# Technical Service Bulletin

August 2012 TSB407.06

## Process Data Logging and Performance Analysis for HYDRAsub®-MBR Systems

This Technical Service Bulletin provides information for manual data logging, data normalization and HYDRAsub® performance analysis.

### General

Most HYDRAsub®-MBR systems have supervisory control and data acquisition (SCADA) such that operating data is capable of being automatically acquired and stored at least every minute. Despite this technical convenience, manual data logging should be performed at every HYDRAsub®-MBR plant. Not only does the physical act of data logging allow operators to inspect their systems, but it also facilitates corroboration amongst transmitters and gauges. Data sheets are also a good backup source of data should the electronic data be lost.

### Data Logging Sheet

A sample data logging sheet is provided below. This sheet lists various process parameters that help to determine HYDRAsub®-MBR performance. Some systems incorporate supplemental equipment as part of the process, such as a screen filter, chemical injection system, tanks, particle counters and pH probes. Data from each of these items should be logged, as well, to ensure proper plant performance and establish baseline characteristics.

A data set from each module or train should be manually logged at least once per day or once per operator shift. A data set includes filtrate pressure data logged one minute prior to soak and one minute after soak. This allows for an accurate assessment of HYDRAsub®-MBR performance.

The following is a description of parameters used in the data logging spreadsheet:

- Date – calendar date.
- Time – local time.
- Hour Meter –machine time, usually in hours.
- Feed Type- secondary wastewater (used during start-up) or primary effluent (used during normal operation), [1,0].
- Screen Filter Pressure In – water pressure entering the screen filter, [psi].
- Screen Filter Pressure Out – water pressure exiting the screen filter, [psi].

- Recycle Flow (from the biological treatment tanks to the membrane tanks) - instantaneous recycle flow, [gpm].
- Recycle Pressure (from the biological treatment tanks to the membrane tanks)- water pressure at recycle pump, [psi].
- Return Activated Sludge (RAS) (from the membrane tanks to the biological treatment tanks) - instantaneous RAS flow, [gpm].
- RAS Pressure (from the membrane tanks to the biological treatment tanks)- water pressure at RAS pump, [psi].
- Filtrate Flow- instantaneous filtrate flow from each module or train, [gpm].
- Filtrate Pressure (one minute before soak cycle)- pressure measured on the suction side of the filtrate pump one minute before the soak cycle begins (or one minute before the filtration cycle ends). This is used to calculate trans-membrane pressure (TMP) in Equation 2, [psi].
- Soak Pressure- static pressure during a soak/relaxation cycle. This determines the feed pressure for the TMP calculation in Equation 2, [psi].
- Filtrate Pressure (one minute after soak cycle)– pressure measured on the suction side of the filtrate pump one minute after soak cycle ends (or one minute after the filtration cycle begins). This is used to calculate TMP in Equation 2 and determines the amount of recovery gained from the soak cycle, [psi].
- Bleed Flow - instantaneous solids bleed flow, or waste activated sludge (WAS). It is important to monitor this parameter to keep track of the solids retention time (SRT) of the system, [gpd].
- Air Flow (Aerobic Tank) - instantaneous air flow into the aerobic tank, if used, [scfm].
- Air Flow (Membrane Tank) - instantaneous air flow into each membrane tank or train, [scfm].
- Air Pressure (Membrane Tank) - air pressure to each module or train or blower discharge pressure. This helps determine if the diffusers are becoming clogged and air is being distributed properly, [psi].
- pH- pH of the membrane tank contents. pH may also need to be monitored in other treatment zones (i.e., aerobic and anoxic tanks), but this is dependent on the biological system design, [s.u.].
- Temperature –temperature of the membrane tank contents, [$^{o}$C].
- Dissolved Oxygen (DO) (Anoxic Tank) - amount of oxygen dissolved in the anoxic tank zone. The DO in the anoxic zone should be close to zero. An excess of DO could mean the flow from the aerobic zone(s) or membrane tank(s) is too high and may cause denitrification to be inhibited, [mg $O_2$/L].
- Dissolved Oxygen (Aerobic Tank) - amount of oxygen dissolved in the aerobic tank contents. The DO in the aerobic zone should meet the system’s

design requirements (typical set points are 1.0- 2.0 ppm$O_2$ for municipal applications). The DO must be measured to ensure sufficient oxygen is present for degradation of BOD and ammonia, [mg $O_2$/L].

- Dissolved Oxygen (Membrane Tank) - amount of oxygen dissolved in the membrane tank contents. The amount of DO present in the membrane tank will typically be close to the saturation point due to membrane air scouring. It is only crucial to monitor the DO in this tank if it is used as an aerobic treatment zone or if DO in the RAS must be minimized before returning to another zone, [mg $O_2$/L].
- Sludge Viscosity (Membrane Tank) - viscosity of the membrane tank contents. The viscosity may be used as a qualitative measure of TSS, [MPa-s].
- Filterability Test Volume- volume of filtrate obtained through a Filterability Test (refer to TSB404 for detailed experimental procedure). The results of this test give a qualitative measure of how flocculations form and how easily the sludge may be filtered, [mL/5min].
- Turbidity of Filterability Test Filtrate– turbidity of the filtrate volume from the Filterability Test (refer to TSB404 for detailed experimental procedure). The turbidity of the filtrate is an indicator of how colloidal material forms into flocculations, [NTU].
- Sludge Volume (SV30) - the amount of settled sludge in a fixed volume after 30 minutes (refer to TSB406). The SV30 value is used to calculate the sludge volume index (SVI) in the Analytical Data (Input) Sheet (refer to TSB408 for details on SVI and other analytical parameters), [mL/L].
- SV30 Dilution Factor- the factor used to dilute sludge in an SV30 test (refer to TSB406). This value is also used in SVI calculations.
- Filtrate Turbidity- turbidity of filtrate sample after membrane filtration. This is representative of the colloidal content in the filtrate, [NTU].
- Filtrate Conductivity- measure of the total dissolved solids in the filtrate after membrane filtration, [mS/cm or cP].
- $T_i$- time to collect initial 500 mL during Silt Density Index (SDI) test (refer to TSB113), [sec].
- $T_f$- time to collect final 500 mL during SDI test (refer to TSB113), [sec].
- $T_T$- total time of SDI test, usually 15 minutes (refer to TSB113), [sec].
- % Pluggage (P30) - the amount of pluggage caused in the filter paper used in the SDI test at a constant pressure of 4.35 psi (30 kPa). The value is calculated from input parameters; $T_i$, $T_f$, and $T_T$ (refer to TSB113), [%].
- Silt Density Index (SDI) - measures the amount of suspended solids and colloidal particles in a filtrate sample. A SDI of less than 5 is typically required for reverse osmosis applications. Typical permeate quality from a HYDRAsub®-MBR system is less than 3.

- Operator Initials- initials of operator recording data. This is needed in order to keep track of who was present when specific data points were taken for clarification and accountability reasons.
- Comments –type of cleaning performed (i.e., chlorine CEB), chemical concentration used during cleaning, any alarms or other notable events.

**Data Input** is required in some sort of electronic format to keep records and to be able to track process parameters. Hydranautics provides a generic Excel file for MBR systems called the MBR Data Sheets which includes a Process Data Sheet for operators to print out (described in the Data Logging section above) as well as a Process Data (Input) Sheet where all the data is to be entered electronically. The latter contains calculations and is linked to graphs so that process data can be tracked and analyzed. The file also includes other data logging sheets for further analysis of the MBR system (refer to TSB408 and TSB409). This file can be obtained through contacting Hydranautics' Technical Department.

**Data normalization** is required to determine HYDRAsub®-MBR process performance. Temperature changes not only affect feed water viscosity, but also membrane permeability. Significant temperature fluctuations yields fluctuations in observed TMP and actual plant performance may not be properly determined. For this reason it is necessary to normalize operating data to a reference temperature. For simplicity, our reference temperature for normalization is 20º Celsius. The following equations should be used in determining HYDRAsub®-MBR system performance:

**Flux** is the filtrate flow rate per unit surface area of membrane. The instantaneous flux should remain as constant as possible, but may fluctuate with feed flow changes. As the temperature of the feed water changes, the instantaneous flux may need to be changed accordingly. A target design flux should be selected and the temperature corrected flux can be calculated as the temperature changes. Using the temperature corrected flux, the corresponding filtrate flow may be determined.

- Flux calculation:

$$J = \frac{1440 * Q}{A_m}, \text{ [gfd]} \qquad \text{Equation 1}$$

where,

$J$ - flux, [gallons/ft$^2$/day]

$Q$ - filtrate flow, [gallons/minute]

$A_m$ - effective membrane area, [ft$^2$]

Appropriate design fluxes to maintain are project specific and should be determined by Hydranautics. Please refer to project warranty or Hydranautics Technical Department for these values.

**Trans Membrane Pressure (TMP)** is the net driving pressure on the membrane. This is the effective pressure for forcing water through the membrane. The TMP is measured by correcting the filtrate pressure reading to the water level in the membrane tank, including pressure losses in the piping. The following equation can be used to calculate the TMP.

$$\mathrm{TMP} = \mathrm{P}_{\mathrm{feed}} - \mathrm{P}_{\mathrm{filtrate}} \qquad \text{Equation 2}$$

Where,

$P_{feed}$ = static water head above the membrane, and

$P_{filtrate}$ = filtrate gauge measurement corrected to the top of the membrane

Equation 2 can be expanded to Equation 3 in reference to Figure 1 and Figure 2. The equation is the same in each case; however, the signs may change for the pressure gauge reading depending on the location and filtrate pressure. All head measurements should use the bottom of the membrane tank as the zero reference, resulting in a positive number for all height values.

$$\begin{aligned}\mathrm{TMP} &= (H_{water} - H_{\mathrm{mod}ule}) - [P_{gauge} + (H_{gauge} - H_{\mathrm{mod}ule})] \\ &= H_{water} - H_{\mathrm{mod}ule} - P_{gauge} - H_{gauge} + H_{\mathrm{mod}ule} \\ &= H_{water} - P_{gauge} - H_{gauge} \qquad \text{Equation 3}\end{aligned}$$

Where,

$H_{water}$ = water head at the tank water level
$H_{module}$= water head at the top of the module
$P_{gauge}$= pressure reading on the filtrate suction line
$H_{gauge}$= water head at the pressure gauge,

and all units are the same for each variable.

Alternatively, Equation 2 can be expanded to Equation 4 to calculate TMP.

$$\mathrm{TMP} = P_{soak} - P_{gauge} \qquad \text{Equation 4}$$

Where,

$P_{soak}$ = the pressure measured during a soak/relaxation cycle (when no suction is applied to the membranes), and

$P_{gauge}$= pressure measured during a filtration cycle

Equation 4 is a simple calculation to use in a programmable logic controller function or to quickly check the TMP during operation.

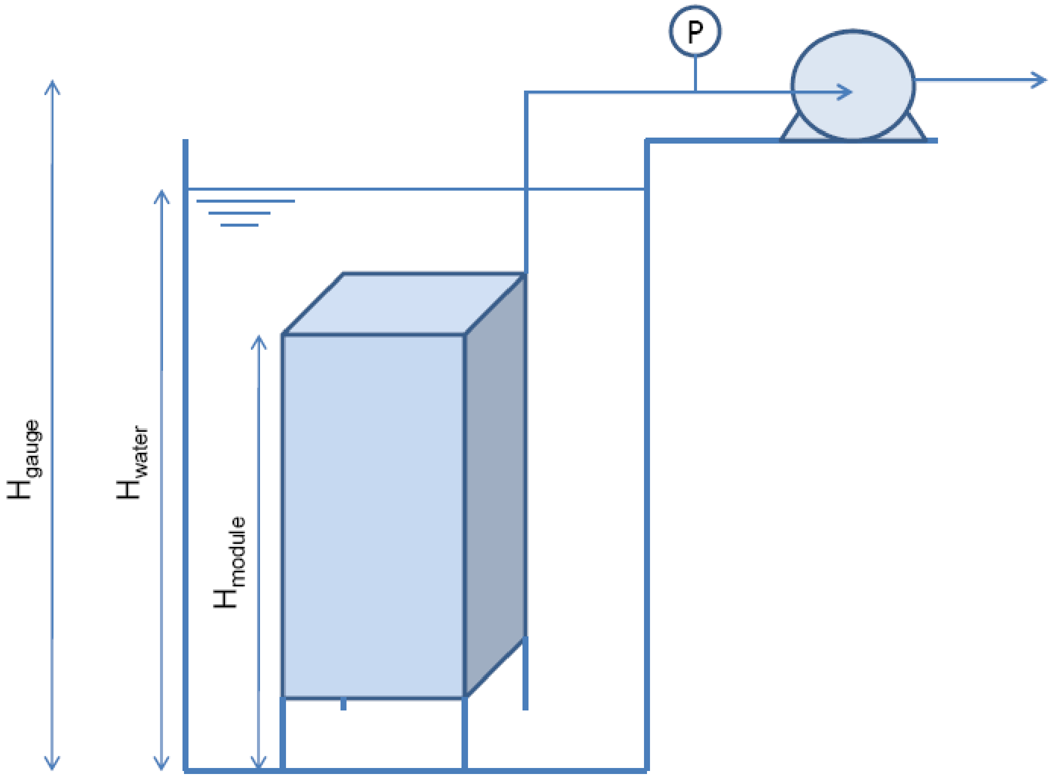

**Figure 1** Filtrate pump above the water level

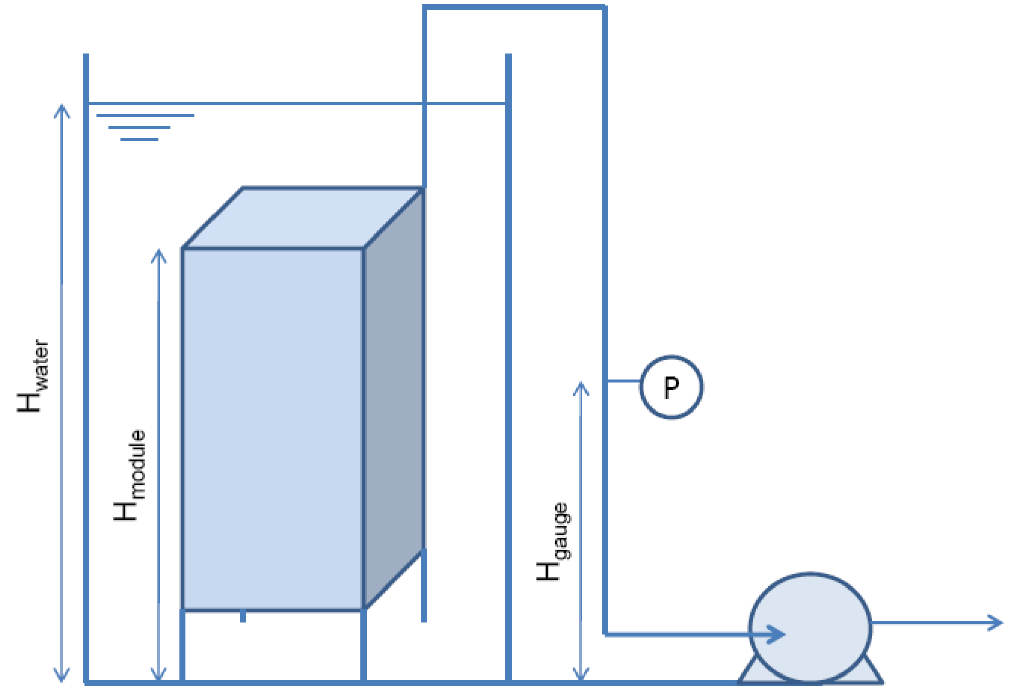

**Figure 2** Filtrate pump below water level

**NOTE: TMP should never exceed 6 psig (0.41bar).**

**Temperature Corrected Specific Flux (TCSF), or Permeability** is an intrinsic property of the membrane and should be used to determine membrane performance. Prior to start-up of new membranes, TCSF should average out to 10-30 gfd/psig (refer to TSB405.00). During normal operation, TCSF values will range from 1-30 gfd/psig, depending on the type of application. A decrease in TCSF is expected over time, but is typically recoverable via chemical cleanings.

- TCSF calculation:

$$\mathrm{TCSF} = \frac{\mathrm{J}}{\mathrm{TMP}} * e^{(-0.031*(\mathrm{T}-20))},\ [\mathrm{gfd/psig}] \qquad \text{Equation 4}$$

where,

TCSF - temperature compensated specific flux.

J - flux, [gfd].

TMP - trans membrane pressure, [psig].

T - water temperature, [$^{\circ}$C].

Equation 2 is valid within a temperature range of 0- 20°C.

## HYDRAsub®-MBR Performance Analysis

### Flux

Flux is a system design parameter that has a direct correlation with membrane fouling rate. As flux increases, so does the fouling rate. The maximum net flux will vary from project to project and must not exceed that given in the technical proposal or warranty documents.

### Trans Membrane Pressure (TMP)

When flux and temperature are constant, the TMP is indicative of the degree of fouling on the membrane. A clean membrane will have a relatively constant TMP, assuming the previous conditions are met. However, water viscosity and membrane resistance are dependent on temperature and can affect the TMP. This effect is common for every membrane process. When water temperature fluctuates significantly, TMP fluctuations will occur. A clean membrane will have a relatively low TMP, whereas a fouled membrane will have a relatively high TMP. Weekly CEB, or maintenance, cleanings should be performed to keep fouling to a minimum and TMP within the proper range, while quarterly CIP, or recovery, cleanings are meant to recover permeability to the initial value. Please refer to the HYDRAsub®-MBR Instruction Manual for more details on cleanings.

### Temperature Corrected Specific Flux (TCSF), or Permeability

For any HYDRAsub®-MBR system it is critical that the TCSF be monitored. TCSF represents the condition of the membrane regardless of the changes in temperature or flux. The TCSF is a true indication of fouling occurring on the membrane surface. The benefits of properly maintaining TCSF will translate into the energy usage as well. As the membrane fouls and the TCSF decreases, energy requirements will increase (if system operating parameters remain constant).

**Useful Tips:**

1. Take data daily and if possible once per shift. Keep on-line data as a more reliable information source and record a complete data set at least every minute.
2. Plot each parameter versus time in such scale to observe sudden spikes on data trends.
3. Log graphs in journal and keep them available at operator control room.
4. Log events of errors in control on the MBR system as well bad service and operation.

5. Try to analyze every upset in data trends (especially TMP, Flux and Permeability).
6. Trace water quality and its relation to system performance.
7. Trace the effect on water temperature to fouling ratio.

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# MBR PROCESS DATA SHEET

**Project Title**

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| | | | Feed | | | Recycle | | | | Filtrate | | | Bleed | Aeration | | | | Reactor | | | | | | | | | | | | Filtrate | | | | | |
| Date | Time | Machine Hours | Secondary Effluent="1", Primary Effluent="0" | Pressure (before screen filter) | Pressure (after screen filter) | Recycle Flow (to Membrane Tank) | Recycle Pressure (to Membrane Tank) | Recycle Flow (from Membrane Tank) | Recycle Pressure (from Membrane Tank) | Filtrate Flow | Transmembrane Pressure (TMP) (one minute after soak cycle) | TMP (one minute before soak cycle) | Bleed Flow | Air Flow (Aerobic Tank) | Air Pressure (Aerobic Tank) | Air Flow (Membrane Tank) | Air Pressure (Membrane Tank) | Feed pH | Feed Conductivity | Feed Temperature | Feed Turbidity | Dissolved Oxygen (Anoxic Tank) | Dissolved Oxygen (Aerobic Tank) | Dissolved Oxygen (Membrane Tank) | Sludge Viscosity (Membrane Tank) | Whatman Paper Filtration Volume | Filtrate Turbidity of Whatman Paper Filtrate | SV30 | SV30 Dilution Factor | Turbidity | Conductivity | SDI- Time to collect initial 500mL | SDI- Time to collect final 500mL | Operator Initials | Comments |
| mm/dd/yy | hh:mm | hours | - | "Hg | "Hg | gpm | psig | gpm | psig | gpm | "Hg | "Hg | gpd | scfm | psig | scfm | psig | - | mS/cm | °C | NTU | ppm | ppm | ppm | mPa-s | ml/5 min | NTU | mL/L | - | NTU | mS/cm | sec | sec | - | . |
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