LG QuantumFlux™ MBR/Submerged UF Membrane

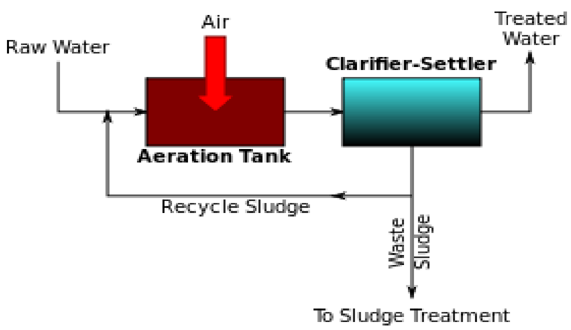
Technical Service Bulletin 804

MBR & Submerged UF System Start-up & Operating Procedures

MBR or Submerged UF System commissioning should not occur until the plant is ready to start normal operations. If not, it is better to leave the modules in their shipping containers, stored according to TSB 801. Once the plant is ready to start normal operations, proceed in the following order:

1. Conduct pre-startup checks
2. System Integrity Test
3. Install modules on skid(s)
4. Operating Sequence Test
5. Switch to auto mode

Terms, Abbreviations, and Definitions

Terms	Definitions
Submerged Membrane Modules (S-SERIES)	LG Chem modules designed for use in submerged applications
Air Scouring	A physical cleaning method for removing suspended solids fouling from the membrane surface
Bubble Point	The pressure (at a given temperature) at which the first bubble of gas is formed
Clean Water	Filtrate, or tap water
Conventional Activated Sludge (CAS) Process	A wastewater treatment process which relies on well mixed, suspended microorganisms for the degradation of wastewater constituents, and a clarifier which relies on gravity for separation of suspended solids from the treated water 
Feed	The flowrate of water into the membrane bioreactor system
Filtrate	Water that has been filtered
Fouling	Deposits of inorganic or organic substances on the membrane surface, leading to reduction in membrane permeability
Maintenance Cleaning (MC)	Regular chemical cleaning during normal operation
Membrane	A physical barrier used for the filtration process
Membrane Bioreactor (MBR)	A wastewater treatment process that combines biological treatment through activated sludge processes and solids separation through membrane filtration
NTU	Nephelometric Turbidity Unit, a measure of turbidity

Terms	Definitions
P&ID	Piping and instrumentation diagram
Permeability	The rate at which water passes through the membrane under defined pressure
Programmable Logic Controller (PLC)	Controls the membrane system pumps and valves based on stored logic of process sequences and inputs from instrumentation
Return Activated Sludge (RAS)	Sludge which is pumped from one zone in the treatment process back to an earlier zone In MBRs, typically, from the end of the membrane tank to the front of the aerobic tank, and from the end of the aerobic tank to the front of the anoxic tank
Skid	A group of UF modules mounted on a frame, connected in parallel to a set of header pipes
Train	A skid or skids operated in unison
Turbidity	A measure of cloudiness or haziness of a fluid; the degree to which a transparent liquid scatters light, usually a measure of the amount of suspended material in the liquid
UF	Ultrafiltration
S-Series Module	A single, distinct component comprised of hollow fiber ultrafiltration membranes fixed in plastic headers, that is ready for connection to a skid
Waste Activated Sludge (WAS)	Sludge disposed of from the system in order to control the MLSS concentration

Key Operating Parameter Definitions

Filtrate Flow Rate

Filtrate flow rate is the rate of the water that passes through the membrane from the feed side to the filtrate side. It is a function of the pressure, and the quality of the feed water. The filtrate flow rate should be set according to LG Chem's recommended membrane flux.

Filtrate Flux

Filtrate flux is the volume of filtered water passing through a unit of membrane surface area in a specified period of time. It is commonly expressed as lmh (Liters of filtered water/m^2 of surface area/hour of filtration time), gfd (gallons of filtered water/ft^2 of surface area/day of filtration time), or m/d (m^3 of filtered water/m^2 of surface area/day of filtration time). Appropriate flux selection is one of the most important design and operating considerations. The filtrate flux should be set according to LG Chem's recommendation for your specific application. The flux may be increased or decreased during operation to account for changes in feed water quality, temperature, or product water demand.

Transmembrane Pressure

Transmembrane Pressure (TMP) is the pressure difference between the feed and filtrate sides of the membrane. It is commonly measured in units of bar, psi, or kPa. TMP is the driving force for filtration. Most ultrafiltration/MBR systems operate at a constant flow rate during filtration. As filtration occurs, solids deposited on the membrane surface will create resistance to filtration causing the TMP to increase. Proper design filtrate flux is necessary to control the rate of TMP increase. Physical and chemical cleaning are required to remove accumulated fouling and reduce TMP.

Normalized Permeability

Normalized permeability, or specific flux, is defined as filtrate flux per applied transmembrane pressure (differential pressure) corrected to a specified temperature, typically 20 or 25 degrees Celsius. It is commonly measured in units of lmh/bar or gfd/psi @20°C. Normalized permeability is one of the most important parameters used to measure the performance of the membrane system. In a properly designed and operated system, the normalized permeability will decrease slowly between cleanings and will return to previous levels after cleaning such that it remains essentially constant over long-term operation.

Filtration Cycle Duration

The filtration cycle duration is dependent on the quality of the feed water. An appropriate design value should be selected per LG Chem's recommendation. The actual time should be set by testing at site and adjusted according to the changes of the feed water quality during the operation. Typical filtration cycle duration is 20 - 60 minutes.

Mixed Liquor Suspended Solids (MLSS)

The Mixed Liquor Suspended Solids (MLSS) is a measure of the concentration of solids suspended in solution in an activated sludge process. It is commonly measured in units of mg/L or g/L. The MLSS is an important design and operating parameter that affects both the biological process and the membrane process. Generally speaking, MBRs operate at higher MLSS concentrations than conventional activated sludge (CAS) processes due to the suspended solids retention capability of the membranes. Higher bacteria density in the MBR system translates to higher removal efficiency of BOD and nutrients in the incoming wastewater. Higher removal efficiency allows hydraulic treatment times, and resulting tank volumes, to be significantly reduced compared to CAS systems. The MLSS concentration impacts the membrane performance by affecting the viscosity of the sludge and the concentration of solids to be filtered. Typically, the viscosity of the sludge increases linearly with increasing MLSS concentration, until the MLSS concentration reaches about 12-15 g/L, at which there is an inflection point and the viscosity increases at a steeper rate with increasing MLSS.

Associated Documents

The following documents will be referred to frequently throughout this document. Have them available for quick reference.

- LG Chem Typical S-Series P&ID (MBR-I-PID-ETS-60001-003)
- LG Chem Technical Service Bulletins
- Project Specific Design Calculation Output

Initial System Start

Once all pre-startup checks have been concluded, the system is ready for module loading and process startup.

Ensure that cassettes and membranes are assembled and installed in accordance with TSB 803.

Fill the system with clean water. Proceed as follows for each skid or train:

- Start the air blower, feeding air to the skid(s) and check that the air diffusion at the membrane skid is evenly distributed. Foaming may occur during clean water operation but does not affect system performance.
- Allow the air blower to operate for 5 – 10 minutes and discard the water in the tank to get rid of any residual membrane preservative.
- Start the filtration process and allow enough time for displacement of air and establishing of a vacuum in the filtrate manifold.
- Make sure that any leaks are identified and repaired prior to introducing the process influent source.
- Conduct a membrane integrity test (MIT) to ensure that there is no membrane damage or installation errors.
- MIT tests the performance level by injecting air into the Membrane filtrate water lines where the Cassette is installed. It is important to check if there is any leak on any and all joints, including filtrate water lines and valves prior to implementation of MIT.
- In case any large air bubbles are observed, contact LG Chem for recommendations.
- Discontinue clean water tests and stop the air supply after these tests are completed.
- For MBR system, prepare and add initial mixed liquor or seed sludge in to the aerobic tank.
- Restart the air blower system(s).
- Start with a low percentage of actual wastewater mixed with clean water.
- Gradually increase the proportion of wastewater over time.

- For MBR, monitor biomass health and activity through microscopic examination and respirometry tests.
- Adjust feed water feed rate to design capacity. For MBR, this is also based on biomass response and effluent quality.
- Maintain close observation on MLSS, F/M ratio (MBR only), and effluent quality during this period.

Unit Operation Control Recommendations

LG Chem's scope of supply is usually limited to the membrane modules or skids. However, other unit operations, such as pre-treatment, feed pumping, fine screening, biological treatment, recirculation, and sludge wasting will impact LG Chem's S-Series product performance. Therefore, a general description of the controls around these unit operations is included. However, LG Chem takes no responsibility beyond what is explicitly stated in any applicable warranty (separate document).

Pretreatment

Pretreatment should be provided and operated, as necessary, to bring feed water quality within LG Chem feed water quality requirements. For example, coarse screening is usually provided to remove large debris and grit. An oil skimmer(s), dissolved air flotation (DAF), or other treatment process(es) may be utilized for removal/reduction of fats, oil, and grease. Pretreatment processes should remain in proper functioning order and should transmit operational status to the membrane control system. In case of pretreatment failure, a shutdown alarm will be initiated and all affected membrane trains should enter STANDBY mode.

Feed Pumping

Feed pumps used to send wastewater to the UF/MBR are normally triggered based on demand. The demand is not determined by LG Chem. For systems which are discharging treated water, the demand is usually triggered by the water level in the upstream collection or equalization tank. For UF/MBR systems which are designed to produce filtrate for direct reuse or for additional treatment (e.g. reverse osmosis), the demand for the feed pumps to operate is determined by the water level in the downstream filtrate collection tank.

Feed pumps can be designed with Variable Frequency Drives (VFDs) intended to match the feeding flow rate with the filtrate production flow rate to minimize cycling the pumps on and off, or without VFDs and are cycled on/off.

In case of a feed pump failure, a shutdown alarm will be initiated and all affected membrane train(s) should enter STANDBY mode. In case a feed pump failure does not send an alarm to the PLC, the water level in the membrane tank will decrease as filtration occurs until a low-low level is reached, causing a shutdown alarm for the affected train(s). The PLC will move the affected train(s) to STANDBY mode.

Flow meters, pressure switches, and pressure transmitters on the feed pump discharge can all be used to communicate feed pump failure to the PLC. The feed pump supplier should be contacted for additional information about failure mode prevention, detection, resolution, and communication to the PLC.

Fine Screening

Fine screening of particles larger than 2 mm in any dimension is critical to membrane performance and longevity. LG Chem recommends punched hole, drum screens, specifically designed for UF/MBR applications. Use of bar or wedge-wire screens is not allowed.

Fine screens should not be bypassed at any time. In case of a fine screen failure, a shutdown alarm will be initiated and all affected membrane train(s) should enter OFF mode. Only after the cause of failure is resolved, the operator should manually put the affected membrane train(s) back into AUTO or MANUAL mode.

The fine screen supplier should be contacted for information about failure mode prevention, detection, resolution, and communication to the PLC.

Activated Sludge Treatment

There are a wide variety of activated sludge treatment processes that can be applied to achieve the treatment goals of a project. LG Chem does not require any particular process. However, proper process selection, design, and operation are key to stable membrane performance. For MBR, the activated sludge process serves to degrade pollutants in the incoming feed water which can accelerate fouling on the membranes.

While there are many factors that can impact membrane fouling, three common parameters to control in MBR operation are:

1. Dissolved oxygen concentration at the end of the aerobic tank
2. MLSS Concentration in the biological treatment tanks
3. Recirculation rate(s)
4. Sludge wasting

Aerobic Tank DO Concentration

A common rule of thumb for reducing organic fouling on the membranes is to ensure that the dissolved oxygen (DO) concentration at the end of the aerobic tank is always greater than or equal to 2 mg/L. Maintaining this DO level will also serve as an indicator of complete BOD removal.

The aerobic tank(s) should be equipped with DO meter(s). The biological air blowers should be equipped with VFDs. The PLC should control the air blower speed by comparing the DO measurement to the HMI adjustable setpoint.

Recirculation

Recirculation, or return activated sludge (RAS), pumping from the end of the membrane tank(s) to the beginning of the aerobic tank(s) (or other prescribed location) is required to control the ratio of MLSS in the aerobic tank to that of the membrane tank. The MLSS in the membrane tank should be kept at less than 12,000 mg/L to prevent accelerated sludge accumulation in the membrane skids. The design MLSS range for the membrane tank is selected during the design stage. Refer to the project specific design calculation.

The recirculation or RAS pump(s) should be equipped with VFDs and the recirculation line(s) should have mag meter type flow meter/transmitter(s). The membrane tank or end of the aerobic tank should be equipped with an online TSS meter. The PLC should control the RAS pump flowrate by comparing the RAS flow rate measurement to the HMI adjustable RAS flow rate setpoint.

In case the system is not equipped with an online TSS meter, the RAS flowrate should be adjusted manually by the operator using a manual measurement of the MLSS in the aerobic tank and the membrane tank.

Wasting

Wasting sludge (referred to as Waste Activated Sludge, WAS) is required to control the overall biomass and the MLSS concentration in the membrane tank. WAS can be removed from the system through use of a pump and valve or with a line and automatic valve teed off the pumped RAS line. In either case, the RAS line should be equipped with a RAS flowmeter.

The WAS pump and/or valve should operate automatically based on the online TSS reading compared to the HMI adjustable TSS setpoint; i.e. when the TSS reading hits a certain value, waste for X (timer set by operational experience) seconds. In case the system is not equipped with an online TSS meter, the WAS equipment should be activated manually by the operator based on a manual measurement of the MLSS in the membrane tank.

LG Chem S-Series Trains

A membrane train is defined as a skid or group of skids and associated equipment required to automatically operate said skid(s) in unison.

Operating Modes

Each membrane train can be placed into one of the following operating MODES. Each membrane train can be in only one operating MODE at any given time. Operating MODES will be written in all CAPS and bold in this document

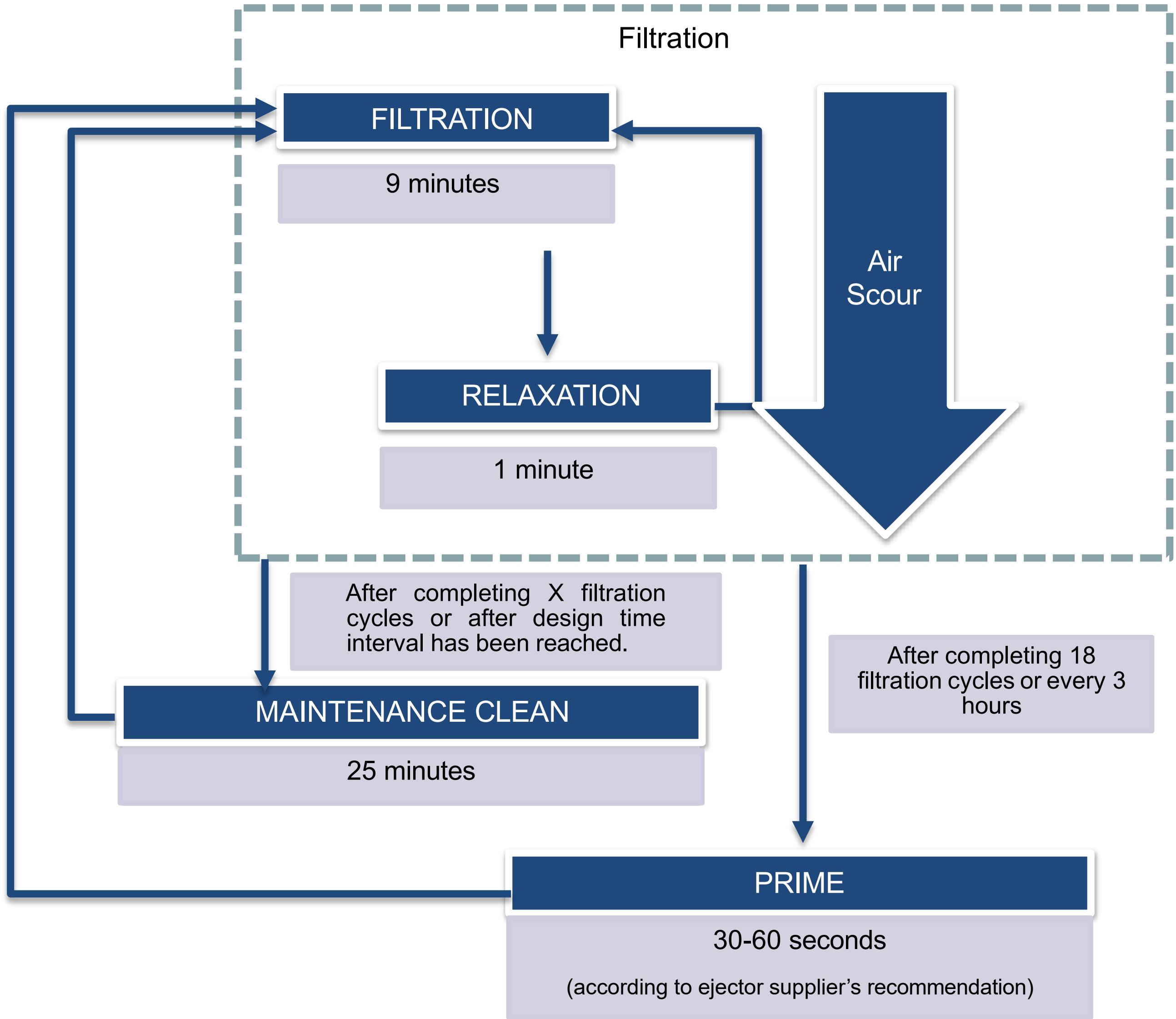
Mode	Definition
AUTO	When the membrane train and all necessary equipment are in **AUTO**, the membrane train proceeds through its normal operating sequences according to the CSTs. Operator cannot manually control any membrane train equipment. Operator can manually stop **AUTO**, putting the membrane train into STANDBY.
MANUAL	In **MANUAL**, operator can manually control membrane train equipment (e.g. open/close valves, turn pumps on/off, etc.). Operator can manually place the membrane train into an operating STATE, such as FILTRATION, RELAXATION, MC, RC, etc.
OFF	In **OFF** mode, all equipment for the membrane train is de-energized. Operator cannot manually control membrane train or equipment. Operator must switch the state to **AUTO** or **MANUAL** mode in order to operate train or equipment.

AUTO Mode

When in AUTO, the train proceeds through the following STATES automatically:

1. FILTRATION;
2. RELAXATION;
3. MAINTENANCE CLEAN;
4. PRIME

Durations are indicative and vary from site to site. Refer to the project specific CSTs for recommended durations of the steps within each STATE, which may be adjusted at site.



Operating States

Each membrane train will be in only one operating MODE and only one operating STATE at any given time. Not all operating STATES are available in each operating MODE. Operating STATES will be written in all CAPS in this document.

Refer to the CSTs for step-by-step details on the valves and equipment status for each of the following STATES.

STATE	Definition
STANDBY	Applicable membrane train exits its current sequence and de-energizes any active valves or pumps. If in **AUTO** and FILTRATION, the membrane train will automatically resume FILTRATION once the conditions which moved the train to STANDBY clears. If in MANUAL when the train enters STANDBY, the operator must manually put the system back into the desired state, once the conditions which moved the train to STANDBY clears.
FILTRATION	Membrane train is producing filtrate. Filtrate is sent to downstream collection tank/process.
RELAXATION	Membrane train is being air scoured but is not producing filtrate.
PRIME	Membrane train is proceeding through priming sequence automatically by operating air removal equipment.
MAINTENANCE CLEAN 1 (MC1) (OXIDANT)	Membrane train is proceeding through MC1 sequence automatically. Operator cannot manually control any membrane train equipment. Operator can manually stop MC1 mode, putting the membrane train into MC EXIT.
MAINTENANCE CLEAN 2 (MC2) (CAUSTIC)	Membrane train is proceeding through MC2 sequence automatically. Operator cannot manually control any membrane train equipment. Operator can manually stop MC2 mode, putting the membrane train into MC EXIT.
MAINTENANCE CLEAN 3 (MC3) (ACID)	Membrane train is proceeding through MC3 sequence automatically. Operator cannot manually control any membrane train equipment. Operator can manually stop MC3 mode, putting the membrane train into MC EXIT.
MAINTENANCE CLEAN (MC) EXIT	Membrane train has been forced by operator or by shutdown alarm to exit MC1, MC2, OR MC3. Membrane train proceeds automatically through MC EXIT sequence, then enters STANDBY.
RECOVERY CLEAN 1 (RC1) (OXIDANT)	Membrane train is proceeding through RC1 sequence automatically. Operator cannot manually control any membrane train equipment. Operator can manually stop RC1 mode, putting the membrane train into RC EXIT.

STATE	Definition
RECOVERY CLEAN 2 (RC2) (CAUSTIC)	Membrane train is proceeding through RC2 sequence automatically. Operator cannot manually control any membrane train equipment. Operator can manually stop RC2 mode, putting the membrane train into RC EXIT.
RECOVERY CLEAN 3 (RC3) (ACID)	Membrane train is proceeding through RC3 sequence automatically. Operator cannot manually control any membrane train equipment. Operator can manually stop RC3 mode, putting the membrane train into RC EXIT.
RECOVERY CLEAN (RC) EXIT	Membrane train has been forced by operator or by shutdown alarm to exit RC1, RC2, OR RC3. Membrane train proceeds automatically through RC EXIT sequence, then enters STANDBY.
MEMBRANE TANK DRAIN DOWN	Membrane train is proceeding through membrane tank drain down sequence automatically.
INTEGRITY TEST	Membrane train is proceeding through integrity test sequence automatically.
SHORT-TERM SHUTDOWN	Membrane train is proceeding through short-term shutdown sequence automatically.

Filtration State

During filtration, the filtrate pump (P-03) is on, the filtrate valve (AV-05) is open, the air scour blower (B-01) is on, and the air scour supply valve (AV-04) is open. The feed water pump (P-01), feed water valve (AV-01), and recirculation pump (P-02) are all on/off, depending on the tank level controls.

The filtration step lasts for 7-12 min, usually 9 minutes. Filtration step timing should be adjustable by the operator through the HMI.

During filtration, the filtrate flow rate is controlled by a VFD on the filtrate pump. The speed of the filtrate pump is controlled by a PID loop comparing the filtrate flow rate measured by the filtrate flowmeter reading (FIT-03) to the filtrate flow rate setpoint, which is HMI adjustable.

Transmembrane Pressure (TMP) Measurement

During filtration, solids will accumulate on the membrane fibers. As the filtrate pump typically operates on a constant flow rate setpoint, this means that the TMP will increase during filtration. TMP is the primary measure of membrane fouling, and is therefore very important to measure correctly. There are two ways to measure the TMP.

TMP = Feed Pressure – Filtrate Pressure

Method 1:

TMP = Pressure measured by PIT-03/N during RELAXATION of filtration cycle X –

Pressure continuously measured by PIT-03/N during FILTRATION of filtration cycle X

Method 1 automatically accounts for the position of PIT-03/N relative to the water level and module.

Method 2:

TMP = [Hw (as measured continuously by LT-03/N) – Hs (Fixed height of the skid to the top of the fibers)] –

[Pressure continuously measured by PIT-03/N during FILTRATION –

Hp (Fixed height of the pressure transmitter above the top of the membrane fiber)]

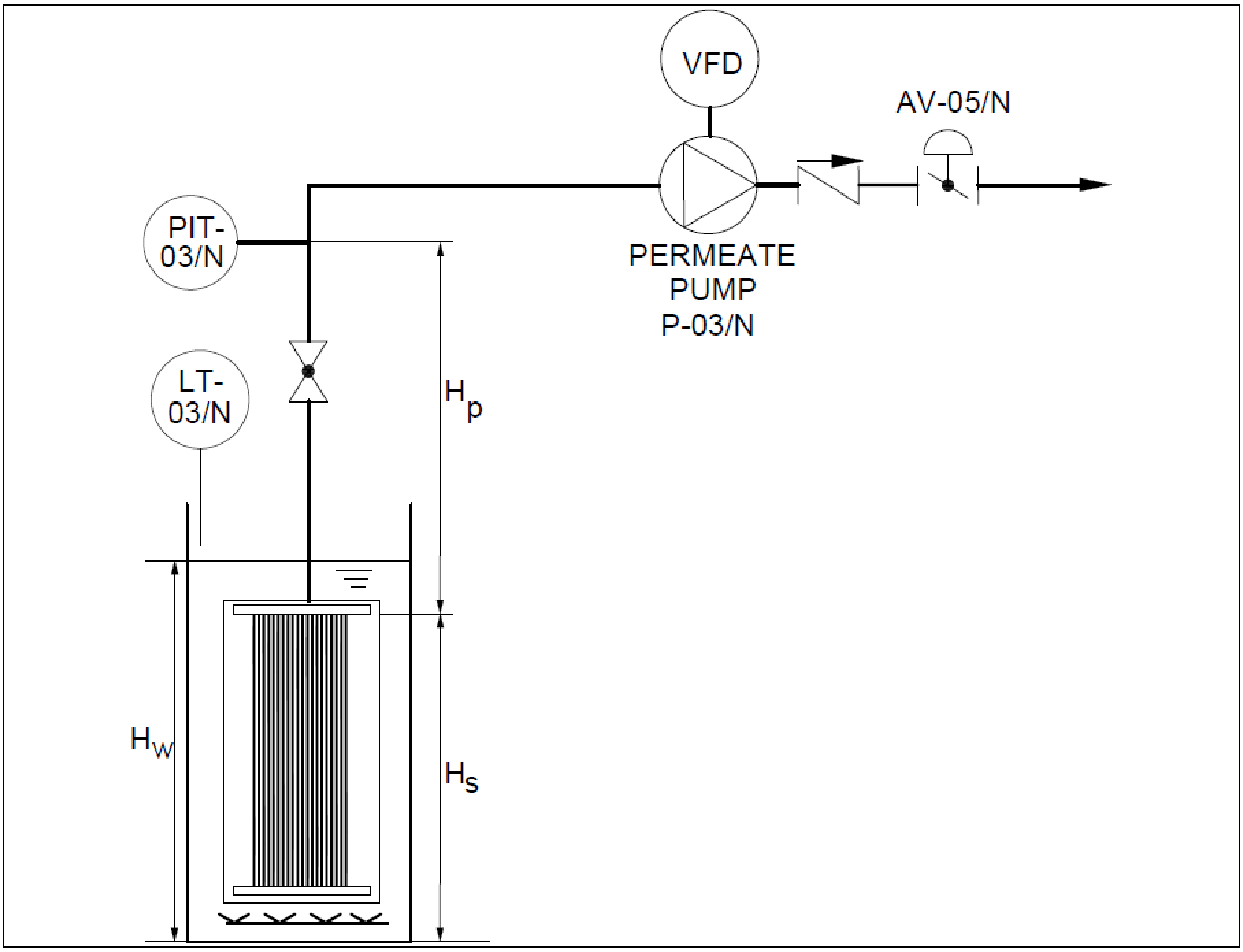


Figure 1: TMP Measurement Graphic

Note:

Make sure that there is no air lock in the filtrate pipes, as the system is running under vacuum. Air lock can create false pressure readings and prevent filtration from occurring.

Note:

Do not exceed the maximum TMP of 0.05 MPa (7.5 psi).

Note:

Ensure that air scouring is taking place while FILTRATION is occurring.

Relaxation State

RELAXATION occurs at the end of every filtration step. During RELAXATION, the air blower (B-01) and the air scour supply valve (AV-04) is open, the filtrate pump (P-03) is stopped, the filtrate valve (AV-05) is closed. The feed water pump (P-01), feed water valve (AV-01), and recirculation pump (P-02) are all on/off, depending on the tank level controls.

During RELAXATION, the thickness of the layer of suspended solids on the outer surface of the membrane fibers will decrease.

Note:

Ensure that air scouring is taking place while RELAXATION is occurring.

Air Scouring

Air scouring is conducted continuously during FILTRATION, RELAXATION, and during sections of MCs and RCs to control accumulation of contaminants on the membrane surface. LG Chem has two types of patented air scouring – big bubble and variable intensity.

The air scouring method used in a particular project is selected during the design stage. The PLC should be programmed for the selected air scouring method and should have two settings for air scouring: NORMAL AIR SCOURING and HIGH MLSS AIR SCOURING.

For trains using big bubble air scouring, the air flow rate during NORMAL AIR SCOURING is 2 m^3/hr/module, continuously. Under HIGH MLSS AIR SCOURING, when the MLSS exceeds 8,000 mg/L, the required air flow rate is 2.5 m^3/hr/module.

For skids using variable intensity air scouring, the required air flow rate during NORMAL AIR SCOURING is 2.5 m^3/hr/module during filtration and 5 m^3/hr/module during relaxation. When the MLSS exceeds 8,000 mg/L, the required air flow rate during HIGH MLSS AIR SCOURING is continuously 5 m^3/hr/module.

The PLC should be programmed to automatically switch from NORMAL AIR SCOURING to HIGH MLSS AIR SCOURING when the MLSS in the membrane tank increases above 8,000 mg/L, based on on-line TSS meter measurement. If the system is not equipped with an online TSS meter, the operator must switch from NORMAL AIR SCOURING to HIGH MLSS AIR SCOURING, based on MLSS measurement.

Note:

Ensure that air scouring is taking place while FILTRATION is occurring.

Note:

Air scouring flow rates are given as actual volumetric values at the site conditions
(air pressure and temperature at the delivery location).

Prime State

There are two situations in which air or oxygen(g) will be present in the filtrate piping. First, during installation or reinstallation. In this case, the entire filtrate piping will be full of air from the water level up to the highest point in the piping. Second, due to changes in partial pressure, there will be gradual accumulation of dissolved oxygen coming out of solution. To avoid potentially cavitating the filtrate pump and to ensure accurate pressure reading from the filtrate pressure gauge, gases in the filtrate line should be removed on a regular basis.

Every 3 hours of operation (18 filtration cycles), after the 1-minute RELAXATION step of the operating process, the PLC should move the train into PRIME and the air removal equipment will turn on for approximately 30-60 seconds.

An air ejector system is recommended for air removal. However, a vacuum pump may also be used. The air ejector or vacuum pump supplier should be contacted for equipment sizing and operation assistance.

Maintenance Clean 1, 2, 3 States

Note

The chemicals used should not damage the membrane module or create secondary pollution.

Chemical cleanings are used to remove fouling that is not removed by air scouring. The 3 types of MAINTENANCE CLEAN are based on the chemicals used. Chemicals should be selected based on the type of foulants present. Refer to the project design calculation for the details for the MCs recommended for a particular project.

MAINTENANCE CLEAN 1: An oxidant chemical, typically sodium hypochlorite, is used to control organic and biological fouling.

MAINTENANCE CLEAN 2: A basic chemical solution, typically sodium hydroxide, is used to control organic and biological fouling, as well as fats, oil, and grease fouling.

MAINTENANCE CLEAN 3: An acidic chemical solution, typically hydrochloric acid, is used to control inorganic fouling.

MC1 and MC2 may be combined into one cleaning.

The procedure for MC1, MC2, and MC3 is the same in all cases. The MAINTENANCE CLEAN is a shorter clean designed to maintain the membrane permeability. In general, a chemical solution is pumped into the membrane trains from the filtrate side of the membranes with the NORMAL AIR SCOUR off. The chemical solution is then allowed to soak in and on the membrane fibers. After a set soaking time is reached, NORMAL AIR SCOUR is resumed. Soaking and NORMAL AIR SCOUR steps may be repeated up to three times. After completing the soaking and NORMAL AIR SCOUR steps, filtration resumes. After MC, the TMP should be at least partially recovered. Refer to the project CSTs for a step-by-step description.

All MC1, MC2, and MC3 sequences should be programmed in the PLC. The PLC should put the membrane train in MC, MC2, or MC3 based on the HMI adjustable time or filtration cycle interval.

Recovery Clean 1, 2, 3 States

DANGER: If sodium hypochlorite and acid are mixed, poisonous chlorine gas will be formed. The PLC should be programmed such that trains are thoroughly rinsed between chemical cleanings so that the chemicals do not mix.

Like MCs, the 3 types of RECOVERY CLEAN are based on the chemicals used – RC1 – Oxidant; RC2 – Basic; RC3

- Acidic. RC1 and RC2 may be combined into one cleaning. Chemicals should be selected based on the type of foulants present. Refer to the project design calculation for the details for the RCs recommended for a particular project.

The RECOVERY CLEAN is designed to recover membrane permeability to the original value. The RECOVERY CLEAN is similar to the MAINTENANCE CLEAN but uses a higher concentration of the chemical and longer soak times. The steps of the RC are very similar to the MC, but the membrane tank is drained prior to filling with chemical cleaning solution. Additionally, the RC always includes at least oxidant and acidic solutions. A RECOVERY CLEAN may be triggered by time (every 30-90 days), or when MC fails to restore membrane permeability and the TMP continues to rise a certain amount about the initial value. For example, more than 50KPa (7.3 psi) above the initial value.

The recovery clean procedure should be programmed into the control system. It should be manually initiated whenever an established number of days has passed (commonly, 30-90 days), or the TMP reaches 0.7 bar (10 psi). The procedure should be repeated for each chemical. Ensure rinsing is complete before introducing a new chemical. Typically, sodium hypochlorite is first, followed by sodium hydroxide. Finally, citric, hydrochloric, or sulfuric acid is used.

Integrity Test State

Pressurized air is applied to one side of the wetted membrane fibers. If the membrane integrity is intact, and the air pressure is lower than the bubbling point, there will be no observable air flow from the membrane pores. However, if there are damaged membrane fibers, air flow can be easily observed at pressure far below the bubbling point. Therefore, the integrity of a membrane module can be tested by observing bubble flow or the pressure change on one side of the membrane fibers.

Membrane Integrity is confirmed by the PLC through online filtrate turbidity readings. The Integrity Test procedure should be programmed in the PLC and triggered manually by the operator, only when required.

Caution: The compressed air used for integrity testing must be oil free. Dirty air will contaminate the membrane. The maximum air pressure allowed during testing is 50kPa (7 psi).

The following procedure is used to confirm system integrity and identify any integrity breach in need of repair.

1. Stop filtration of the train to be tested by closing the filtrate valve (AV-05) or stopping the filtrate pump (P-03).
2. Stop air scouring of the train to be tested by closing the air scour supply valve (AV-04).
3. Make sure the membrane modules are completely submerged.
4. Slowly open the integrity test (IT) valve (AV-08). Compressed air applied through the integrity test valve will drive the water from the filtrate side of the membrane to the feed side. As water evacuates and air fills the filtrate side, the pressure will slowly increase until the it reaches a regulated set point, which should be less than 50 kPa (7 psi).
5. Allow the pressure to stabilize at the set point, typically ~2 minutes. This will occur once all the water on the feed side of the membrane has been evacuated.
6. After the pressure has stabilized, close the IT valve. Note the pressure.
7. Hold the pressure for 5 minutes.
8. Typically, if the pressure drop is less than 17KPa (2.5 psi) in 5 minutes, the system integrity is intact. If the pressure drops rapidly, it indicates that there is a leak in the system.
9. Look for and mark areas of vigorous bubbles to be removed for further testing and repair.

Membrane Train HMI Adjustable Operating Setpoints

The following setpoints are key operating parameters for the membrane trains. LG Chem suggests that the membrane system operating parameters in the following table are adjustable by the operator in the HMI.

Table 1 : Adjustable Operating Parameters – Membrane System

Item	Description	Default Setpoint Value
1	Feed flow rate	Project Specific
2	Filtrate flow rate	Project Specific
3	Recirculation flow rate	Project Specific; 3 – 6 x Filtrate flow rate
4	Air scouring flow rate	2.0-2.5 m^3/hr /module (Big Bubble Aeration) or 2.5-5 m^3/hr /module (Variable Intensity Aeration)
5	Chemical Cleaning Solution Pump flow rate	Project Specific
6	NaOCl Dosing Pump flow rate	Project Specific
7	NaOH Dosing Pump flow rate	Project Specific
8	Acid Dosing Pump flow rate	Project Specific
9	Filtration cycle time	9 Min.
10	Relaxation time	1 Min.
11	MC interval	Project Specific - 3 to 7 days; Adjusted on-site
12	MC chemical solution injection time	Adjusted on-site to achieve target cleaning solution
13	MC chemical soak 1 time	300 Sec.
14	MC chemical air scour 1 time	300 Sec.
15	MC chemical soak 2 time	300 Sec.
16	MC chemical air scour 2 time	300 Sec.
17	MC chemical soak 3 time	0 Sec.
18	MC chemical air scour 3 time	0 Sec.
19	RC interval	Project Specific - 30 to 180 days; Adjusted on-site
20	Membrane tank drain time	600 Sec.
21	Oxidant RC chemical solution injection time	Adjusted on-site to achieve target cleaning solution
22	Oxidant RC chemical soak 1 time	3600 Sec.
23	Oxidant RC chemical air scour 1 time	300 Sec.
24	Oxidant RC chemical soak 2 time	2400 Sec.
25	Oxidant RC chemical air scour 2 time	300 Sec.
26	Oxidant RC chemical soak 3 time	300 Sec.
27	Oxidant RC chemical air scour 3 time	300 Sec.
28	Membrane tank chemical drain time	Adjusted on-site to reach empty tank

Item	Description	Default Setpoint Value
29	Membrane tank chemical flush time	Adjusted on-site to reach target residual
30	Membrane tank drain time	Adjusted on-site to reach empty tank
31	Acid RC chemical solution injection time	Adjusted on-site to achieve target cleaning solution
32	Acid RC chemical soak 1 time	2700 Sec.
33	Acid RC chemical air scour 1 time	300 Sec.
34	Acid RC chemical soak 2 time	1800 Sec.
35	Acid RC chemical air scour 2 time	300 Sec.
36	Acid RC chemical soak 3 time	1800 Sec.
37	Acid RC chemical air scour 3 time	300 Sec.
38	Membrane tank chemical drain time	Adjusted on-site to reach empty tank
39	Membrane tank chemical flush time	Adjusted on-site to reach target residual
40	Membrane tank drain time	Adjusted on-site to reach empty tank
41	Membrane tank refill time	Adjusted on-site to reach target tank level
42	Air removal system operation interval	Once every 12 to 18 filtration cycles
43	Air removal system operation duration	Per Supplier's recommendation

Default values listed in Table 1 are for reference only. The initial set points for these parameters should be according to the system design recommendations provided by LG Chem. Adjustments will likely be made over time depending on the actual feed water quality and the observed system performance.

Membrane Train Power Outage

If a power outage occurs, the membrane train will enter OFF status. When the power returns, the system will remain in OFF. The operator will need to switch the system back to AUTO or MANUAL. Depending on the duration of the shutdown, it may be necessary to conduct MCs or RCs. If the shutdown was long enough for the sludge to die, a complete drain down and re-seed may be required.

Membrane Train Alarms

There should be two types of alarms – Shutdown and Operator Alert. Shutdown alarms move the system to STANDBY or OFF, depending on the alarm type. Operator Alert alarms notify the operator visually and/or audibly at the HMI.

Alarm	Response
Low filtrate flow	Operator Alert; Operator to assess situation.
High filtrate flow	Operator Alert; Operator to assess situation.
High-High filtrate flow	Shutdown; Enter STANDBY; Operator to assess situation.
Low filtrate pump Pressure	Operator Alert; Operator to assess situation.
High TMP	Operator Alert; Operator to assess situation. MC or RC may be required.
High-high TMP	Shutdown; Enter STANDBY; Operator to assess situation. MC or RC may be required.
Low-low air scour flow	Shutdown; Enter STANDBY; Operator to assess situation.
Low air scour flow	Operator Alert; Operator to assess situation.
High air scour flow	Operator Alert; Operator to assess situation.
High-high water level	Shutdown; Enter STANDBY; Resume previous MODE once the alarm is cleared and the level drops below the high setpoint in the membrane tank.
Low-Low water level	Shutdown; Enter STANDBY; Resume previous MODE once the alarm is cleared and the level hits the high setpoint in the membrane tank.
High turbidity	Operator Alert; Operator to assess situation. Check turbidimeter. INTEGRITY TEST may be initiated by the operator.
High-high turbidity	Shutdown; Enter STANDBY; Operator to assess situation. Check turbidimeter. INTEGRITY TEST may be initiated by the operator.
Low turbidimeter flow	Operator Alert; Operator to assess situation.
High-high temperature	Shutdown; Enter STANDBY; Operator to assess situation.
High filtrate Pressure	Shutdown; Enter STANDBY; Relieve pressure on filtrate line.

Membrane Train Performance Monitoring

Membrane System

It is very important to record the operating data of the system accurately and completely. At minimum, the following variables should be recorded automatically and stored in an exportable format on the SCADA system or other data logging equipment. Recommended minimum frequency is once every 15 minutes.

Each train:

- Membrane tank level (m) (ft)
- Filtrate pressure (kPa) (psi)
- Filtrate flow rate (m^3/h) (gpm)
- Air scour flow rate (delivery m^3/h) (acfm)
- Product water turbidity (NTU)

Minimum one per membrane system:

- Membrane tank sludge temperature (°C) (°F)
- Membrane Tank MLSS (mg/L)
- Membrane Tank DO (mg/L)
- Filtrate Soluble BOD5 (mg/L)