Contents

Chapter 1 - Introduction ........................................................................................................... 3

Chapter 2 – Shipping, Handling and Storage ........................................................................... 4

Chapter 2.1 – Shipping .............................................................................................................. 4

Chapter 2.2 – Handling .............................................................................................................. 4

Chapter 2.3 – Storage ............................................................................................................... 4

Chapter 3 – Fundamentals ....................................................................................................... 5

Chapter 3.1 - What is Ultrafiltration? ..................................................................................... 5

Chapter 3.2 - Definition and Explanation of Common Terms .................................................. 6

Chapter 3.3 – Membrane Fouling ............................................................................................. 9

Chapter 4 – Design of AQUADYN® UA1060 ......................................................................... 11

Chapter 4.1 - Pre-treatment of the raw water ....................................................................... 11

Chapter 4.2 - Membrane Fiber and Membrane Module Specification ................................. 12

Chapter 5 – Design of the Filtration Stage ............................................................................. 14

Chapter 5.1.1 - Tanks .............................................................................................................. 14

Chapter 5.1.3 - Valve ............................................................................................................... 16

Chapter 5.1.4 - Instrumentations .............................................................................................. 17

Chapter 5.1.5 - Pipings ............................................................................................................ 18

Chapter 5.2 - Cleaning Strategy .............................................................................................. 19

Chapter 5.3 - Rack Installation ............................................................................................... 20

Chapter 6 – Operation Procedures of AQUADYN® UA1060 .................................................. 22

Chapter 6.1 – Start Up Checks ............................................................................................... 22

Chapter 6.2 – Regular Operating Procedures .......................................................................... 22

Chapter 6.2.1 - Operation of Filtration stage ....................................................................... 22

Chapter 6.2.2 - Operation of Regeneration ........................................................................... 24

Chapter 6.2.3 - Operation of CIP (Cleaning-in-place) stage ................................................... 30

Chapter 6.3 - Shut Down ........................................................................................................ 32

Chapter 6.4 - Operating and Cleaning Logs ........................................................................... 33

Appendix – Basic P&ID of AQUADYN® UA1060 plant .......................................................... 34

Appendix – AQUADYN® UA1060 data sheet ...................................................................... 35

Appendix- Operation and Cleaning Record Logs .................................................................... 36
Chapter 1 - Introduction

This manual is intended to give you an overview of the AQUADYN® UA1060 module and provides basic information. This manual covers the design as well as the operating and maintenance procedures of the UA1060 module.

Please completely read this instruction manual before handling and operating the AQUADYN® UA1060 modules. It is important to follow all instructions and operate the modules only under the required operation conditions. Mishandling can result in the compromise of the module performance and in the worst case scenario result in the destruction of the module.
Chapter 2 – Shipping, Handling and Storage

Proper handling of the modules is necessary to maintain the chemical and mechanical integrity of the membrane modules.

Chapter 2.1 – Shipping

Every AQUADYN® UA1060 module undergoes a stringent quality check before it is released for the use of our customers. The module is preserved for storage. All open ports are sealed with caps or plugs.

Upon receipt and prior to installation, the modules must be inspected for physical damages and accurate product identification. The manufacturer or its representative must be notified immediately in written in the event of damage, leakages or wrong product identification (serial numbers etc.). In the event that damages have occurred during third party transportation, damages must be reported and documented to the freight forwarding company as well.

Chapter 2.2 – Handling

Only remove the module from its original packing when it is ready to install. The module should be handled with care at all times to avoid damage due to its weight. All personnel handling the module should be given the correct Personal Protective Equipment (PPE) and also ensure proper lifting guidance must be provided. **DO NOT use the connectors to lift the module.** Please ensure safety at all times when doing these operations.

Avoid contact of the module with any solvents or substances except those specified by MICRODYN-NADIR as this could have irreversible damage on the fibers. The module must be kept wet all the time, failure to comply will dry out the membranes and damage the fibers.

Chapter 2.3 – Storage

The shelf life of each module is one year from the date of delivery without additional preservation measures as long as correct storage conditions are fulfilled.

For uninstalled modules, it is recommended to store the modules in a cool, dry and well-ventilated area protected from direct sunlight and extreme temperatures at an ambient temperature of between 5 to 45 °C in its original packing.

The connection ports of the membrane modules are sealed with caps and plugs from the factory and should be checked for tightness and leakages and it is not allowed to remove these caps before installation.

Modules can be considered to be in storage if they have been installed into a rack but without operation and been blanked off, hence storage conditions must also be followed. Doing otherwise renders the warranty void.
Chapter 3 – Fundamentals

Chapter 3.1 - What is Ultrafiltration?

Ultrafiltration (UF) is a variety of membrane filtration in which hydrostatic pressure forces a liquid against a semipermeable membrane. Suspended solids and solutes of high molecular weight are retained, while water and low molecular weight solutes pass through the membrane. This separation process is widely used in water treatment, industry and research for purification and concentration of solutions.

Ultrafiltration is not fundamentally different from microfiltration or nanofiltration, except in terms of the size of the molecules it retains. The basic process of membrane filtration is shown in Figure 1 below. The process is pressure driven and typically operates with a feed pump that pushes the water through the membrane.

![Figure 1: Schematic representation of membrane filtration process](image)

The filtration spectrum and the selectivity of various filtration methods are shown in Figure 2. Typically, UF membranes range from 0.01 – 0.1 micron in pore size. Two of the most common classification parameters for membranes are pore size and molecular weight cut-off (MWCO):

- The pore size is the nominal diameter of the openings or micro pores in the membrane expressed in microns.
- The MWCO is the molecular mass or weight of a solute that rejects greater than 90 percent. The unit of measurement for MWCO is Dalton (Da).
**Chapter 3.2 - Definition and Explanation of Common Terms**

The following section describes the most important commonly used terms which are closely related to UF operations.

**Hollow Fiber (HF)**

A hollow fiber is one of many forms and shapes in which membranes are produced. The most common ones in the range of ultrafiltration are: hollow fiber, flat sheet, spiral wound and tubular membranes.
Hollow fiber membranes consist of a very thin (Ø 1-3mm) and long fiber that is fixed to a holding frame on both ends. At least one end is open to allow for permeate extraction. The advantages of hollow fiber membranes include high packing density inside the module, back flush ability, high permeability and good mechanical strength.

There are two ways to introduce the feed to the membrane: outside-in and inside-out, while the more common operation mode is outside-in.

During the outside-in operation, the fibers are surrounded by feed water, enabling a very even flow distribution along the entire length of the fiber and among all fibers within a module. The permeate is collected inside the fibers.

The inside-out operation is the exact opposite; with the feed water distributed to the inside of the fiber and the permeate surrounding the fibers. This operation mode allows for low pressure operation and frequent and efficient back flush, as the volume on the feed side is much smaller than compared with the outside-in operation.

Dead-End/Crossflow filtration mode

There are two principle ways to operate UF membrane modules: dead-end and crossflow. If there is no retentate stream and the entire medium either passes through the membrane or it is accumulated on the feed side, then the process is called dead-end; if the retentate stream is continuously flowing and only a small fraction of the feed flow is filtered through the membrane, then the process is called crossflow. See the principle below:
Trans-Membrane-Pressure (TMP)

TMP is the driving force for filtration. It is the pressure difference between the feed pressure and the permeate pressure. Usually, TMP is applied by usage of pumps, but it can also be achieved by gravity flow in certain applications.

The TMP is measured by pressure sensors in the feed and retentate pipe as well as in the permeate pipe. Generally, TMP is equated as follows:

\[
TMP = \frac{\text{Feed Pressure} + \text{Retentate Pressure}}{2} - \text{Permeate Pressure}
\]

Flux

The flux presents the absolute hydraulic flow in relation to the active membrane area that is presently being used for filtration. Increasing the flow also increases the flux. Reducing the active membrane area (e.g. by isolating a module) also increases the flux. See the formula below.

\[
\text{Flux} = \frac{\text{hydraulic flow \ [L/h]}}{\text{membrane area \ [m}^2\text{] \ [L/m}^2\cdot \text{h or L/H]}}
\]

Gross/Net Flux

Gross flux (GF) is the instantaneous, “real” flux through the membranes. The net flux (NF) is the average flux with consideration of relaxation times and back flush periods. The gross flux which is the higher value compared to the net flux must be considered when sizing the pumps. The net flux is the determining factor when dimensioning the membrane surface area. The ratio between the gross and the net flux is dependent on the filtration time (FT), the relaxation time (forward flush, air scouring) (RT), the back flush flow (BF) and the back flush time (BT). The formula below can be used to calculate the gross flux:

\[
GF = \frac{(FT + RT + BT) \cdot NF + BF \cdot BT}{FT} \ [L/H]
\]

Average and Peak Flux

The average flux is defined as the specific flux over a longer period, e.g. over a week, month or even a year. It can be calculated by the following formula (for instance for a period of one week):

\[
\text{Average Flux (week)} = \frac{\text{Filtered Water during one week}}{\text{Total membrane area used} \cdot 168 \text{ hours}} \ [L/H]
\]

The peak flux is referring to the maximum hydraulic conditions, usually during a short time event over a period of hours or maximum period of several days. It is calculated by the same equation; just the time period is shorter. Note that both values describe net flux values including back flush and relaxation periods.
Both parameters – peak and average flux – are important for the dimensioning of the membrane area needed.

**Permeability**

Permeability expresses the ratio of specific hydraulic flux to the transmembrane pressure (TMP). Permeability is an important factor for evaluation of the membrane performance.

\[
\text{Permeability} = \frac{\text{specific flux}}{\text{TMP}} \left[ \frac{L}{m^2 \cdot h \cdot \text{bar}} \right]
\]

**Normalized permeability**

The permeability is strongly related to the viscosity of the medium which in turn depends on the temperature. Usually, the permeability is normalized to a temperature of 20°C for better comparison of membrane modules operated at different temperature conditions. The following equation can be used for that purpose. \( T \) is the actual temperature of the medium:

\[
\text{Normalized permeability} = \frac{\text{specific flux}}{\text{TMP}} \cdot 1.024^{(20-T)} \left[ \frac{L}{m^2 \cdot h \cdot \text{bar}} \right]
\]

**Recovery**

The recovery or recovery rate is the ratio of the usable product flow to the total feed water flow during any given time. The relaxation and regeneration process has the biggest impact on the recovery rate – the more often and longer this process runs, the lower the recovery rate.

\[
\text{Recovery} = \frac{\text{product flow}}{\text{feed flow}} \times 100\%
\]

**Chapter 3.3 – Membrane Fouling**

Fouling and fouling control is an inevitable topic in all membrane filtration processes. Fouling describes the process of particulate and solutes accumulating on the feed side of the membrane due to the membranes selectivity. There are three general types of fouling:

**Particulate Fouling**

Particulate fouling is caused by suspended solids, colloids and turbidity in the feed water. This fouling is controlled by mechanical cleanings through regular air scouring, forward flushing and back flush.
Inorganic Fouling / Scaling
Most inorganic fouling occurs when filtering ground water or alkaline industrial waste water. Inorganics precipitate onto the surface of the membrane and create a solid layer. This can be solved by using acid for cleaning (no sulfuric acid as it can worsen the condition). In general, the use of citric acid is sufficient. The exact type and concentration is dependent on the kind and condition of the fouling (exact composition, age of the precipitate).

Organic Fouling
Organic fouling occurs when filtering water containing a certain amount of organics. Alginates, humic acids and fatty acids are the most common ones. Bacteria growth on the membrane is also a common cause. Alkaline solutions as sodium hypochlorite (NaOCl) are commonly used for removal of organic fouling.

All three types of fouling will occur during the lifetime of a membrane module. The severity of each fouling type is dependent on the feed characteristics. To understand the limitations of membranes in certain areas, it is important to know that not all fouling is reversible. It is classified into

1) Reversible fouling \(\rightarrow\) can be fully removed by physical cleaning, performance may be substantially recoverable.
2) Irreversible fouling \(\rightarrow\) can be fully removed by chemical cleaning, performance may not be entirely recoverable, with gradual deterioration over time.
3) Irrecoverable fouling \(\rightarrow\) cannot be removed, performance is compromised and non-recoverable.

Irrecoverable fouling will permanently reduce the performance of the membrane and can only be recovered by replacing the affected membrane module(s).
Chapter 4 – Design of AQUADYN® UA1060

Chapter 4.1 - Pre-treatment of the raw water

The selection of appropriate pre-treatment processes is essential for the efficient operation of the AQUADYN® UA1060. For UF the pre-treatment processes are especially important as certain materials may exacerbate the fouling processes or even cause immediate damage to the membrane module.

Specific site parameters, such as water characteristics and variation of flow distribution determine the type and amount of pre-treatment necessary for successful operation of the UF system. The complexity associated with additional pre-treatment must be weighed against the advantages and disadvantages of the downstream processes, especially to minimize membrane fouling and maximize membrane lifetime.

Typical pre-treatment processes include:

- Fat, oil and grease removal
- Pre-screening
- Coagulation and flocculation
- Flow (load) equalization

Fat, Oil and Grease removal

The AQUADYN® UA1060 does tolerate a maximum concentration of 5 mg/l fat, oil and grease (FOG).

If the FOG concentration exceeds this maximum concentration in the feed water, an additional pre-treatment step has to be conducted before entering the UF process. Generally, FOG is removed by flotation or skimming. The type of flotation can vary based on local availability and the FOG concentration in the raw feed water.

Pre-Screening

All UF plants will require basic pre-screening, to avoid larger particles from entering the membrane module. The TSS load should not exceed the maximum allowable limit of 350 mg/l. Please confirm the type and sizing of pre-screening equipment with your MICRODYN-NADIR representative. Depending on the total plant flow rate and the particle size, several types of pre-filtration are possible; amongst the most common ones for basic pre-screening are auto self-cleaning filters with 100 μm openings.

Coagulation and Flocculation

Coagulation and Flocculation are two methods of pre-treatment, in which chemicals are added to the raw feed water in order to remove specific particles/ foulants that may have a detrimental effect to the modules located downstream.

Coagulation occurs when a chemical (coagulant) is added to water to ‘destabilize’ colloidal suspensions. In a colloidal suspension, particles will settle very slowly or not at all because the particles carry electrical charges on the surface that mutually repel each other. A coagulant (typically a
metallic salt) with the opposite charge is added to the water to overcome the repulsive charge and "destabilize" the suspension and allow the colloidal particles to stick together and form flocs.

Conversely, flocculation uses polymers to clump the small destabilized particles together into larger flocs, which can be separated from the water easily. Flocculation is a physical process and does not involve neutralization.

Both methods are often used together to allow for largest possible flocs that can easily be removed by either filtration or sedimentation.

**Flow Equalization**

With an equalization process the peak flux is virtually eliminated or at least reduced and the average flux becomes the main driving force in dimensioning the required membrane surface area. Removal of highly variant peak fluxes drastically reduces both the stress on the membrane and the fouling potential. Moreover the overall process flow is much more stable, with less frequent regeneration and chemical cleaning steps.

Equalization is used if the overall cost of the plant can be reduced; consideration factors are frequency, amount and duration of peak flows and the availability of space. Flow equalization also enables consistency in Raw UF Feed and stability of processes.

**Chapter 4.2 - Membrane Fiber and Membrane Module Specification**

Please consider the AQUADYN® UA1060 data sheet for detailed information regarding membrane and module specifications as detailed in Appendix – AQUADYN® UA1060 data sheet.

The AQUADYN® UA1060-module consists of Polycrylonitrile (PAN) hollow fiber-membranes. The hydrophilic modified PAN is very well known and widely used in many applications because of its narrow pore size distribution with high selectivity and flow.

The UF fibers developed by MICRODYN-NADIR are assembled into a membrane cartridge which is the final AQUADYN® UA1060 product. In order to optimize the hydraulics and distribution efficiency of the membrane modules, the internal construction has been precisely designed to a high quality standard.

These include a patented distribution ring inside the membrane module which evenly and effectively distributes the feed water during filtration as well as air scouring and forward flush during the regeneration cycle.

The membrane modules are designed to be installed and used vertically and should not be installed and used otherwise, this would provide the membrane with the correct operation as designed.

The membrane modules are also optimized for low pressure use, which in turn reduces the OPEX of the whole membrane filtration system.
Figure 5: Membrane Module Dimensions

There are six connections on each membrane module of which 4 connections are on the bottom cap and 2 connections on the top cap. The feed water flows during filtration and forward flush through the port at the bottom of the membrane module. The air feed is located at the side of the bottom port and is used for the air scouring during the regeneration cycle. The permeate ports are located slightly above on the bottom cap which provide treated water flow during filtration. The reject ports are positioned on the top cap.

Due to the design of the cartridge with 2 connectors located on each side of the reject and permeate ports, it allows flexibility in the design and installation of the membrane modules on a rack. Additionally, it allows the membranes to be connected end to end up to 2 membrane modules per row which allows for a smaller footprint with less piping works required.
Chapter 5 – Design of the Filtration Stage

Operational specifications are detailed in Appendix – AQUADYN® UA1060 data sheet.

The important aspect of the UF design is the calculation of the required membrane area and flux based on the specific application of the membrane modules. As a result, the flux calculation must be done based on the maximum water flow into the membrane modules at the lowest possible temperature throughout the year. Other factors affecting the flux include the physical, chemical and biological parameters such as particle size and water ionic composition. The required membrane area can be subsequently determined based on the set flux rate. The design of the entire system should account for any disruptions and shut-downs due to cleaning, disturbances as well as any process impacts from both upstream and downstream processes e.g. RO system operations and CIP downstream.

In case of industrial water applications, please contact your local MICRODYN-NADIR (MN) agent. MN recommends conducting pilot trials before designing a large scale plant.

A basic P&ID of an AQUADYN® UA1060 plant is detailed in Appendix – Basic P&ID

Chapter 5.1.1 - Tanks

After the system is designed with the correct flux and membrane area, the size of the tank can be dimensioned.

In order to prevent frequent start/stops of the system, size of tanks upfront and behind the UF system should be considered.

Feed tank

The feed tank should cater to the amount of required water for the forward flushing of the membrane module based on 2x the maximum filtration flux.

The tank should also come with the corresponding inlet/outlet and drain valves, open overflow pipe and level switches for the proper control of the tanks. The level switch should have the ability to detect high level in order to prevent overfilling and to detect low levels in order to stop the operation of the system to prevent damage to the equipment and membrane module.

If the system is configured with several filtration lines, then the feed tank can be sized to allow the continuous running of only 1 system with the rest in standby mode in the event of insufficient feed water.

Permeate/ back flush tank

The permeate and back flush tank can be designed as a combined tank for easier operation.

In case of a combined tank, the tank must also be sized sufficiently for the above and in addition minimum one back flush per filtration time, taking into account the lost capacity when the system is not operating due to regeneration/Enhanced Back Flush (EBF) as well as the water loss through regeneration/ EBF in addition to the buffer capacity mentioned above.
**Dosing tank**

A dosing tank is required to store the chemical required to perform the EBF and cleaning-in-place (CIP). Each chemical used frequently, must be stored in an individual tank. It is recommended for safety reasons that dosing tanks are placed in its individual bund for containment in case of leaks.

Based on the design of the EBF for the system, the tank is recommended to have sufficient capacity to cater for at minimum a week to reduce the amount of manpower required to top up the chemicals. The material must also be suitable for the chemical to be used.

In the case of Sodium Hypochlorite (NaOCl), care must be taken that the solution loses strength over time and the rate of degradation increases with heat and sunlight. Due to off-gassing, the tank must also be designed with venting of this gas.

It is recommended to store sodium hypochlorite under dark and cool (≤ 15 °C) conditions.

**Cleaning-in-place (CIP) tank**

In case intensive cleaning is required, a CIP tank may be required. The cleaning of the membrane modules in CIP mode requires the cleaning of the membrane on the outer surface. In order to cater for the amount of CIP water needed in the membrane module, each tank should be sized for approx. 70 L per membrane module. Additional allowance would need to be done for volume of the water in the piping. The tank should also have a freeboard of approx. 20%.

**Chapter 5.1.2 - Pumps and Blowers**

**Feed pump**

The feed pump can be designed based on the designed filtration flux; designed head of the pump can be determined by the amount of pre-pressure upfront of the pump. Allowance for flow and pressure must also cater for any pre-filtration equipment such as auto-filters up front.

A typical pump to be used can be of a centrifugal design which should be equipped with MN recommendation to install a frequency invertor for better process control.

The suction piping to the pump must also be installed with sufficiently large suction to prevent cavitation.

In case the pump should be used for CIP or sea water application as well, depending on the chemicals and chloride content, the pump material has to be suitable to prevent premature failure of the pump.

When there are multiple filtration lines there is a possibility of sharing a common feed pump for several lines, however there should be a redundancy built in so that there is no possibility of a single point failure which causes the stoppage of the entire plant.

**Back flush pump**

The back flush pump is designed based on 2 times the filtration flux, i.e. if the filtration flux is 40 LMH, then the back flush pump should be designed for 80 LMH.

The same design considerations as for the feed pump applies to the back flush pump as well.
**Air Blower**

Air blowers or pressurized air can be used with the UA1060 modules with the air scouring pressure max. 0.6 bar.

The purpose of the air blower is in essence to provide sufficient agitation of the membrane fibers during the regeneration process.

It should be designed with a blower discharge flowrate of up to 10.0 Nm³/h per module.

**Dosing pump**

The chemical dosing pump is required to supply the required chemicals to the membrane modules during the EBF. Each different chemical would require a different dosing pump to ensure there is no mixing of different chemicals into the same dosing system.

Depending on the application and dosage of chemicals into the system, a solenoid or motor driven dosing pump may be used.

The dosing pump capacity is normally determined by the following parameters:

- target concentration
- source concentration
- number of membrane modules
- back flush flux

**Chapter 5.1.3 - Valve**

Valves to be used can be of pneumatic or electrical motor driven design. However, care must be taken in both cases that the opening and closing of the valves are well controlled to prevent fast opening and closing which may result in water hammers, directly pressuring onto the membrane modules.

It is recommended that the valves come with position indicators which are connected to the control panel in order to ensure all valves are in the correct open/close position before transitioning to the next operation step.

**Reject outlet valve**

The reject outlet valve is an open/close device that is closed during filtration and opened only during forward flush, regeneration, EBF and CIP. Therefore the sizing of the valve must be designed for the largest possible flow depending on the back flush and forward flush flux.

**Permeate outlet valve**

The permeate outlet valve is an open/close device that is opened during filtration and closed during regeneration, EBF and CIP. Therefore the size of the valve must be designed for the largest flow possible depending on the filtration flux. In addition, this permeate outlet valve prevents a flow of water during back flush to the permeate line.
Feed inlet valve
The feed inlet valve is recommended to be installed in cases where there is a possibility of feed water flowing to the membrane modules and a high hydraulic pressure can be subsequently applied. This could affect the back flush efficiency of the regeneration process as there is an additional backpressure when the back flush water is sent from the back flush pump to the membrane modules and subsequently to the reject line.

Air Blower inlet valve
An air blower inlet valve is recommended to be installed inside the air pipe to fully isolate the air blower section from the rest of the water filled piping to prevent that there is a backflow of water into the air blower.

The valve should be installed as close as possible to the junction where the pipe is joining directly to the feed inlet of the UF membranes modules to minimize the flooding of the line.

Drain outlet valve
A drain outlet valve can be added wherever necessary that allows the heavier solids to be drained from the bottom of the membrane module in case that the solids are unable to be pushed out via the reject line. Draining is carried out by opening simultaneously the drain outlet valve and the reject outlet valve.

Check valves
Check valves are to be installed in pipes sections where there is a possibility of backflow or where there are multiple pipe routes. An example is at the air pipe where there is a possibility of water backflow into the air blower when the air blower line/valve is open and the air blower has not yet built up sufficient pressure to push the air in the direction of the membrane modules.

Sampling and drain valves
Sampling valves and drain valves are recommended to be added wherever required, typically where it is required to do a drain of water for the maintenance of the system. Sampling valves can be added in front of and behind the membrane modules in order to collect samples for water analysis as a secondary check for the system operation.

Chapter 5.1.4 - Instrumentations
A set of monitoring equipment is necessary to ensure that the entire system works correctly, safely and within permissible limits.

Digital process monitoring equipment (i.e. pressure gauges, flow meter) is preferred over analog ones and recommended for optimum monitoring and control of the process.

Pressure Measurements
The TMP is measured according to the equation given in Chapter 3.2 - Definition and Explanation of Common Terms. Therefore pressure sensors must be installed at the feed and reject as well as on the
permeate line of the membrane module. Pressure sensors must be located near to the membrane module to reduce the influence of pressure loss caused by piping.

The pressure during back flush can be monitored to ensure that back flush is carried out correctly. The back flush TMP should be similar for each back flush. Investigation has to be done if that is not the case.

The feed pressure must be measured before and after the pre-treatment filters in order to determine the differential pressure to start the cleaning/ replacement process for the pre-filters. It also allows the monitoring of the real pressure entering the membrane module. Additionally it also allows for manual monitoring to ensure that the pre-filter is operating correctly. Correct operation of the pre-filters is necessary to ensure that the membrane modules are able to work as intended.

The air blower pressure (P2) must also be monitored closely to ensure that there is sufficient pressure to push the air into the modules and the pressure into the modules must not exceed 0.6 bar.

**Permeate flow meter**

A permeate flow meter must be added at least to the permeate line in order to monitor the correct flow during back flush and filtration.

**Turbidity measurement**

A turbidity measurement can be added in order to determine the separation performance of the system so that monitoring fiber breakage or system failure is possible. Initial turbidity readings should be recorded as a guide. High turbidity measurements could be in indication of failures in the system or the membrane fibers and the system must be immediately stopped and source of failure investigated.

**pH measurement**

pH measurements should be added to check the effectiveness of the EBF and CIP cleanings that are carried out. Additionally, the pH range must be attained according to Appendix – AQUADYN® UA1060 data sheet.

**Chapter 5.1.5 - Pipings**

A series of pipes and fittings are necessary for connections to the auxiliary equipment and modules. A plumbing system according to good engineering practice is imperative to ensure the entire UF system works at its optimum. The necessary piping should be designed effectively as short as possible and with fittings such as elbows as far as possible minimized. This will decrease the overall pressure drop within the system as well as optimize hydraulics.

The permeate piping should be designed with a flow velocity approximately 1 m/s ($V_p < 1.0 \text{ m/s}$) while the backwash piping designed with a flow velocity not more than 2 m/s ($V_b < 2 \text{ m/s}$). If there is a shared section of piping between the permeate and back flush piping, the piping must be designed for the larger flow, bearing in mind pressure loss and distancing. Take note that these also apply for the feed pipe where forward flush is applied. The pipe size on the feed side should also be designed for a forward flush with a flow velocity not more than 2 m/s ($V_{ff} < 2 \text{ m/s}$).
In most cases there is no issue by formation of air pockets in the system if the permeate outlet piping is located above the UF system. However there is a possibility of air pockets at the high points of the piping if the permeate tank is located at a height below that of the UF. It would be necessary in that case to have a degassing device installed at the high point of the piping. Similar degassing should also be considered for the reject/ back flush outlet.

**Chapter 5.2 - Cleaning Strategy**

Depending on the specific application and water quality, organic fouling and inorganic scaling may occur, thus requiring different cleaning regimes.

Organic and biological fouling is normally caused by growth of microorganisms and organics adsorbed on the membrane surface that can be normally cleaned by doing an EBF or CIP with caustic, for instance sodium hypochlorite.

Inorganic scaling is caused by the precipitation of inorganics on the membrane surface that can be removed by EBF or CIP with acid, for instance citric acid at pH 2.

There are two different modes that can be adopted, EBF and CIP. Additionally, dependent on the feed water quality and applications, different chemicals can be adopted for an optimum cleaning efficiency.

The frequency of the cleaning is dependent on the site conditions as needed.

**Enhanced back flush (EBF)**

Back flush water flows to the membrane module via the back flush pump, at the same time chemicals are injected via a dosing pump into the pipeline and well-mixed before it is sent to the membrane module.

The purpose is to clean the lumen side of the fibers, as the chemical mixed water will flow from the inside of the fiber outwards to the reject outlet.

There can be a pre-set timer to determine the amount of air scouring required, typically the default timing is 30 s but has to be adjusted based on site conditions. The back flush pump is then switched on and sent with the chemicals to the membrane modules. A soaking timer can also be set on request depending on how much soaking is required.

**Cleaning-In-Place (CIP)**

Clean water is firstly in the CIP tank as a batch and subsequently the chemical mixed water is sent via the feed pump to the membrane module. The mode of entering the membrane module is via the feed inlet manifold. The water then flows through the distribution fins in the membrane module before being diffused outwards to the fibers. The water then flows to the reject outlet at the top of the membrane module. The purpose is to do a cleaning on the shell side of the fibers along with removal of foulants and deposition on the exterior of the fibers.

Typically, it is advised to have longer soaking times to ensure sufficient dissolutions of scales when doing an inorganic cleaning and to have sufficient recirculation when doing an organic cleaning to ensure the organic materials are adequately flushed out from the membrane fiber surfaces.
In order to check if sufficient chemicals are used for the cleaning of the module pH-determination at the reject outlet pipe (which corresponds to the CIP-outlet) is recommended. The cleaning medium circulates from the reject outlet pipe to the CIP tank. The pH-measurements can be conducted on the one hand manually using a pH-meter for acid and caustic cleaning. In case of NaOCl a free chlorine measurement can be done ensuring that there is at least free chlorine detected exiting the reject outlet. On the other hand a pH-sensor and transmitter set-up can also be used to ensure automatic monitoring during such operation.

Chapter 5.3 - Rack Installation

The modules can be arranged as a fixed unit. This unit is called rack. MN recommends an installation of the rack according to Figure 6:

Preparation before rack installation

- Clean the entire system, especially pipings in order to avoid a contamination of the membrane modules.
- Check the functionality of the membrane modules after unpacking.
- Membrane modules should be installed shortly before start-up is planned in order to avoid too long storage in the rack after unpacking the membrane modules.
- Write down the module serial number and the rack position.

Rack installation

All important information about the following points is illustrated in Figure 6.

- It is allowed to install maximum two membrane modules per line on each side of the manifold in order to minimize as much as possible a pressure loss between the front and back of the membrane modules.
- Install the rack at an even ground. Otherwise, adjustable mountings are recommended for profile adjustments.
- The frame of this rack must be designed and built to have fully support of the membrane modules.
- Protect the modules against overturning, rocking and instability, therefore holding straps are recommended to be installed at the top and bottom to provide lateral stability and grip to the membrane modules.
- Vibrations in the rack must be avoided and compensated.
- Sufficient space must be allocated on the bottom for maintenance and pipe/hose length connections.
- Not used connectors are closed with Victaulic connectors during assembly.
- Do not use the modules or the module connectors for mechanical support during assembly.
- Dimension the headers in order to reduce the pressure loss inside the headers to a minimum.
Figure 6: UA1060 Rack with hard pipe connections

- Membrane modules connected via Victaulic connection
- Do not use the connectors for mechanical support and close the not used connectors with a Victaulic connection
- Holding straps for stability
- Row (R)
- Line (L)
- Reject manifold
- Air manifold
- Permeate manifold
- Feed manifold
- Module support
- Adjustable mountings
- Adjust the mountings
- Do not use the connectors for mechanical support and close the not used connectors with a Victaulic connection
- Membrane modules connected via Victaulic connection
- Holding straps for stability
- Row (R)
- Line (L)
- Reject manifold
- Air manifold
- Permeate manifold
- Feed manifold
- Module support
- Adjustable mountings
- Adjust the mountings
- Do not use the connectors for mechanical support and close the not used connectors with a Victaulic connection
Chapter 6 – Operation Procedures of AQUADYN® UA1060

The following chapter describes the start-up and operation guidelines for the AQUADYN® UA1060 membrane module.

Before the commencement of any start-ups, we recommend that a reverification of the feed water composition is carried out.

MN also recommends that wherever possible, operation and maintenance staff should be involved in the commissioning process. Additionally it is recommended that the start-up is carried out in manual mode for all function tests prior to switching to automatic start-up for monitoring any anomalies.

Chapter 6.1 – Start Up Checks

Before any start-up, i.e. starting of any operations with water, always ensure the following recommendations for visual inspection and functional checks:

1) The equipment (valves, pumps, air blowers, dosing pumps etc.) to be used is installed correctly and in good working condition.
2) The measuring instruments to be used are calibrated and properly installed.
3) The program controlled by the PLC is functional and runs without any error which can result in any constant switching on/off of the system resulting in water hammering during flushing.
4) The membrane modules are installed correctly.
5) Make sure that the entire system is clean, especially piping in order to avoid a decontamination of the membrane modules.

Chapter 6.2 – Regular Operating Procedures

The regular operating procedures would comprise the follow:

1) Filtration
2) Regeneration/ Enhanced Back flush (EBF)
3) Cleaning-In-Place (CIP)

Chapter 6.2.1 - Operation of Filtration stage

During filtration, the feed water is treated by applying pressure through the ultrafiltration membrane fibers from the shell side (exterior of the fibers, within the membrane modules) to the lumen side (interior of the fibers, accumulated at exposed lumen-ends). The rejected particulates are thus blocked by the fibers, accumulating and forming a filtration layer on the exterior of the membrane fibers.

The permeate water flows to the product/back flush tank where it is stored until the water is required downstream for further treatment or consumption via back flush. In case that there is a back flush tank there must always be water inside this tank.

The flux rate is recommended to be constant. Hence it is advisable to install the feed pump with a frequency inverter controlled by means of flow output with safety interlocks against over-pressurizing.

Depending on the quality of feed water and flux rate, an operation time of between 30-60 minutes of filtration time (filtration cycle) between regeneration cycles can be expected.
During dead-end filtration rejected particulates will accumulate throughout the filtration time of the membrane module as described above. This accumulation will result in an increase of transmembrane pressure (TMP).

If the TMP reaches the maximum allowed pressure the membrane module must be regenerated soonerest possible via EBF or CIP.

Excessive buildup over prolonged periods will affect performance and recoverability of the membrane module and must be removed regularly through regeneration methods which will be covered in the next section.

Figure 7: Filtration Mode shows an example of the operating mode during filtration.
Chapter 6.2.2 - Operation of Regeneration

Four steps are normally involved in the regeneration cycle.

- Air Scouring (AS)
- Forward Flushing
- Drain (optional)
- Back flush

The sequence of these steps can be altered in order to improve the efficiency of the regeneration. In addition, a drain step can be implemented for better discharge of solids.

**Air Scouring (AS)**

Air Scouring is essential as this agitates and dislodges the accumulated particles on the exterior of the membrane fibers. The air is delivered via the air blower or pressurized airline to the inlet located at the bottom of the membrane module. Ensure that the inlet air pressure is above the feed pressure. The pressurized air is injected from the bottom of the membrane module, which in turn is released in the form of air bubbles through the patented air distribution air diffuser. As the air bubbles rise, turbulence is created which is sufficient to dislodge the foulants from the membrane fibers without damage. The timer to be set is approximately 30-60 seconds per air scouring step.
Figure 8: Air Scouring Step during regeneration cycle

Forward Flush

A forward flush step is implemented to remove the solids out of the system which have been loosened in the air scouring step. This can optimize the amount of product water required for the next regeneration step.

Performing a forward flush is highly recommended. This is because during forward flushing, the product line will be closed. The advantage is to force the water flow lengthwise along the exterior of the membrane fibers, which also provides a scrubbing effect on the membrane surface. The forward flush step normally varies between a time set of 30 to 60 seconds.

As the forward flush is also done using the feed pump, there would be no additional equipment required.
Drain

In case of high solids content or contents that have a high specific gravity in the feed water the forward flush step may be insufficient to remove all the solids. If so a drain step can be added to the regeneration cycle. This would allow the denser solids to be drained via the feedline at the bottom.

Depending on the size of the system the time to drain may take up to 30-60 seconds or longer. Time duration must be set during commissioning.

Back flush

Back flush is used to remove the remaining suspended particles from the membrane modules. During back flush the permeate water is drawn from the product/back flush tank and forced through the module from the filtrate side using the back flush pump.

The flow direction is opposite to the direction of flow in the filtration mode and enters the membrane module from the permeate port at the bottom of the module, entering the fibers via the lumen side and exiting through the shell side.
The back flush water with loose suspended particles are then forced out through the reject port located at the top of the membrane module through the reject line before going to the drain. The back flush must be conducted at a flux of between 1.5 to 2 times the filtration flux, depending on the water quality, to be sufficiently effective.

Effective back flush duration is typically at least 30-60 seconds discounting the time taken for the pump to ramp up and down where applicable. The time duration can be extended depending on the size of installation and the quality of the feed water.

![Diagram of back flush process]

**Figure 10: Back flush step during regeneration cycle**

An alternative sequence depending on the feed water quality can be done by implementing the back flush as step 3 and drain as step 4. A filling step is added to fill the module again before filtration starts.

Air Scouring → Forward Flushing → Back flush → Drain → Filling

In this mode of operation the membrane fibers are agitated and cleaned as much as possible and the back flush helps to expel the accumulated particulates or foulants from membrane modules which are
helpful in the cases of lighter particles. The remaining suspended particles are then completely drained out through the drain step in step 4.

Following this mode of operation, the membrane module is emptied. Hence a filling step is required prior to filtration. The system adopts a sequence similar to flushing, whereby feed water fills up the membrane modules while the reject valve is opened. Additionally the permeate valve is also left open in order to effectively de-aerate both exterior and interior of the fibers. Once a pre-fix timer has completed its cycle the reject valve will close leaving the feed pump running and permeate valve remains open, thus, transitioning into filtration mode proper.

It is highly recommended to ensure a reliable regeneration regime. A constant back flush flow rate is adopted by using an inverter-controlled back flush pump. The pump should be controlled such that the back flush flux to be adopted is progressively ramped up without pressure spikes or water hammering effects.

Figure 11: Filling Step during regeneration cycle if required
Enhanced back flush (EBF)

An enhanced back flush (EBF) cycle may also be adopted as means to optimize performance and as a form of maintaining sustainability before CIP is carried out. Typical frequency for EBF may be set at once every few hours or days of operation dependent on feed characteristics. A typical chemical that is used during EBF is sodium hypochlorite (NaOCl).

EBF is similar to a regeneration cycle with the exception that chemicals are introduced into the back flush water to enhance the cleaning effect in the membrane modules. Three additional steps are incorporated into the back flush cycle, namely dosing of chemical during back flush, soaking, followed by additional back flush.

Air Scouring →Forward Flushing →Enhanced back flush →soaking → back flush

Take note that whenever possible, always perform at least one back flush cycle prior to EBF to ensure the larger suspended particles are removed as much as possible for effectiveness of the EBF. Descriptions of EBF are as follows:

1) Air Scouring to loosen the foulants on the membrane fibers.
2) Forward flush for removal of particles inside the membrane module. Drain step may be eliminated if there was a back flush cycle prior to EBF.
3) During EBF, when back flush pump is initiated, the dosing pump will also be in operation in order to inject the required chemicals into the system. The flux rate during the EBF is also typically lower than the back flush flux rate and should not exceed 40 LMH. EBF is normally performed with less than 50 ppm free chlorine for 30 to 90 seconds.
4) In most cases, a soaking time can be attached after the chemicals are introduced. Typically, a soaking time is between 5 to 20 minutes.
5) The rinsing of the chemicals from the system and membrane modules must be done after soaking or if soaking was not carried out, directly after the chemical injection. The rinsing of the chemicals is carried out in the finishing step, whereby the back flush pump is operated at the designated back flush flux rate, without chemical dosing. Time duration must be adjusted during the plant start-up to ensure that all chemicals are completely removed from the membrane modules and system. Take note that after EBF, if setup permits, initial UF Permeate should be discarded as these may contain residual chemicals which may result in complications to systems down-stream.
Chapter 6.2.3 - Operation of CIP (Cleaning-in-place) stage

When there is fouling and scaling that cannot be removed by regeneration and EBF, a CIP can be performed.

This may happen due to upsets in the water quality or due to difficult operating conditions such as ineffective pre-treatment or incorrect chemical doses.

The major difference is that the CIP necessitates the use of a CIP tank. Additionally; the time taken to perform CIP is typically longer than that taken for regeneration or EBF.

The CIP is normally done only on the feed side and does not involve the permeate side of the membrane module. This means that CIP is specific in targeting exterior of fibers, whereas EBF in specific in cleaning fibers from inside-out. Thus, both procedures may complement each other well, depending on the nature of anticipated fouling.
A CIP cycle is typically carried out once every few months. In certain feed water conditions the CIP may be as frequent as every 20 days.

The following points are important and care should be taken before performing the CIP.

1) The CIP should be performed if periodic regeneration and EBF is unable to adequately recover performance. The CIP should be considered effective if it recovers up to 75% of the membrane performance.

2) The chemicals to be used must be as per recommended in chapter 5.2.

3) The water used to prepare the CIP cleaning solution must be free of particles (tap water or permeate). This is especially valid for caustic and high pH cleaning. Additionally, a high pH cleaning must be followed by flushing prior to an acid cleaning.

4) Typical CIP time may take up to 12 hours but should not exceed this time.

5) The CIP solution must be fed only from the feed side of the membrane modules to prevent any substances that can cause scaling or fouling ending up in the permeate side of the membrane module during the recirculation.

6) Always disconnect the system undergoing CIP from the rest of the systems whenever possible.

The following steps are carried out during CIP and must be monitored closely and done manually:

1) The CIP tank must be filled first with water before the addition of any chemicals.

2) The chemicals must be properly mixed with a mixer. After the mixing process, it should be checked that the concentration of the solution is as per the targeted values. It is important the solution concentration does not exceed the maximum limits set according to Appendix – AQUADYN® UA1060 data sheet.

3) To prevent a contamination, the feed tank and product/back flush tank must be isolated from the system by closing the valves on the feed line and back flush line.

4) The chemical solution then passes through the feed pump from the CIP tank. The process should be monitored that the recirculated solution is passed through the entire system, always check the concentration of the recirculated chemical solution is the same as that entering the system.

5) While the solution is recirculating and entering via the feed port of the membrane module, the air scouring can be operated intermittently during soaking so as to enhance the effect.

6) Once the solution has been thoroughly circulated, up to a period of 30 minutes, a soaking can be carried out for a time period of 30 to 120 minutes to allow the chemicals to thoroughly soak the membrane fibers.

7) The water can then be flushed back to the CIP tank after this is done. Always inspect the cleaning solution that it is still potent. If the water turns dirty, replace the chemical solution and repeat the cycle.

8) Once the cleaning is deemed effective, always drain and dispose of the chemicals safely. Then clean the tank and top up again with clean water before rinsing the membrane modules.
Figure 13: CIP mode

Chapter 6.3 - Shut Down

UF systems are typically designed to run continuously. If shut down is required and exceeds more than one week an enhanced back flush (EBF) is necessary:

1) Do at least one regeneration cycle.
2) Perform an EBF with 100 ppm NaOCl as described in Chapter 6.2.2 - Operation of Regeneration.
3) During shut down time the medium in the module is replaced with permeate or drinking water by back flush to prevent bacterial growth.
4) After back flush, all valves on the UF system are closed completely in order to isolate the system from any source of external contamination.
5) Take note that at no point the fibers should be allowed to dry out as this would cause an irrecoverable deterioration of performance due to damages.
6) This cleaning procedure has to be repeated every month when modules are not operated in filtration mode.
7) The module must be stored in an upright position and free of any oxidizing agents during the system shutdowns.

Longer shut down times should be discussed with a MICRODYN-NADIR specialist.

Chapter 6.4 - Operating and Cleaning Logs

Operation and cleaning logs are important for tracking operating conditions and to optimize operations. In Appendix- Operation and Cleaning Record Logs are three record forms for monitoring of cleaning. Failure to furnish this information when requested shall render the warranty void.

The first is for the operation record form which is used to collect the data during normal filtration and regeneration. The second and third are the maintenance/cleaning record forms which records the data during EBF and CIP.

The data should be recorded from the moment the modules are put into operation, the customer is required to maintain complete and continuous documentations of the operating conditions and the amount of time the plant is operated and cleaned.

Use of chemicals for feed water pre-treatment and EBF /CIP must be monitored closely. The information should also be additionally recorded.

The forms provide a guide to the required information for tracking the performance of the membrane modules but should not be a limit of any additional information required.
Appendix – Basic P&ID of AQUADYN® UA1060 plant
Appendix – AQUADYN® UA1060 data sheet

Module Specification

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
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<tbody>
<tr>
<td>Filtration type</td>
<td>Ultrafiltration</td>
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<tr>
<td>Membrane type</td>
<td>Hollow fiber</td>
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<tr>
<td>Membrane structure</td>
<td>Double asymmetric</td>
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<tr>
<td>Membrane potting</td>
<td>Epoxy</td>
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<tr>
<td>Membrane material</td>
<td>PAN</td>
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<tr>
<td>Housing material</td>
<td>uPVC</td>
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<tr>
<td>Fiber arrangement</td>
<td>U-Shape</td>
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<td>Flow type</td>
<td>Out/In</td>
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<td>Type of filtration</td>
<td>Dead End</td>
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<tr>
<td>Regeneration</td>
<td>Back Flush, Forward Flush, Air Scouring</td>
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<tr>
<td>Membrane area</td>
<td>60 m²/646 ft²</td>
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<td>Hollow fiber diameter OD (ID)</td>
<td>1.7 mm (0.9 mm)/0.067 in (0.035 in)</td>
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<td>Pore size</td>
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<td>Module diameter</td>
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<td>Module length</td>
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<td>Connectors</td>
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<tr>
<td>Permeate port:</td>
<td>2” Victaulic</td>
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<tr>
<td>Reject port:</td>
<td>2” Victaulic</td>
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<td>Air inlet port:</td>
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<td>Weight of module at shipping</td>
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<td>Standard preservative</td>
<td>Sodium meta-bisulphite</td>
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Operation Specification*

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<th>Feature</th>
<th>SI Units</th>
<th>US Units</th>
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<td>pH range, cleaning</td>
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<td>Max. active chlorine exposure</td>
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<tr>
<td>Max. active chlorine conc.</td>
<td>100 ppm (mg/l)</td>
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<tr>
<td>Max. hydrogen peroxide exposure</td>
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<td>Max. NTU feed</td>
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* Depending on feed water quality and operating conditions

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E-Mail: info@microdyn-nadir.de
Internet: www.microdyn-nadir.de
## Appendix - Operation and Cleaning Record Logs

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<th>Conductivity</th>
<th>Ozone Value</th>
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<th>Nitrate</th>
<th>Ammonia</th>
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<th>BOD</th>
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<th>TSS</th>
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*Note: Data should be filled in as applicable.*
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