the results are comprehensible, connect the piping and membrane module again. The tests are finished.

7.3.3 Permeate Pipe and Assembly Integrity Testing

An integrity test onsite is used to locate leaks in the module and its periphery after onsite assembly. An integrity test of the membrane sheets or membrane blocks themselves is not required, since individual blocks are 100% integrity tested after production. When mechanical imperfections due to operation are found, a repair possibility must be evaluated. Please contact UNISOL for further information.

An integrity test must be conducted under supervision of UNISOL or by trained professionals. Please contact UNISOL for further information.

⚠ Waring
WRONG INTEGRITY TESTING WITH TOO HIGH (≥ 300 MBAR) TEST PRESSURES CAN CAUSE DAMAGE TO THE MEMBRANE SYSTEM.

Materials
The following materials are required for integrity testing:

- Air supply at ≥ 80 mbar.
- Manometer and pressure controller (needle valve) for pressure range of 0 to 400 mbar.
- Air injection point in membrane module permeate line to permeate header.
- Integrity test adapters and hoses.

Instruction
It is recommended to conduct integrity testing with water with low turbidity for better visual identification of possible leakages in connections and piping. To complete the test, perform the following steps:

Table 6. Integrity Test Procedure

Step	Description
1	Go offline – Crossflow aeration and permeate production are stopped.
2	Reduce the water level in the membrane tank to 10 cm above the membrane sheets that the membranes are completely submerged and covered with water.
3	Before making any connections, ensure that the valve to permeate process pump is closed.
4	Connect the integrity test adapters to the next possible connection point in the permeate line near to the module.
5	Connect the manometer and pressure controller to the adapters.
6	Connect the compressor to the integrity test kit.
7	The safety valve remains closed.
8	The compressor starts, and the pressure controller is used to adjust a pressure of 80 mbar.
9	The safety valve is slowly opened as soon as the pressure is stabilized at 80 mbar and air is released into the module. The air will slowly displace the liquid inside the membrane modules and emptying it into membrane tank. This will again increase the water level in the membrane tank. If necessary, drain the tank again to a level of 10 – 20 cm above the membrane sheets.
10	Wait until the adjusted pressure is stabilized again at 80 mbar to ensure the air has purged

	the water through the membrane. The duration of this process is highly depending on the installed membrane area, permeate pipe dimensions and air supply, but should be at least around 5 minutes.
11	Examine the membrane module and periphery piping for escaping bubbles.

If no leaks are found, disconnect the integrity test kit, adjust all valves to its initial operational position and go back to normal operation. Make sure the whole system is properly vented before starting the system again.

Otherwise, make sure that all leaks are resolved (see section 10.1 for repair procedures) and repeat integrity test. In case there are further questions, please contact UNISOL.

7.4 Initial Membrane Conditioning

The membranes are preserved with a solution containing high COD concentration (glycerin solution). For optimal membrane performance a conditioning cleaning is strongly recommended during startup. The procedure is analogous to the maintenance cleaning procedure described in section 8.3.6, but the conditioning cleaning is performed in clean water with minimum 20°C water temperature. Lower temperatures may make longer soaking times necessary.

Table 7. Guidelines for Conditioning Cleaning

Concentration Typical (range)	**Soaking Time** Typical (range)	**Backwash Flux** Typical (range)	**Fill volume** Typical (range)
2000 mg/L (500 - 2000 mg/l)	6 hours (6 - 20 hours)	15 LMH (10-20 LMH)	3 L/m² (3 - 4 L/m²)

7.5 Starting Up with Mixed Liquor

Before starting up with mixed liquor, Clean Water Test Protocol, section 10.7.2, must be completed to ensure all works involved with the membrane system have been checked and completed.

⚠Caution
DO NOT FILL SEEDING SLUDGE DIRECTLY INTO THE MEMBRANE TANKS (E.G. FROM TANKER TRUCKS). SEEDING SLUDGE NEEDS TO PASS THE WHOLE MECHANICAL PRETREATMENT OF THE SYSTEM, ESPECIALLY THE FINE SCREENING STEP IS VERY IMPORTANT.

Basic test steps:

1) Open the gate or valve leading to the membrane tank.
2) Ensure recirculation pump is turned on. Once membrane tank is full, proceed to next step.
3) Put the train on Standby mode so that the recirculation pumps and membrane air scour blowers are on automatically.
4) Start Priming Mode to remove air from the permeate pipes and cassettes.
5) Turn the train to Permeation mode, with Relaxation enabled. The permeate pump and membrane blower will turn on. Do not exceed 15 LMH during first hour of operation or until air has left system.
6) Do not do any backpulsing until any air in the permeate lines has been removed.
7) Once the air has left the permeate system, turn off Relaxation mode and allow the train to backpulse.
8) Removing all the air from the membranes and permeate piping may take a few hours in some cases.

7.6 Adjustments after Start-up

7.6.1 TMP Sensor Offset

Transmembrane pressure (TMP) is calculated by using the equation below. During filtration, the value is negative, for backwash and chemical cleanings, it is positive. Occasionally it will take longer than a few permeation cycles to get all the air out of the permeate lines. Before correcting the TMP reading make sure there is no air in modules and permeate piping.

TMP is calculated from a pressure sensor on the permeate header. The data from the pressure sensor needs to be corrected to get the real TMP. The corrected TMP needs to consider the position of the sensor relative to the water level in the membrane tank using the following formula:

TMP = Pressure from Sensor + (D x C)

Where

- D = Distance from water level in membrane tank to the pressure sensor
- C = Conversion factor for distance in e.g. mm of water to mbar

Distance A must be verified after startup and must be programmed into the PLC to ensure the correct TMP value is being displayed. A method to check the correct TMP reading is checking the TMP in relaxation mode with no permeate flow. During that time, the TMP needs to be “0” ± 5 mbar. To do so it needs to be ensured that there is no closed valve between pressure sensor and membrane modules during relaxation mode.

In cases of varying water level in the membrane filtration tank, this variation must be considered and programmed into the PLC.

7.6.2 Membrane Aeration – Even Airflow and Diffusor Pressure Loss

Please check general air scour range setting for your MYTEX membrane module based on the product specification/fact sheet and according to section 8.5.

⚠ **Caution**

PREVENT OVER AERATION OF THE MEMBRANE MODULE AND THE DIFFUSORS. TOO HIGH AIR FLOW RATES MAY CAUSE DAMAGE TO THE DIFFUSORS AND REDUCE SERVICE LIFE OF THE WHOLE MEMBRANE SYSTEM.

An even air distribution across the membrane modules is critical for MBR operation. Uneven air distribution will result in inadequate air scouring between the membrane sheets and possible areas for solids accumulation in the modules. During the clean water test and soon after starting up, make sure there is an even amount of air bubbles coming up through all areas of each membrane module. If there are more air bubbles coming up from one side of the module the diffusors and the leveling need to be checked.

In the first two weeks of operation slight inequality regarding air distribution is normal. The diffusor perforation needs some time to fully open.

Please not diffusor pressure loss, air flow rate and air temperature in the corresponding Start-up Protocol, section 10.7.3.

8 Operation and Maintenance

8.1 Performance monitoring

Performance monitoring of the entire membrane system is essential for a proper and safe operation.

8.1.1 TMP, Flux, Permeability

TMP, flux and temperature are the main parameters for monitoring the performance of a membrane system. As a combination of all 3 parameters the so-called temperature corrected permeability (TCP) is used quite often.

Transmembrane Pressure (TMP)

It is essential that the TMP is correctly implemented in the PLC and corrected by sensor position and water level (see also section 7.6.1). Correct TMP calculation is proven by checking the pressure in the relaxation phase (flow rate at 0) whereas any valves membranes and pressure sensors need to be opened and the TMP showing a value around 0 ± 5 mbar.

Flow & Flux

The permeate flow rate is positive during filtration and negative during backwash and is transferred to the PLC with the respective plus or minus signs. Make sure that the flow device can measure in both directions.

The flux is the flow in L/h through the membrane surface area in m_2. The unit is given in in $L/m_2/h$ or LMH.

Flux = Flow rate / membrane area

Temperature Corrected Permeability

To obtain a continuous flow through a membrane, a negative pressure is applied on the permeate side of the membrane. Permeability is the product flow through the membrane (flux) divided by the applied pressure.

Permeability = Flux / TMP

The temperature corrected permeability takes temperature into account and is calculated based on the flux and TMP. The unit is given in $L/m_2/h/bar$ or LMH/bar.

Temperature corrected permeability (TCP) = Flux / TMP x $1.024_{(20\text{-Temp in }°C)}$

8.1.2 Gross & Net Flux

When designing a system using MYTEX membrane modules, there are two flux values which must be considered: gross flux (GF) and net flux (NF). Gross flux is the instantaneous, “real” flux through the membranes, whereas the net flux is the average flux with consideration of relaxation and backwash steps. The higher gross flux must be considered when sizing the permeate pump and the net flux is the determined by the feedwater flow (that is what needs to be treated). The gross flux is dependent on the net flux, filtration time, relaxation time (RT), backwash time (BT) and backwash flux (BF). The formula below can be used to calculate the gross flux:

$$GF = \frac{(FT + RT + BT) \cdot NF + BF \cdot BT}{FT}$$

8.1.3 Monitoring Diffuser Performance

Proper operation of diffusers is required for safe and reliable operation of MYTEX modules, since the diffusers provide the required crossflow aeration preventing a cake-layer from building up on the membrane surface. In addition, the membrane diffusers have major benefits such as excellent oxygen transfer efficiency characteristics. However, membrane diffusers also have maintenance requirements that are dependent on the characteristics of the wastewater.

Please check general air scour range setting for your MYTEX membrane module based on the product specification/fact sheet and according to section 8.5.

Pressure Loss, Temperature & Air Flow of Diffusers

The pressure loss of the diffusers is a good monitoring parameter because an increase in pressure loss usually indicates scaling or fouling issues. There are two methods to measure diffuser pressure loss. The first method is measuring the pressure inside the air piping. This measurement does not measure the actual pressure loss of the diffusers very accurately since it also depends on the system pressure. However, this measurement may give an indication of the pressure loss. To account for system pressure, the head pressure at the diffusers is subtracted from the measured pressure inside the air piping. During start-up the initial pressure drop is used as reference value and further changes in pressure drop are compared with this initial start-up data. It is critical that the pressure gauge is installed near the membrane modules to avoid significant pressure loss due to the air piping.

Temperature and air flow should also be measured. Too high temperature and/or too high air flow rate may cause damage to the diffusors and thus cause membrane clogging with increased maintenance effort. In worst case damaged diffusors may cause damage to the membrane and thus reduce service life of the whole membrane system. Please check section 8.5 for correct aeration settings of your membrane module.

Influent Properties Effect on Diffuser Service Life

The service life of diffusers is highly influenced by the influent properties such as foulants and scaleants, and by operation. The expected service life is 5 to 10 years but may be less or more depending on various factors. For some industrial or very aggressive wastewater applications, the service life may be reduced. Also, if no improvement is seen after applying the cleaning strategy discussed in this document, the economics of replacement should be considered since operation at high pressure or with unequal air distribution decreases the efficiency of the diffusers.

The presence and concentration of certain dissolved substances in wastewater increases the risk of formation of deposits inside and on the outside of the diffuser membranes. The risk of clogging (scaling or biofouling) is strongly dependent on the pH conditions in the biology, which are a result of buffer capacity (carbonate hardness), microbial activity and physical properties of the activated sludge (i.e. temperature, turbulence).

8.1.4 Monitoring Mixed Liquor - Mixed Liquor Sieve Tests

Proper pretreatment is one of the most important factors for proper operation of the filtration stage and significantly influences maintenance requirements. All the particles that pass the fine screen will accumulate in the membrane tank. To monitor the efficiency of the pretreatment, the MLSS is sieved and the residual number of particles is measured. A detailed instruction is provided in section 10.

8.1.5 Monitoring Influent & Effluent Characteristics and Biological Characteristics

For proper operation, the influent and effluent characteristics should be measured frequently to adjust operation if necessary.

Most biological parameters are covered in the design based on tank sizing, MLSS concentrations and sequence of treatment stages. However, it is important to monitor the biological characteristics and to alter the process if significant deviations to the recommended values are noticed. Most important design parameter is the F/M ratio besides flux. It is basically saying how much food to deliver to your biology. If there is too much food present, your biology may be not able to digest it and fouling may be getting severe. A detailed description of the basic biological design requirements is given in section 5.3.

8.1.6 Monitoring Filterability of Sludge & Mixed Liquor Sieve Test

The sludge filterability is a key parameter in monitoring the performance of a filtration process. These parameters may illustrate the tendency of how frequently a cleaning should be performed. However, these parameters are impacted by the MLSS concentration since the viscosity increases at higher MLSS.

Possible test methods and parameters are Sludge Filterability Testing (SFT), Capillary Suction Time (CST) and the recommend Time to Filter (TTF) as a standard monitoring parameter.

The Sludge Volume Index (SVI) is also a good indication of sludge filterability, as a correlation between settleability and filterability of sludge is considered. The detailed instructions for all tests are provided in section 10.

Table 8. Sludge filterability results criteria

Test	Units	Results	
		Good	Poor, needs improvement
Time to Filter (TTF)	Seconds	<200	> 200
Sludge Filterability Testing (SFT)	mL	> 10	<5
Capillary Suction Time (CST/MLSS)	s/(%MLSS)	≤30	≥150
Sludge Volume Index (SVI)	mL/g	<150	> 150

Time to Filter (TTF)

The Time to Filter is a parameter like MLSS characterization. A mixed liquor sample is filtered through a filter and time is stopped to collect 100 mL of permeate. During this test, a defined pressure is applied.

Capillary Suction Time (CST)

The Capillary Suction Time test is a commonly used method to measure the filterability and the easiness of removing moisture from slurry and sludge. The higher the CST value, the more the water is bound to the solid particles in the sludge. The lower the CST, the better the sludge filtration properties are.

Sludge Filterability Testing (SFT)

Sludge Filterability Testing is an index used to measure sludge quality in a MBR plant. A sludge sample is filtered through a filter by gravity flow for 5 min and the collected volume is measured.

8.2 Preventative Maintenance and Data Logging

This section describes various preventative maintenance measures that may be done to enhance and maintain the operation of the system.

Technical specifications of the mechanical and electrical items in the system that are not scope of supply of UNISOL, as well as detailed maintenance guidelines and procedures, are available in the respective vendor data. All routine maintenance should be carried out according to the technical specifications of each system component, as described in the vendor data.

If any of the problems discussed in this chapter persist or other difficulties arise, the operator should contact UNISOL regarding the products supplied by UNISOL. Completed log sheets are necessary to determine the source of the problem and are mandatory for warranty purposes.

8.2.1 Preventative Maintenance Schedule

The purpose of the preventive maintenance schedule is to keep the equipment ready and to detect signs of equipment malfunction during operation and scheduled maintenance checks. When the following data is not measured online and logged in the PLC, please follow the preventative maintenance schedule. This list is in line with the logged data requirements as detailed in section 8.2.2.

All analog and digital instruments should be checked and calibrated as per the manufacturer's recommendations.

The following codes are used to determine the frequency of maintenance:

- D – Daily maintenance check
- T – Three times a week check
- W – Weekly maintenance check
- M – Monthly maintenance check
- Q – Quarterly maintenance check
- S – Semi-annually maintenance check
- A – Annually maintenance check
- P – Project specific check

Table 9. Preventative maintenance schedule

D	T	W	M	Q	S	A	P	Task
Log Sheet								
X								Fill out system log sheet (points that are not logged automatically)
Analytical Testing								
	X							Influent water (pH, COD, TSS, MLSS)
		X						Influent water (BOD_5)
	X							Effluent water (pH, COD, Turbidity or TSS)
		X						Filterability parameter (TTF or CST, SFT)
			X					Mixed Liquor Sieve Test
	X							MLSS in each filtration tank
		X						FOG
General Equipment Inspection								
X								Verify proper function of all equipment (fine screens, pressure transmitters, flow meters, valves, turbidity meter, pumps, etc.)
X								Check for leaks in the system
						X		Inspect the piping for corrosion and leaks; repair as required

						X		Inspect the membrane tanks for damage; repair as required
MYTEX Membrane Modules								
		X						Check that the aeration is working correctly and equally distributed; visually observe aeration pattern in the membrane tank
							X	Maintenance cleaning with sodium hypochlorite dependent on monitoring parameter
							X	Maintenance cleaning with citric acid dependent on monitoring parameter
				X				Verify that modules are still leveled and properly fixed so they cannot move
				X				Inspect at least one module per tank. Take pictures of membranes in the tank if there is debris, solids in or at the modules or if there is damage to the modules
		X						Measure air pressure and temperature of diffuser for monitoring pressure loss (fully automated monitoring and control via PLC is strongly recommended)

8.2.2 Data Logging

As already mentioned, completed log sheets are necessary to determine the source in case of issues with the system and are mandatory for warranty purposes. Any inspections or actions that are not automatically logged within the PLC must be documented.

Inspections should be documented according to the Please find the protocol on the following pages.

Inspection Protocol, section 0. Each chemical clean should be logged according to the template Chemical Cleaning Logbook, section 10.

The following data are logged for process monitoring and should be forwarded to UNISOL in case of any warranty issues. If the warranty contract states other requirements for logged data, follow the requirements of the warranty contract.

Table 10. Logged data for process monitoring

System Component	Parameter	Frequency of Measurement	
		Online*	Laboratory
Inflow	pH	--	3 /week
	COD in mg / L	--	3 / week
	BOD5 in mg/L	--	1 / week
	Total Suspended Solids in g/l (TSS)	--	3 / week
Mixed liquor (sampling in membrane tanks)	Mixed Liquor Suspended Solids in g/l (MLSS)	(By minute)	3 / week
	Filterability (e.g. SFI or CST) Sedimentation properties (SVI)	--	1 / week
	Mixed Liquor Sieve Test	--	1 / month
	Fat, oil and grease in mg/l (FOG)	--	1 / week
	pH	--	3 / week
MBR Modules	Level membrane tank in m	(By minute)	
	Transmembrane Pressure (TMP) in mbar during filtration, backwash and relaxation	(By second)	--
	Flow rate per line in m³/h	(By second)	--
	Temperature in °C (effluent or mixed liquor)	(By minute)	--
	Crossflow air scour rate per line in Nm³/h	(By second)	--
	Air pressure in mbar or psi in air header	(By minute)	3 / week
	Air temperature in air header in °C or °F	(By minute)	3 / week
Chemical Cleaning (MC, RC)	Concentration in mg/l and pH of cleaning solution	Note date and required data for each chemical cleaning	

	Chemical fill volume in m³ (amount of chemical solution per line)		
	Soaking time from start backwash till end of soaking in hours		
	Consumption of source chemicals in L or gal		
Effluent	Turbidity in NTU or FNU	(By second)	3 / week
	COD in mg/L	--	3 / week
	pH	--	3 / week
	Total Suspended Solids in mg/L	--	3 / week

*By minute: minimum 1 data point per minute; by second: minimum 1 data point per second; (…) means that this online measurement is not a must but strongly preferred to lab measurement.

8.3 Operation modes

The description of the following standard operation modes are based on the Standard P&ID for MBR Applications, section 10.3.

8.3.1 Standby Mode

The Standby Mode is needed in the case that the system needs to be isolated due to low flow or if routine maintenance is performed. The recirculation pumps will continue to pump to ensure a flow of mixed liquor between the membrane tank and the biological stage. Compared to production mode the flow may be reduced or operated in batch mode. The blowers are usually also operating in batch mode to keep the mixed liquor mixed and to provide oxygen. No membrane permeation will occur, so the permeate pump will be shut off.

8.3.2 Production Mode

The main operation involves repeated production cycles of filtration followed by a short interval of mechanical cleaning that may consist only of backwash, relaxation or a combination of the two. The duration of the production cycle is the sum of the filtration duration plus the relaxation/backwash duration and the time required for valve switch-over.

Filtration refers to the use of a vacuum (created by a permeate pump or by gravity) as the driving force to induce water through the membrane (from the outside of the membrane to the inside) to produce permeate. During filtration, there is a net flow of mixed liquor or feed water solids towards the membrane surface. Some of this solid accumulation at the membrane surface is reduced by aeration.

Relaxation refers to a short period when filtration is stopped (by stopping the permeate pump or closing the permeate valve) while membrane aeration is continued. During relaxation, there is a net flow of mixed liquor or feed water solids away from membrane surface.

Backwash or also **backpulse** refers to a short period when permeate flow direction is reversed (compared to filtration). This creates positive pressure and causes permeate flows from inside of the membranes to the outside. Typically, this cleaning uses permeate produced during the production mode and is taken either from a permeate collection manifold or directly from a CIP/backwash reservoir. During backwash, there is a net flow of mixed liquor or feed water solids away from membrane surface.

The following table shows the range of acceptable durations for filtration, relaxation and backwash cycles:

Table 11. Standard production cycle

Cycle Step	Mixed Cycle	Backwash Only	Relaxation Only
Filtration	540 s	570 s（480 to 720 s）	540 s（480 to 720 s）
Relaxation	20 s	--	60 s （30 to 120 s）
Backwash/Backpulse	20 s	30 s（15 to 60 s）	--
Relaxation	20 s	--	--

Notes:

- The values in the table above are standard values to start with. If the performance is not within acceptable ranges, the filtration, relaxation and/or backwash cycle time may be increased/decreased accordingly. Make sure that the pumps are designed to handle a net/gross flux ratio of minimum 80%.
- If the backwash and/or relaxation cycle is too short, it may reduce physical cleaning efficiency and may cause excessive or irreversible fouling. The chemical cleaning frequency may also increase.
- Backwash affects the system's efficiency since produced permeate is returned into the process fluid and must be re-extracted.
- It is important to allow enough time for the pump to ramp up and down during backwash only cycles. This will prevent the membranes from experiencing sudden pressure shocks.
- For some venting options the possibility for regular backwash is mandatory. Please make sure a suitable venting option is used.

Use of Relaxation Alone

The use of filtration/relaxation allows for similar performance as the use of filtration/backwash for most MBR applications under normal operating conditions. The benefits of relaxation include a reduction in the amount of permeate used for membrane maintenance, an increase in system recovery and a reduction in the capital costs associated with backwash.

Backwash Guidelines

The backwash system should be designed to be able to deliver a backwash flux of 10-20 LMH for all types of wastewaters. The maximum TMP during regular backwash must not exceed 300 mbar. The backwash water quality must fulfill the following requirements:

- TSS <5 mg/l, COD <50 mg/l
- TDS and water hardness must be low enough in order to prevent formation of precipitates when changing the pH for example by adding NaOCl
- Higher COD is possible, especially in cases of industrial applications with non-biodegradable COD but it will lead to higher NaOCl consumption since part of the NaOCl will already be consumed by the COD in the permeate.

8.3.3 Diffusor Flushing Mode

The Diffusor Flushing Mode is used to support the self-cleaning effect of the diffusors by blasting off mineral deposits from the diffusor slits. It is usually performed once per week for 10 minutes. The mode operates in parallel to the standard production mode. No additional down time is needed. The additional air flow capacity can be provided by the blower (VFD needed) or by using the blower capacity from another line that is in standby mode at this time. Please find the general description below and more details in section 8.5.2.

Table 12. Diffusor Flushing Mode

Step	Procedure
1	The standard frequency of this cleaning step is once per week from the beginning. In certain cases, e.g. operating the module at very low air flow rate (>20% less than design value), a daily flushing may be necessary.
2	During standard production mode (see section 8.3.2) switch off the aeration briefly (5 – 10 s). The production mode itself is not stopped.
3	Start up the aeration again with minimum 20% - 40% higher air scour rate compared to standard operation. Do not go higher as the maximum air scour rate allowed in the technical data sheet of the membrane module.
4	Operate at high air scour rate for 10 minutes
5	Go back to normal air scour rate

Notes:

- This mode is strongly recommended during long intermittent mode operation (< 50% operation time per day) and during standby periods (e.g. seasonal operation) as well as continuous operation at minimum air scour rate according to the technical data sheet of the membrane module.

- If a high amount of process-related deposits are expected (e.g. simultaneous precipitation, dairy wastewater, high water hardness), a correspondingly adapted flushing operation is recommended.

8.3.4 Prime Mode or Venting Mode

In Prime Mode, the air ejector or venting system is activated to remove air entrapped in the membrane modules, permeate pipes, and/or permeate pumps. Specific operation of ejector or venting systems can vary depending on the type of system installed.

Prime mode must be initiated before putting the system into Production Mode. It should occur automatically before going to Production if the system was previously not permeating. Prime can also be initiated manually if air is trapped in the permeate piping system.

The frequency of the venting process strongly depends on the amount of air accumulated. Attributes such as dissolved oxygen (DO) content and TMP determine the amount and rate of air accumulation. High DO in the activated sludge and high TMP exacerbate air accumulation.

Please note, very frequent venting is often caused be leakages in the piping system. Please check piping, flanges, or other connections in case of unusually frequent venting.

8.3.5 Off Mode

In Off Mode, the permeate pump for the train will be shut off. The aeration valve for membrane aeration will close for that train, and the inlet sluice gate will close. Precautions must be taken when the train is to be turned off for long periods.

8.3.6 Maintenance Clean Mode

Maintenance Clean Mode will involve backwashing chlorine into the membranes and allowing them to soak for a period of time. Please see section 8.4 for details.

8.3.7 Recovery Clean Mode

Recovery Clean Mode will involve draining the membrane tank and refilling with NaOCl and then citric acid solutions by a separate line. It is also possible to backwash the chemical solutions through the membranes. Please see section 8.4 for details.

8.4 Membrane Cleaning

During normal operation, membrane surfaces may be fouled with particulate material including biomass, salt precipitates and insoluble organics (such as oil). These deposits may build up if not adequately controlled through use of mechanical cleaning procedures (e.g. relaxation, backwash and aeration). The continued growth of such deposits may eventually result in a decline in membrane performance (e.g. loss of membrane permeability).

8.4.1 General Chemical Cleaning Procedures

As for all MBR products also for MYTEX the typical chemical cleaning procedures are used.

Maintenance Cleaning: The in-situ Maintenance Cleaning is based on frequent chemical cleans with backwashing a chemical solution into the membrane modules. Usually the procedure is fully automated. In case of less frequent cleans (e.g. monthly) a partly manual procedure is also an option.

The frequency of maintenance cleaning is process and wastewater dependent. Permeability or TMP can be used as a guide for cleaning frequency. Maintenance cleanings are typically performed several times a month using lower concentrations of chemicals for short periods of time (e.g. an hour). This cleaning is intended to maintain a sanitized system and to prevent significant growth of fouling deposits or scales on membrane surfaces and within permeate piping.

In some cases, a less frequent (e.g. one per month) chemical cleaning approach with higher concentrations, higher fill rates and longer soaking times may be applied. This intensive or extended version of the maintenance clean is intended to significantly recover permeability and remove fouling deposits on membrane surfaces.

Recovery Cleaning: This cleaning uses clean water and is intended to remove all fouling residuals from membrane surfaces and "recover" membrane permeability close to its initial or an acceptable value. It is recommended to use warm water for a higher cleaning efficiency. The recovery cleaning is not part of routine maintenance but may be required in specific cases when extended maintenance cleaning combined with inspections and removal of debris and sludge accumulation is not effective anymore.

8.4.2 Cleaning Chemicals

Depending on the type of fouling and required cleaning, a sodium hypochlorite solution, citric acid solution or combinations of the two may be required. Sodium hypochlorite is used to remove organic

and biological fouling from the membrane while citric acid is used to remove mineral scaling such as iron, metal salts or calcium salt and other scaling compounds.

UNISOL recommends using these two cleaning agents. In special cases other chemicals may be used, please get in contact with UNISOL for more information.

When using sodium hypochlorite, little amounts of AOX are formed due to the reaction of active chlorine with mixed liquor. If AOX effluent limits are an issue, hydrogen peroxide (H_2O_2) may be used as an alternative to avoid AOX discharge. Please consider that hydrogen peroxide has a quick degradation rate and should be just stored for only short periods of times.

Hydrochloric Acid (HCl) or other strong acids may only be used for pH adjustment during an acid cleaning. Monitoring is extremely important to avoid the pH dropping below the critical value of pH 2.

8.4.3 Frequency of Chemical Cleaning

For all municipal and most industrial applications with systems using MYTEX membrane modules, the maintenance cleaning frequencies are provided in the following table:

Table 13. Maintenance and Recovery Cleaning frequencies

Approach	Maintenance Cleaning (# per month)		Intensive Maintenance Cleaning (# per month)		Recovery Cleaning (# per year)	
	Sodium Hypochlorite	Citric Acid	Sodium Hypochlorite	Citric Acid	Sodium Hypochlorite	Citric Acid
Preventative Cleaning	2-8	0-1	0-1	0	0-2	0-2
Low frequency Cleaning	0	0	1-2	0-1	0-1	0-1

The frequency of cleaning depends on several factors such as:

- Permeability or TMP
- Type and chemistry of wastewater
- Scaling and fouling potential: Higher alkalinity (> 70 mg/l) wastewater and coagulant dosing (especially ferric chloride) may need much more citric cleaning than low alkalinity water
- Membrane conditions (extent of fouling)
- Efficiency of production cycles (backwash and relaxation)
- Operating temperature: Especially sodium hypochlorite is much more effective at higher temperatures. At cold temperatures (< 15°C) to reduce soaking times it may be useful to heat the chemical solutions to 30 - 35 °C. A full recovery cleaning should always be performed in this temperature range.
- Pretreatment efficiency: Bad pretreatment causing accumulation of solids in the membranes will significantly reduce the efficiency of chemical cleaning.
- Completeness of biological degradation: Substances that are not completely biologically degraded accumulate on and in the membrane and can cause severe biofouling.
- Permeate flow rates
- Aeration intensity

8.4.4 Chemical Cleaning Specifications

The general chemical cleaning specifications must be considered before conducting chemical cleanings.

Table 14. General chemical cleaning specification	
Parameter	**Units**
pH range (Operation/Cleaning)	2 … 11
Temperatures (Operation/Cleaning)	≤ 50°C (≤ 35°C for NaOCl, H2O2)
Sodium Hypochlorite Target Concentration	200 … 3000 mg/L
Total Active Chlorine Resistance	≥ 500,000 ppm•hrs
Hydrogen Peroxide Target Concentration	0.5 … 1 wt %
Citric Acid Target Concentration	0.2 … 1 wt %
Total Soaking Time	1 … 20 hours
Chemical Fill Volume without Piping	1 … 4 L/m2
Backwash Flux with chemicals	10 … 20 LMH
TMP during chemical backwash	≤ 300 mbar
Membrane sheet inner volume	0.7 L/m2

The **Total Chlorine Resistance** is calculated based on the target concentration of sodium hypochlorite multiplied by the time the membranes are exposed to chemicals. For example, if a chemical cleaning is conducted using 250 mg/L of chemical and the total exposure time (dosing time + soaking time) is 2 hours, the chemical exposure is 500 ppm•hrs.

8.4.5 Maintenance Cleaning Procedure

A template for a chemical cleaning logbook is provided in section 10.7.5 and is used to collect essential data for continuous improvement of the cleaning strategy.

This standard maintenance cleaning is done with the modules submerged in biomass/process fluid. The quality of the backwash liquid must fulfill the standards for backwash water as stated in the backwash guidelines in section 8.3.2.

Table 15. General Guidelines for Chemical Cleaning via Backwash				
Chemical	**Concentration** Typical (range)	**Soaking Time** Typical (range)	**Backwash Flux** Typical (range)	**Fill volume** Typical (range)
Maintenance Cleaning in-situ (with mixed liquor in tank)				
Sodium Hypochlorite	200 mg/L (200 - 750 mg/l)	1 hour (1 - 3 hours)	15 LMH (10 - 20 LMH)	1.5 L/m² (1 - 2 L/m²)
Citric Acid	2000 mg/L -	1 hour (1 - 3 hours)	15 LMH (10 - 20 LMH)	1.5 L/m² (1 - 2 L/m²)
Extended Maintenance Cleaning in-situ (with mixed liquor in tank)				
Sodium Hypochlorite	1000 mg/L (1000 - 3000 mg/l)	6 hours (4 - 20 hours)	15 LMH (10 - 20 LMH)	2.5 L/m² (2 - 3 L/m²)
Citric Acid	5000 mg/L (5000 – 10,000 mg/l)	6 hours (4 - 20 hours)	15 LMH (10 - 20 LMH)	2.5 L/m² (2 - 3 L/m²)
Recovery Cleaning in-situ (with water in tank)				
Sodium Hypochlorite	1000 mg/L (1000 - 3000 mg/l)	6 hours (4 - 20 hours)	15 LMH (10 - 20 LMH)	3.5 L/m² (2 - 4 L/m²)
Citric Acid	5000 mg/L (5000 – 10,000 mg/l)	6 hours (4 - 20 hours)	15 LMH (10 - 20 LMH)	3.5 L/m² (2 - 4 L/m²)

The target levels for fill/backwash and rinse volume do not consider additional volumes needed to flush or fill the piping. The dosing points for the chemicals should be as close as possible to the membrane modules and the fill volumes need to be adjusted to the specific site conditions.

The main steps of the maintenance cleaning procedure are summarized below:

Table 16. Maintenance Cleaning procedure	
Steps	**Procedure**
1	Stop filtration of filtration line scheduled to be cleaned. Continue to aerate membranes and recirculate mixed liquor for minimum 2 minutes (minimum 5 minutes for extended version)
2	Shut off mixed liquor recirculation and isolate membrane tank. Shut off membrane aeration system.
3	Backwash membranes in the train with at least 1 L/m² while dosing appropriate chemical (see cleaning parameters in Table 15)

4	Relax membranes to let the chemical soak for minimum 30 minutes
5	Refresh the chemicals by backwashing the membranes a second time to reach the desired fill volume while dosing appropriate chemical
6	Soak membranes for minimum 30 minutes
7	Backwash membranes in the train without adding chemicals to rinse out the chemicals from piping. The typical rinse volume for the modules is 1.0 L/m².
8	Open the valves that isolate the membrane tank/line.
9	Turn on mixed liquor recirculation pump and membrane aeration for minimum 5 minutes (minimum 30 minutes for extended version).
10	Resume normal operation.
11	Log maintenance cleaning event in a protocol

Notes:

- A pH adjustment to pH 11 during hypochlorite cleaning is not required.
- pH monitoring is recommended for acid cleanings. The pH should be between 2 and 3 in case of extended cleans.

The procedure is based on a first initial chemical fill and a second refresh step. This is just an example. It is also possible to add all chemicals in one step or to have several refresh steps.

8.4.6 Recovery Cleaning Procedure

If permeability recovery with maintenance and extended maintenance cleans is not effective any more a recovery cleaning will be necessary. In-situ recovery cleanings are the ideal solution since the modules can stay in place. However, an ex-situ recovery cleaning may be alternatively carried out depending on the onsite configuration.

There are two options for recovery cleaning of MYTEX membrane modules. For both options it is recommended to totally clean the membrane tank during recovery cleaning for removal of any deposits and accumulated sludge inside tank. When there is an indication of clogging (dewatered sludge between the membrane sheets), please follow the clogging recovery procedure as outlined in section 8.4.10.

The first recovery cleaning option is based on chemical backwash. This option is ideal for big tanks that would cause very high chemical demand in case of a chemical bath. The second recovery cleaning option is the typical chemical bath. This option is very effective but also consumes a lot of chemicals.

8.4.7 Procedure for Recovery Cleaning by Backwash

The procedure for recovery cleaning by chemical backwash is as follows:

Table 17. Procedure for Recovery Cleaning by Backwash

Step	Procedure
	Preparing MBR train
1	Stop filtration of membrane train scheduled to be cleaned. Continue to aerate membranes and recirculate mixed liquor for 15 minutes.
2	Shut off mixed liquor recirculation and isolate membrane tank. Shut off membrane aeration system.
3	Drain the membrane tank manually or using the recirculation pump.
	Cleaning MBR tank and modules
4	Perform Clogging Recovery Cleaning if required
5	Fill the membrane tank with permeate water using an external pump. Note that other membrane trains are required to stay in operation mode to keep the permeate tank full of permeate during this process.
6	Aerate membranes for 60 minutes.
7	Drain the membrane tank again to remove all excess sludge removed from membranes.
	Manual option to steps 5-7: Wash down the modules and the tank with a water hose.
8	Fill the membrane tank again with permeate water using an external pump.
	Perform the chemical clean with sodium hypochlorite and citric acid according to the maintenance cleaning procedure. Please use chemical concentrations and fill volumes according to Table 15.

8.4.8 Procedure for Recovery Cleaning in Chemical Bath

Ideally the water for cleaning fulfills the standards for backwash water as stated in the backwash guidelines in section 8.3.2.. Since the recovery cleaning in a chemical bath usually does not include backwash steps also water with higher TSS and COD is possible. The higher TSS and COD the less effective the cleaning procedure may be. Total Dissolved Solids or water hardness must be low enough to prevent formation of precipitates when changing the pH (e.g. adding NaOCl).

Table 18. General Guidelines for Recovery Cleaning in Chemical Bath

Chemical	**Concentration** Typical (range)	**Soaking Time** Typical (range)	**Fill volume** Typical
Sodium Hypochlorite	1000 mg/L (200 - 3000mg/L)	8 hours(@ 30°C) (6 – 20 hours)	Min. 5 cm above the top of the membranes
Citric Acid	5000mg/L (5000 – 10000mg/L)	4 hours (2 – 20 hours)	

Notes:

- At low initial concentrations, the chemicals must be added regularly to ensure an effective cleaning result.
- In general, monitoring the chemical concentrations or pH (for acid) during the recovery cleaning is recommended to get optimum results regarding recovery, chemical consumption and down time. The pH should be between 2-3.

In most cases a recovery clean is performed with sodium hypochlorite and citric acid. The typical down time for the whole procedure including preparation work and a short inspection is 30 hours. Depending on the type of feedwater and the degree of fouling and scaling an additional chemical clean with sodium hypochlorite after the citric clean may be necessary.

The main steps of the recovery cleaning procedure are summarized below. The following things and materials should be prepared or be available:

- Compensating reservoir for mixed liquor
- Additional pump for transfer of mixed liquor and draining tank
- Preparation for potential Clogging Recovery Procedure

Table 19. General Recovery Cleaning procedure

Step	**Procedure**
	Preparing MBR train
1	Stop filtration of membrane train scheduled to be cleaned. Continue to aerate membranes and recirculate mixed liquor for 15 minutes.
2	Shut off mixed liquor recirculation and isolate membrane tank. Shut off membrane aeration system.
3	Drain the membrane tank manually or using the recirculation pump.
	Cleaning MBR tank and modules
4	Perform Clogging Recovery Cleaning if required
5	Fill the membrane tank with permeate water using an external pump. Note that other membrane trains are required to stay in operation mode to keep the permeate tank full of permeate during this process.
6	Aerate membranes for 60 minutes.
7	Drain the membrane tank again to remove all excess sludge removed from membranes.
	Manual option to steps 5-7: Wash down the modules and the tank with a water hose.
	Performing chemical clean with sodium hypochlorite
8	Fill up the membrane tank with water for cleaning to minimum 5 cm above the membrane modules
9	Add the sodium hypochlorite through a separate line directly to the membrane tanks. Use 5 minutes of air scour at 50% standard air scour rate to mix the chemicals in the tank.
10	Soak membranes in the cleaning solution. Air scour the modules for 5 minutes every hour to mix and refresh the chemicals.
	Rinsing modules and performing chemical clean with citric acid
11	Follow the neutralization procedure if required.
12	Drain the cleaning solution and refill with fresh water for citric cleaning

13	Fill up the membrane tank with water for cleaning to minimum 5 cm above the membrane modules.	
14	Add the citric acid through a separate line directly to the membrane tanks. Use 5 minutes of air scour at 50% standard air scour rate to mix the chemicals in the tank.	
15	Soak membranes in the cleaning solution. Air scour the modules for 5 minutes every hour to mix and refresh the chemicals.	
	Rinsing modules and preparation to resume normal operation	
16	Open the valves that isolate the membrane tank/train.	
17	Turn on membrane aeration and start to recirculate mixed liquor for minimum 60 minutes.	
18	Continue to recirculate mixed liquor until the membrane tank cleaning volume has been completely replaced.	
19	If necessary due to effluent limits backwash membranes in the train without adding chemicals to rinse out the chemicals in the membranes. The typical rinse volume for the modules is 0.7 L/m².	
20	Resume normal operation.	
21	Log recovery cleaning event in a protocol.	

Notes:

- Numbers presented in this table are used as a starting point and may need to be adjusted for each project.
- A pH adjustment to pH 11 during hypochlorite cleaning is not required.
- pH monitoring is required for acid cleanings. The pH should be between 2-3.

8.4.9 Neutralization

Neutralization is not required by means of membrane but can be performed if requested by local discharge requirements. The goal is to neutralize residual chlorine. Methods of measurement can be either free chlorine (test kits are available i.e. from Hach Lange) or redox potential. During this time, recirculation from the membrane tank to the biology is stopped. The steps for neutralization are:

Table 20. Neutralization procedure

Steps	Procedure
1	Make sure the membranes are still completely covered with cleaning solution. Fill up with clean water if required.
2	Neutralize the chemicals in the tank by adding appropriate neutralization agents. Use air scouring to mix the chemicals. Make sure you do not overdose the chemicals and that the membranes do not get in contact with highly concentrated chemicals. For chlorine add sodium thiosulfate (Na2S2O3•5H2O) or equivalent to the gutter channel of the membrane tank for neutralization. The following equation may be used to calculate the needed amount. $Na_2S_2O_3 \bullet 5H_2O\ [g] = V_T\ [m^3] \cdot AC \left[\frac{mg}{l}\right] \cdot 0.88$
3	Manually check the pH (citric acid) and the residual chlorine concentration. Proceed to the next step when the residual chlorine concentration is less than the required level for discharge.
4	Open the valves that isolate the membrane tank/train.
5	Turn on mixed liquor recirculation pump and recirculate mixed liquor until the membrane tank cleaning volume has been completely replaced.
6	Turn on membrane aeration and continue to recirculate mixed liquor for additional 60 minutes.
7	Backwash membranes in the train without adding chemicals to rinse out the chemicals in the membranes. The typical rinse volume for the modules is 0.7 L/m².
8	Resume normal operation.

8.4.10 Clogging Recovery Cleaning Procedure

A Clogging Recovery Cleaning is required if the membrane modules are clogged with sludge or with fibers and hair (ragging). At an early stage, this clogging is easily removed with a water hose. For more details please contact UNISOL.

8.5 Membrane Aeration and Diffuser Cleaning

8.5.1 Air Flow Ranges for Air Scouring

Proper air flow settings are essential for low maintenance, low energy cost and long service life of the MYTEX membrane modules. You can find the allowed air flow range in your project specific specification/fact sheet for the MYTEX membrane module. Figure 14 shows an example fact sheet with the air flow ranges circled in green.

At the beginning it is recommended to start with the typical design air flow rate. To optimize energy demand air scour rate may be reduced to the minimum value at low permeate flux rates or low MLSS concentrations. Please reduce the air scour rate in steps to find the optimal value. In case of high MLSS rates combined with high permeate flux rates, for example during peak hour or peak day operation at limited RAS rate, the air flow rate can be increase above the typical design value.

Continuous operation above the typical design air flow rate is not recommended as this may shorten the life of the diffusers. For applications that require very high air flow rates (e.g. thickening applications), more frequent replacement of the diffusers must be considered.

Submerged Membrane Modules For Water And Wastewater Treatment

Fact Sheet

Module Specification			
Type Name	**520m²**		
Membrane Area	m²	520 on 2+3 levels	
Width B | Max. Width	mm	1204	1543
Length A | Max. Length	mm	1024	1295
Height C | Max. Height	mm	3377	3543
Dry Weight | Wet Weight Wo. Solids	kg	645	910
Air Flow Rate Min | Max	Nm³/h	58	134
Typical Design Air Flow Rate	Nm³/h	96	
Materials of construction			
Base support and attachment parts	SS304, PVC-U		
MYTEX.BLOCK	ABS, membrane sheets		
Block membrane area and quantity	52m² each, 10 pieces totally A single block replacement is easily done, benefit by the excellent design		
Type of membrane			
Type, material	UF PES		
Operation mode	Ultrafiltration		
Nominal pore size	0.04 µm		
Connections (other types on request)			
Permeate	Flange PVC-U; DN40 (PN16)		
Aeartion	Flange SS304; DN65 (PN16), DIN2633		
Operating conditions			
Temperature range	°C	0..50	
Transmembrane pressure range	mbar	-800 .. 300	
Ph range (cleanings)	-	2..11	
Min chlorine resistance (active chlorine)	ppmh	500.000	
Minimum water level	m	3,8	

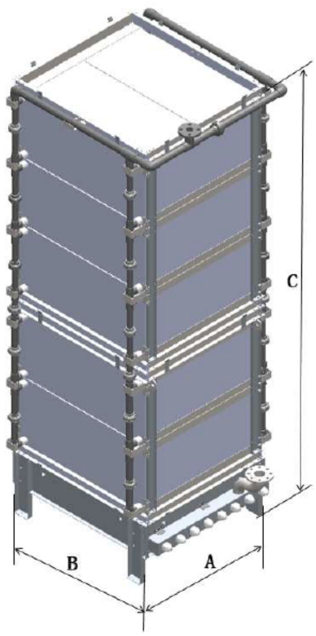


Figure 14: Example specification sheet with details about allowed air flow ranges

8.5.2 Diffusor Flushing

For typical municipal wastewater the only routine cleaning of membrane tube diffusers used in MYTEX membrane modules is frequent diffusor flushing based on the usually fully automated diffusor flushing mode, see section 8.3.3.

Depending on the wastewater composition, load and process control of the plant, more or less pronounced biological deposits (slime, fouling) and scaling effects (mineral deposits) can occur. Deposits on the diffusor hose and especially in the diffusor slots must be avoided in any case, as they lead to a long-term deterioration of the pressure loss and the service life of the aerator. Depending on the process design and air flow rate, the elastic slots of the diffusors experience an alternation of expansion and relaxation, which cause a self-cleaning process and can "blast off" mineral deposits. To support this self-cleaning effect, an additional flushing process should be carried out regularly and ideally implemented as a standard operating mode within the PLC.

The flushing process as described in Table 12, section 8.3.3, needs minimum 20% higher air flow rate compared to standard operation. This additional air flow capacity can be provided by an appropriately designed blower with VFD or by using the blower capacity from another line that is in standby mode at this time.

8.5.3 Manual diffusor cleaning

For certain applications manual diffusors cleaning may be necessary if:

- Sludge intrusion into the air piping or diffusors due to lose connections or other leakages in the piping
- The bubble pattern of the membrane module appears irregular and inhomogeneous. Check if this is caused by dewatered modules which may be an independent issue from the diffusers.
- Visual inspection of the diffusers show that they are scaled or fouled.
- Clogging (dewatering, sludging) of modules has occurred due to improper aeration.
- Pressure loss of the diffuser is higher than the initially measured pressure loss. Cleaning must be initiated when the pressure increase is higher than 40 mbar.

In case of damage to the diffusor hose or massive sludge intrusion into the diffusor combined with stretching of the diffusor hose material it is strongly recommended to replace the diffusor hose with a new one.

Table 21. Manual diffuser cleaning method

Step	Procedure
1	Please check section 10.1, Replacement or Repair of Parts for diffusor assembly and disassembly.
2	**Manual Method - Water Hose** Use a low-pressure water hose with a nozzle to clean the diffuser surface. The nozzle should be at least 50 cm away from the diffuser.
3	**Manual Method - Wiping with Cloth, Soft Brush or Sponge** Deposits may also be removed by carefully wiping the surface with a cloth or soft brush.
4	a) Prepare a chemical cleaning bath with 500 ppm sodium hypochlorite (go to step 5) b) Prepare a chemical cleaning bath with 0.5% citric acid
5	Let the diffuser soak for 30 minutes
6	Repeat Steps 2 and 3 for removal of all deposits on the diffusers. Perform a citric clean as second step (see step 4b)
7	Reinstall the diffusers.
8	Fill up the basin and check the pressure loss and equal air distribution.

9 Troubleshooting (In Progress)

10 Appendix

10.1 Replacement or Repair of Parts

Please get in touch with UNISOL for further information.

10.2 Spare Parts and Accessories

10.2.1 List of Spare Parts

Please get in touch with UNISOL for further information.

10.2.2 Lifting Tool

To transfer the module into or from a tank the module can only be lifted by using the module specific steel ropes provided for this purpose. These ropes are an integral part of the module and need to be attached to the corresponding lifting eye bolts at the base rack (see assembly instruction in section 10.1). The module must be lifted with a special traverse (see Figure 14) to keep the steel ropes in the correct position.

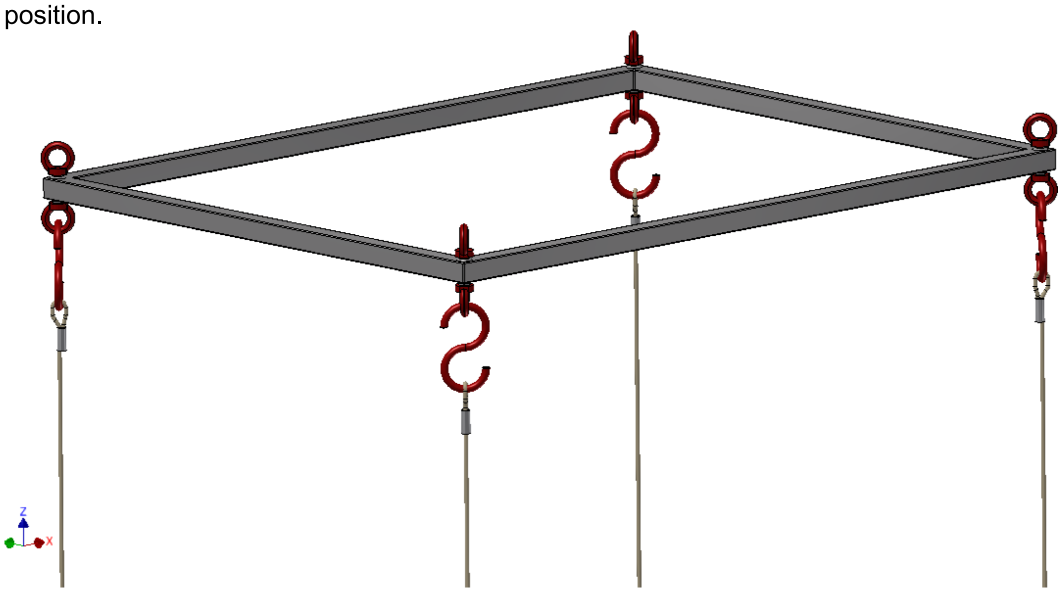
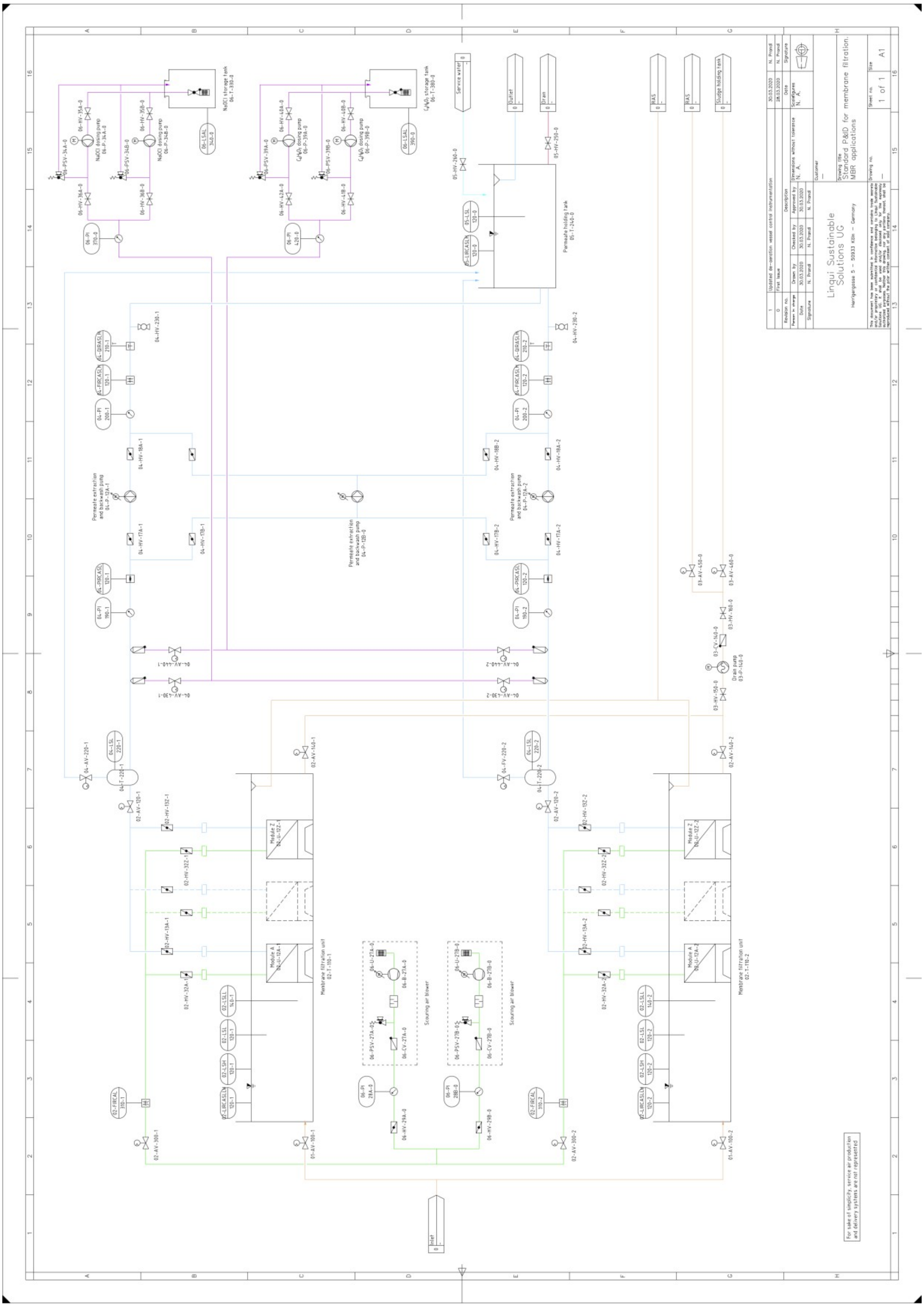


Figure 15: Accessory - Lifting Tool for MYTEX U1L Membrane Modules

10.2.3 Standard P&ID for MBR Applications



10.3 Chemical Compatibility

Certain chemicals may potentially cause irreversible damage to the membranes. Some chemicals may coat the membrane and reduce the flux (e.g., this can occur if silicones are introduced into the system), or they may damage membrane structure or break down its components (e.g., solvents can dissolve membrane constituents such as polymers). In addition to the membranes, different components used in fabrication of membrane modules (e.g. metals, plastics) may also get damaged due to various chemical compounds. The following table contains a list of chemicals and their compatibility.

The information below is based on individual compounds. Interactions between multiple compounds may occur when they are used together. Excessive exposure or high concentrations of compatible chemicals listed here may also harm the membrane products. Please contact UNISOL if you have specific questions regarding duration, concentration and temperature when using these chemicals.

Table 22. Chemical compatibility of MYTEX membrane products

Chemical	**Affiliation (Group of Chemicals)**	**Usage (Cleaning/Influent Compounds)**	**Compatibility Yes**	**No**
Acetic Acid	7			x
Acetone	3			x
Acetonitrile	6			x
Aluminum sulfate	12			x
Ammonia	10	Cleaning chemical, apply according to manual	(x)	
Aniline	4			x
Anionic polymer	13	Irreversible flux loss potential	(x)	
Benzene	4			x
Butyl acetate	3			x
Cationic polymer	13	Irreversible flux loss potential	(x)	
Citric Acid	7	Cleaning chemical, apply according to manual	(x)	
Di-butyl phthalate	3, 4			x
Dichloromethane (DCM)	5			x
Di-cyclohexyl amine	4			x
N,N-Di methylacetamide	6			x
N,N-Dimethylaniline	4			x
N,N-Dimethylformamide	6			x
Esters	3			x
Ethanol	1			x
Ethylbenzene	4			x
Ferric chloride	12			x
Ferric sulfate	12			x
Formalin	3			x
Gasoline	4			x
Glycerin	1			x
Halogenated Hydrocarbons	5			x
Hexamethyldisiloxane	13			x
Hydrochloric Acid	9	Cleaning chemical, apply according to manual	(x)	
Hydrogen Peroxide	11	Cleaning chemical, when applied according to concentrations given for NaOCl in the manual	(x)	
Hypochlorite	11	See Sodium hypochlorite, apply according to manual	(x)	
Isopropyl alcohol	1			x
Kerosene	4			x
Ketones	3			x
Lime	12			x
Metals	14			x
Methanol	1			x
N-Methylpyrrolidinone	6			x

Mono Ethylene Glycol (MEG)	1			x
Nitric Acid	9	Cleaning chemical applied in case of strong $CaSO_4$ or $MgSO_4$ fouling, at pH according to manual	(x)	
Oxalic Acid	7	Cleaning chemical for strong ferric or manganese fouling, up to 5% concentration for cleaning according to manual	(x)	
Ozone	11			x
Phenol	4			x
Phosphoric Acid	9	Cleaning chemical sometimes applied in food applications, at concentrations and pH according to manual	(x)	
Potassium Hydroxide	10			x
Seawater	14			x
Silicone	13			x
Soda	12			x
Sodium Hydroxide	10	Cleaning chemical, apply according to manual	(x)	
Sodium Hypochlorite	11	Cleaning chemical, apply according to manual	(x)	
Sulfolane	4			x
Sulfamic Acid	9	Cleaning chemical, apply according to manual	(x)	
Sulfuric Acid	9	Cleaning chemical, apply according to manual	(x)	
Tetrahyrofuran	2			x
Toluene	4			x
Triethylamine	8			x
Ultrapure Water	14			x
Xylene	4			x

(x) indicates chemical is compatible at limited concentrations and specific instructions should be followed.

10.3.1 Groups of Chemicals

1) Alcohols
2) Ether
3) Ester, Aldehydes, Ketones
4) Saturated and non-saturated Hydrocarbons
5) Chlorinated hydrocarbons
6) Aprotic, polar organic solvents
7) Organic acids
8) Organic alkaline solutions
9) Inorganic acids
10) Inorganic alkaline solutions
11) Oxidative compounds
12) Inorganic salts
13) Polymers
14) Others

1) Alcohols

Low molecular weight, simple alcohols (such as methanol, ethanol and propanol) cause swelling of membrane material, but do not cause chemical deterioration of the membrane. Higher molecular weight alcohols (such as glycol and glycerin) cause almost no swelling of the membrane material and do not chemically deteriorate the membrane.

2) Ether

Exposure to low concentrations of low molecular weight ethers may cause intense swelling and membrane deterioration, causing the membranes to become brittle over time. High exposures to higher concentrations will result in brittle membrane in just a short period of time.

Higher molecular weight ethers, (especially glycol and glycol ether) may cause severe deterioration of the membrane and, when present in high concentration, may cause dissolution of the membrane matrix. When present in lower concentrations, these higher molecular weight ethers weaken the membrane matrix and cause enlargement of the pores.

3) Ester, Aldehydes, Ketones

Low molecular weight aliphatic esters cause rapid deterioration of the membrane when present in high concentrations. In low concentrations, the membrane slowly becomes brittle, reducing membrane life. Aldehydes and Ketones (such as acetone) will result in swelling of the membrane material. High concentrations will make membranes brittle; reducing membrane life.

4) Saturated & Unsaturated Hydrocarbons

Although these compounds may not cause chemical deterioration, they do tend to block the membrane pores through adhesion of the chemicals to the membrane polymers (on the surface as well as pore plugging). This blocking and fouling of membrane is not easily reversible with chemical cleaning.

5) Chlorinated Hydrocarbons

Like the non-chlorinated hydrocarbons, chlorinated hydrocarbons may adhere to the membrane matrix (either on the surface or within the pores). In addition, they may weaken and potentially cause deterioration of the membrane (e.g., in the case of dichloroethane). Some chlorinated hydrocarbons are solvents for membrane polymers. Generally, halogenated hydrocarbons are more destructive than non-halogenated hydrocarbons and aromatic hydrocarbons are more destructive than aliphatic hydrocarbons.

6) Aprotic Polar Organic Solvents

These solvents cause swelling of membrane material. In higher concentrations, they can also damage the membrane by weakening or even dissolving the membrane matrix.

7) Organic Acids

Low molecular weight acids (such as formic acid or acetic acid) cause swelling of the membrane material. In higher concentrations, they may also damage the membrane by dissolving the membrane matrix.

8) Organic Alkaline Solutions

In higher concentrations, these solutions (e.g., triethylamine) may damage the membrane material and weaken the membrane matrix.

9) Inorganic Acids

Pure nitric acid and sulfuric acid are known to be solvents for polymers and may dissolve the membrane matrix. The known strong acids may cause deterioration of the membrane matrix. The deterioration effect increases with concentration, contact time and temperature. The pH limits, as shown in the manual should not be exceeded to ensure membrane compatibility.

10) Inorganic Alkaline Solutions

Caustic soda is generally tolerated at limited concentrations. However, higher concentrations of caustic potash (KOH, potassium hydroxide) may cause irreversible damage to membranes and ammoniac cannot be tolerated. The pH limits, as shown in the membrane data sheet and manual should not be exceeded to ensure membrane compatibility.

11) Strong Oxidants (NaOCl, H_2O_2, O_3, peracetic acid)

In higher concentrations, strong oxidants may cause deterioration of the membrane modules and modules. They can also make different components brittle by degradation of the carbon chains of the polymer molecules. Because oxidants are destructive in any concentration (e.g. NaOCl, H_2O_2, etc.) they should be used only for chemical cleaning purposes and strictly in accordance with cleaning instructions.

12) Inorganic Salts

While direct negative effects have not been observed, dissolved ions may significantly shift the pH towards alkaline values (Na_2CO_3, “Soda”) or acidic values (NH_4Cl, “ammonium chloride”). As long as the normal pH operating range (pH 5 to 10) is not exceeded, there is no adverse chemical effect on the membrane material.

In addition, salts with low solubility in water (such as $CaCO_3$, lime) may precipitate in the (aerated) environment around the membrane. When they precipitate directly onto the membrane surface, they may create lime scaling (which is reversible to a certain extent with acid cleanings). They may also form sharp-edged crystals which may mechanically damage and erode membrane surfaces.

13) Polymers

While polymers do not cause deterioration of the membrane, they do adhere to the membrane material and block the membrane pores. In some cases (i.e. silicones), this blocking may be irreversible.

Polymers in MBR applications are normally added as part of sludge treatment to help dewater sludge. However, the supernatant generated during dewatering contains certain levels of dissolved polymers. Such fractions of soluble polymers normally have lower molecular weights. Typically, supernatant is returned in front of the process. As a result, soluble polymer concentrations increase in the bioreactors and membrane tank. Most of such polymers may be fouling and damaging to membranes. The following type of polymers should not be used:

- Cationic polymers
- Molecular weight of polymer additive < 50,000
- Molecular weight of polymer additives between 100,000 and 200,000
- Any dewatering polymers system that may contain oil-based additives. Most of commercial dewatering polymers are water base.

14) Others

Metals, glass splinters, sand and grit are abrasive and may damage the membrane. Proper pretreatment should be used to remove such materials to the recommended levels noted in this manual.

10.3.2 How to Handle Critical Chemicals in the Feed to the System

This chapter described the effect of particular chemicals on the membrane material and matrix. It should be noted that, in the case of a properly designed wastewater treatment system using mechanical pretreatment (including fat, oil and grease removal as well as sand and grit removal) and a membrane bioreactor system (MBR), membranes should not come in contact with elevated or unacceptable levels of chemicals found at the inlet of the plant. This is because they have already been properly degraded and treated by the upstream processes.

Different designs should be considered by responsible engineers for the design of the upstream process steps. These considerations include the following:

- A well designed and operated aerated grit and sand chamber
- A well designed and operated process for the removal of fat, oil and grease as well as most of the non-soluble hydrocarbons.
- Acids and alkalis neutralize one another. The acid buffer capacity of a huge bioreactor with activated sludge is considerable, so the pH should be stable around 7-8.5. This also reduces the potential of precipitation of inorganic salts in the system.
- Strong oxidants should be exhausted in the activated sludge before coming into contact with membranes.
- Dissolved hydrocarbons should be biologically degraded in the bioreactor to the extent needed to protect the membranes.
- Hydrocarbons and nutrients are typically incorporated into the bacteria cell mass.
- Adhesion of some chemical compounds (macromolecules) to the structure of sludge flocs may

prevent their direct contact with the membrane as they are withdrawn out of the system with the excess sludge.

These processes and considerations make the overall wastewater treatment system a much more stable environment. Membranes used in an MBR system are significantly less prone to damage than when they are used for direct filtration. It is the responsibility of the system designer and of the system builder to weigh and account for these effects and to evaluate the extent to which different chemical compounds may get through the system resulting in potentially detrimental effects on the membranes.

10.4 Antifoam Product Use

MBR systems may generate foam depending on wastewater characteristics and presence of fat, oil, grease and surfactants. Foam generation is normal and typically occurs at low enough levels that it is manageable without the need for any additional considerations. However, if there is excessive foam, the foam may be removed mechanically or suppressed chemically using antifoam product. The use of antifoam should meet the following main conditions:

- The antifoam should be effective for the type of foam that is generated in the plant.
- The antifoam should be should not cause fouling of the MYTEX membranes

Most antifoams have the potential to severely foul the membranes due to their high BOD/COD content. The antifoam products that contain any of the following compounds should not be used in systems using MYTEX membrane modules:

- Antifoam products are high in BOD/COD and this additional organic load should be considered.
- Antifoams may change the small and stable air bubbles into larger bubbles which will in turn, reduce the oxygen transfer efficiency.
- If antifoam product is not biologically degraded, the left-over product may be found downstream affecting other processes such as RO or ion exchanges.
- Antifoams should not be added directly on top of the membrane units but in the feed inlet to the membrane tank or even better in the aeration tank.

Most antifoams have the potential to severely foul the membranes due to their high BOD/COD content. The antifoam products that contain any of the following compounds should not be used in systems using MYTEX membrane modules:

- Organic silicone
- Petroleum hydrocarbon (oil)
- Petroleum solvent (light paraffin)
- Polymer additives with molecular weight < 50,000 Daltons (Da)
- Polymer additives with molecular weights of 100,000 to 200,000 Da
- Polymers dissolved or part of a white oil-based products

On the other hand, chemical compounds found within an antifoam product that are desirable include glycerin or polyether polyol with a molecular weight < 5,000 Da ac the main active ingredient.

Some of the commercially available antifoam agents that are compatible with MYTEX membranes:

- Nalco: IL08, 7465, 72028
- Air Products: Surfynol DF-110L, DF-110D
- Pelron Corporation, P-463
- Dow, Polyglycol: FR-530, 45-200, P-1200, 112-2, P-1000TB, P-2000, P-4000
- PPG, MAZU-DF-04

The following agents are not compatible and should not be used:

- O’Brien Products/Zinkan Enterprises, O’B No Foam 24
- Surpass Chemical Co, Nofoam AK
- Ultra Additives Inc: Foamtrol WT-2, WT-73

- Ultra Additives Inc: Foamban MS-5
- Brose Chemical C, BCC-336
- Drew Chemical, Drewplus L-674
- Betz, Foamtrol AF1660, AF3550, AF3551

10.5 Mixed Liquor and Permeate Test Procedures

10.5.1 Sludge Filterability Testing

Please get in touch with UNISOL for further information.

10.5.2 Mixed Liquor Sieve Test

Sludge trash in MBR applications is measured and monitored using sieve tests. The sieve test can be used to determine the amount of material that is contained in the mixed liquor of an activated sludge wastewater treatment plant. It can be used to quantify the effectiveness of the pretreatment and screening equipment of the plant.

The mixed liquor sample should be taken from the membrane tank. The following guidelines should be used for sludge quality based on the Sieve Test:

- Material/Trash > 3 mm: less than 1 mg/L
- Material/Trash > 2 mm: less than 10 mg/L

If the Sieve Test results are higher than these limits, it is likely that the fine screens are allowing material to overflow or bypass into the membrane tank and the fine screens and overall pretreatment process should be reviewed for corrective actions. Any overflow or bypass should be eliminated, and the performance of the system should be improved to meet these requirements.

Please get in touch with UNISOL for further information.

10.5.3 Silt Density Index (SDI)

Please get in touch with UNISOL for further information.

10.6 Forms and Protocols

10.6.1 Installation Protocol

Please find the protocol on the following pages.

10.6.2 Clean Water Test Protocol

Please find the protocol on the following pages.

10.6.3 Start-up Protocol

Please find the protocol on the following pages.

10.6.4 Inspection Protocol

Please get in touch with UNISOL for further information.

10.6.5 Chemical Cleaning Logbook

The chemical logbook is essential to evaluate chemical cleaning performance and to improve chemical cleaning efficiency. Therefore, please fill in the form for every chemical cleaning conducted. A detailed example is available as an excel sheet from UNISOL.

Installation Protocol

Project Name and Number	**Location**
Customer	**Customer Contact Person On-site**

Topic	Description
Goal of this protocol	- Be ready for clean water testing
Requirements to proceed with this protocol	- Membrane modules are on site and a suitable lifting device is available. - Safety equipment to enter the tank is available. - It is possible to protect the installed membrane units from direct sunlight and rain. - Relevant personnel on site available (representative of system integrator, software programmer, certified electrician, pipe fitter
Notes	**Important information** - **DO NOT** FILL THE FILTRATION TANK BEFORE COMPLETING THIS CHECKLIST. - THE INTRODUCTION OF DEBRIS INTO THE MEMBRANES AND DIFFUSERS IN ANY WAY CAN RESULT IN IRREVOCABLE DAMAGE TO SYSTEM PERFORMANCE. - MODULES MUST BE STORED AND COVERED ACCORDING TO THE REQUIREMENTS SPECIFUIED IN THE PRODUCT MANUAL.

The following items are necessary for a successful commissioning.

Items to be checked	YES	NO	PARTLY
All requirements to proceed with this protocol are met.	☐	☐	☐
Comments:			
Basic PLC program structure guarantees an operation within limits.	☐	☐	☐
Comments:			
All equipment has been delivered on site without any damages.	☐	☐	☐
Comments:			

Items to be checked	YES	NO	PARTLY
Final assembly of modules according to instruction.	☐	☐	☐
Comments:			
Lifting of membrane modules into the filtration tank according to manual.	☐	☐	☐
Comments:			
Membrane modules are fixed and secured against floating according to the product manual.	☐	☐	☐
Comments:			
Permeate and air piping is flushed/purged and free of debris.	☐	☐	☐
Comments:			
Permeate flange / nozzle is connected to permeate header, air flange / nozzle is connected to air header.	☐	☐	☐
Comments:			
Permeate flange / nozzle is connected to permeate header, air flange / nozzle is connected to air header.	☐	☐	☐
Comments:			
Installed membrane modules are covered in a way to be protected against direct sunlight and rain.	☐	☐	☐
Comments:			

Final Conclusion or Comments

We hereby confirm the accuracy of the preceding details of the Installation Protocol.

Customer's Name (please print)

Date

Customer's Signature

In case of UNISOL on-site support and assistance:

UNISOL Commissioning Engineer (please print)

Date

UNISOL Commissioning Engineer Signature

Clean Water Test Protocol

Project Name and Number	**Location**
Customer	**Customer Contact Person On-site**

Topic	Description
Goal of this protocol	Be ready for final start-up with mixed liquor.
Requirements to proceed with this protocol	All items on the **Installation Protocol** are completed -Supply of clean water is available on-site. -All chemicals for cleaning (typically citric acid and bleach) are on-site. -Technical air system is connected and operational -Drain and neutralization systems are in place and functional -If a permeability test is required, the possibility for internal recirculation in the filtration tank needs to be ensured. -Relevant personnel on site (Responsible Operator, Software programmer, Certified electrician)

The following items are necessary for a successful commissioning.

Items to be checked	YES	NO	PARTLY
All clean water test requirements are fulfilled.	☐	☐	☐
Comments:			
All tanks are flushed/purged and free of debris before filling the system with clean water.	☐	☐	☐
Comments:			
Membrane filtration tank and permeate tank are filled with clean water. The water level should be in the range of the standard operating conditions.	☐	☐	☐
Comments:			
Air flow to the membrane units is adjusted with respect to max allowable air flow rate and hydrostatic pressure caused by the water level.	☐	☐	☐

Comments:			
Aeration system is tested on uniform distribution and potential leakages according to the product manual.	☐	☐	☐
Comments:			
Permeate system is tested on leakages. Do not run a backwash cycle unless all air has been purged from permeate piping and membrane units.	☐	☐	☐
Comments:			
All relevant measurements (flow meters, pressure sensors, level sensors/switches, etc.) and permeate pumps have been tested.	☐	☐	☐
Comments:			
Venting unit is installed at the highest point of the permeate header and tested.	☐	☐	☐
Comments:			
Position of pressure sensor has been considered for correct TMP calculation. TMP is 0 mbar (± 5 mbar) during relaxation phase.	☐	☐	☐
Comments:			
TMP alarm scenarios (shut off for backwash pressure) has been performed.	☐	☐	☐
Comments:			
Permeate pipe integrity test has been performed according to the product manual. No leakages detected.	☐	☐	☐
Comments:			
An initial membrane conditioning cleaning has been performed according to the product manual.	☐	☐	☐
Comments:			
Leave clean water in membrane tank above the membranes to keep them wet until sludge seeding is to be started.	☐	☐	☐

Comments:

Final Conclusion or Comments

We hereby confirm the accuracy of the preceding details of the Clean Water Test Protocol.

Customer's Name (please print)

Date

Customer's Signature

In case of UNISOL on-site support and assistance:

UNISOL Commissioning Engineer (please print)

Date

UNISOL Commissioning Engineer Signature

Start-up Protocol

Project Name and Number	Location
Customer	**Customer Contact Person On-site**

Topic	Description
Goal for this protocol	-Successful start-up with mixed liquor and finalizing adjustments after start-up.
Requirements to proceed with this protocol	Start-up in clean water is accomplished. **Clean Water Test Protocol** is finished. -Supply of seeding sludge to obtain a start MLSS in the filtration and biological tank of at least 2 to 3 g/l -Possibility of daily measurement of MLSS and COD during start-up phase.

The following items are necessary for a successful commissioning.

Items to be checked	YES	NO	PARTLY
All clean water test requirements are fulfilled.	☐	☐	☐
Comments:			
Seeding sludge has been filter by the fine screens before entering the system.	☐	☐	☐
Comments:			
Start venting of the membrane units and permeate piping. Do not run a backwash cycle unless all air has been purged from the permeate piping and membrane modules.	☐	☐	☐
Comments:			
All relevant measurements (flow meters, pressure sensors, level sensors/switches, etc.) and permeate pumps work with mixed liquor according to the requirements.	☐	☐	☐

Comments:			
TMP is correctly working in mixed liquor. 0 mbar (± 5 mbar) during relaxation phase.	☐	☐	☐
Comments:			
Aeration system is tested on uniform distribution in mixed liquor.	☐	☐	☐
Comments directly after start-up: Comments 1 day after start-up: Comments 7 days after start-up: Comments 30 days after start-up:			
Note diffusor pressure drop at start up and the first weeks after start-up with mixed liquor.	☐	☐	☐
Pressure drop directly after start-up: Pressure drop 1 day after start-up: Pressure drop 7 days after start-up: Pressure drop 30 days after start-up:			

Final Conclusion or Comments

We hereby confirm the accuracy of the preceding details of the Start-up Protocol.

Customer's Name (please print)

Date

Customer's Signature

In case of UNISOL on-site support and assistance:

UNISOL Commissioning Engineer (please print)

Date

UNISOL Commissioning Engineer Signature