PUBLIC HEALTH DIVISION
Drinking Water Services
Kate Brown, Governor

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October 5, 2021

Jason Diamond, PE
Suez Water Technologies & Solutions
Jason.diamond@suez.com

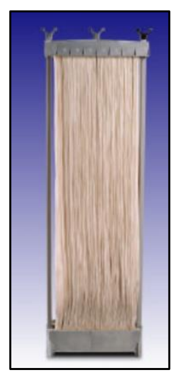
Re: City of Pendleton (PWS ID#00613)
Partial Membrane Module Replacement with 18 ZW500D Cassettes w/ Twenty (20) ZW500Ds Modules in Each Cassette
Conditional Approval – PR# 126-2021

Dear Mr. Diamond:

Thank you for submitting information regarding the membrane module replacement project for the City of Pendleton. On June 25, 2021 we received a project Summary from Bob Patterson, which summarized work encompassing the following:

1. Replacing existing older ZeeWeed® (ZW) 500C membrane modules with new ZW500D modules, PLC replacement hardware, and PLC software updates; and
2. Sandblasting and repainting all the concrete basins in the water filter plant with an NSF-61 approved paint system.

An online payment in the amount of $825 was received on July 29, 2021 to cover the cost of the plan review, assigned plan review (PR) #126-2021. Various subsequent e-mails containing the LRV programming and specifics of the membrane replacement project were received, including the number of new modules being installed (360 new modules and 18 new ZW500D cassettes), total number of trains (4), and the specific model of membrane modules (**360 new ZeeWeed® 500Ds hollow-fiber, outside-in, ultrafiltration modules with 350-ft^2 of membrane surface area per module**).



ZeeWeed® Module ↑

ZeeWeed® Cassette

Trains 1 & 2 will have a mixture of membrane modules as shown in the table below:

Trains	# and Type of Module in Each Train (surface area of each module)	
	# of new ZW500Ds Modules (350-ft^2 ea.)	# of pre-existing ZW500C Modules (250-ft^2 ea.) purchased and installed in 2011/2012
1 & 2	9 cassettes w/20 ZW500Ds modules in each train	3 cassettes w/26 ZW500C modules in each train
3 & 4	None	12 cassettes w/26 ZW500C modules in each train
Total	360 ZW500Ds modules in the 4 trains	780 ZW500C modules in the 4 trains

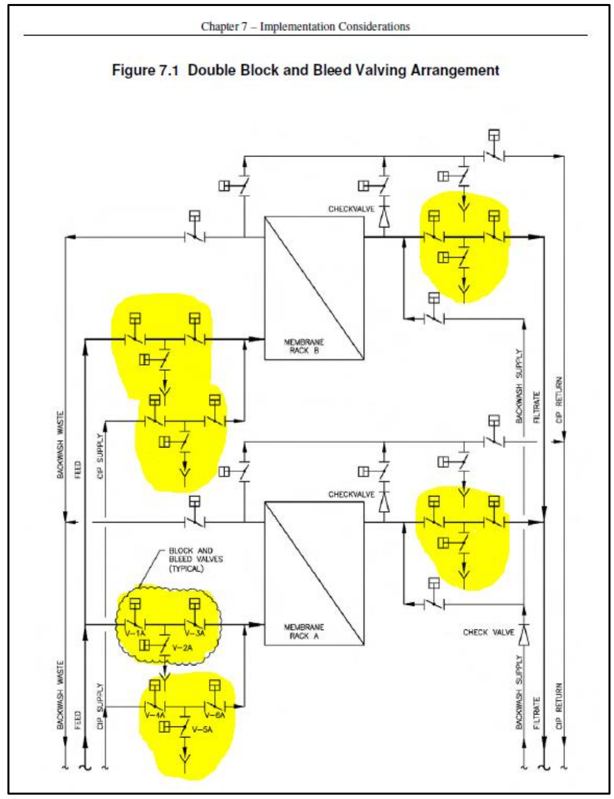
The Oregon Health Authority grants **Conditional Approval** for the project with the following conditions that will need to be met prior to granting Final Approval:

1. Documentation is submitted that demonstrates the coating applied to the inside of the membrane cells (trains) is ANSI/NSF Standard 61 approved for potable water applications.

2. Direct integrity testing parameters will need to be verified and programmed into the SCADA system. These parameters include:
   a. A **direct integrity test pressure**, which is to be set no less than 10.3 psi. It is understood that the starting direct integrity test pressure is anticipated to be 11 psi;
   b. An **upper pressure decay control limit** in psi/min is determined that indicates a failure of the direct integrity test and prompts an automatic shut-down of the filtration skid; and
   c. **A log removal value ($LRV_{ambient}$)** reflective of particle and pathogen removal in the 3 micron or less size range that is calculated every 15 minutes based on current ambient operating conditions (a metric commonly referred to as $LRV_{ambient}$) and the most recent direct integrity test result. In summary, **$LRV_{ambient}$** is the metric for demonstrating 4.0-log (99.99%) Cryptosporidium removal credited for the membrane filters.

3. Alarm set points are updated to reflect the following operating limits which, if exceeded, prompt an automatic shut-down of the filter skid:
   a. Maximum flux of 60 gfd, or equivalent flow setpoint. Since the membrane surface area of the ZW500C is 250-ft^2, 60 gfd equates to a flow of 10.41 gpm/module. Since the membrane surface area of the ZW500Dc is 350-ft^2, this equates to a flow of 14.58 gpm/module.
   b. Maximum transmembrane pressure (TMP) of 12 psi.
   c. Minimum $LRV_{ambient}$ of 4.0-log (calculated every 15 minutes and visible in SCADA)
   d. Maximum direct integrity test pressure decay rate as determined upon commissioning.
   e. An alarm set point established to trigger all four filter trains to shut down when the combined filter effluent turbidity exceeds 0.10 NTU for more than 15 minutes so that a direct integrity test can be performed on each of the 4 filter trains.
4. SCADA programming should ensure that the variables and constants used to determine the pressure decay rate and $LRV_{ambient}$ are viewable to the operator for verification purposes.

5. Measures are taken to ensure that the membrane filter train is isolated during the CIP. A double block-and-bleed system may be used to accomplish this as shown in the schematic to the right =>



Chapter 7 – Implementation Considerations

Figure 7.1 Double Block and Bleed Valving Arrangement

6. The Operation and maintenance manual is updated, or an addendum added to incorporate the new ZW500Ds specifications, including any necessary changes to the membrane testing and module fiber repair/pinning procedures.

The remainder of this letter includes:

1) Table 1 - Log removal credits (LRC) granted for the ZeeWeed® 500C and 500Ds modules.
2) Table 2 - Operating limits that help ensure that the log removal credits granted are met.
3) Appendix A - Explanation of operating limits and terms in Table 2.
4) Appendix B - Formulae and variables used in calculating the log removal value ($LRV_{ambient}$) of each membrane filter unit/train containing using current ambient operating conditions.
5) Appendix C – Product specifications for the ZeeWeed® 500C and 500Ds modules.
6) Appendix D – Combined filter effluent turbidity for indirect integrity monitoring letter.

When final approval is granted, the membrane filter trains will be granted log removal credits (LRCs) for pathogen removal as shown in Table 1. The LRCs are based on a verification of the Challenge Study Reports for the installed ZeeWeed® 500C and 500Ds membrane modules.

Table 1 – Filter Log Removal Credit (LRC) – ZeeWeed® 500C and 500Ds

Pathogen	Removal Credit (log_{10})
Giardia lamblia	4.0
Cryptosporidium sp.	4.0
Viruses	0.0

The LRCs above are only valid provided operations are within the limits shown in Table 2. Ensure SCADA/PLC programming accounts for the operating limits in Table 2 (e.g. set system alarms to ensure operating limits are met). **Some of the limits in Table 2 are yet to be determined as indicated by "TBD" and will need to be determined prior to Final Approval.**

Table 2 – Operating Limits

Operating Parameter	Limit
Direct integrity test (DIT) frequency	**Conduct at least 1 DIT each day of operation**
DIT duration/hold time	*5 min/300 sec*
DIT starting test pressure	*11 psi*
Minimum allowed DIT pressure	**10.3 psi (may change based on BP_{max})** throughout the DIT duration (starting test pressure is anticipated to be *11* psi) *SUEZ: Depends on BPmax, FSR to confirm maximum water level in membrane tank*
Maximum allowable pressure decay rate (PDR) upper control limit (UCL)	**UCL = TBD psi/min**
Minimum DIT pressure transducer accuracy for the established UCL[1]	***± 0.15% of span (-15 to 15 psi or 30 psi), 0.01 psi/min (equal to the stated accuracy of the ABB-614 pressure transducer installed).***
Membrane Minimum Performance ($LRV_{ambient}$)[2]	**$LRV_{ambient}$ = 4.0-log (must be ≥ 4.0-log LRC)**
DIT Sensitivity (LRV_{DIT})	**TBD log.** ***LRV_{DIT} as the maximum LRV that can be reliably demonstrated by the MIT***
Maximum transmembrane pressure (TMP)	**12 psi** at 20°C
Maximum allowed filtrate flux [gfd]	**60 gal/SqFt/day** @ 20°C. the following is to be verified: peak plant production of ***14,000*** **gpm using *240* out of *240* possible modules per filter train/cell** (***14.6*** **gpm/module**) *but plant design is for 9 MGD/6,250 gpm*. *1,563* gpm is programmed into the PLC as the maximum design flow per train (*27* gal/SqFt/day)
Combined filter effluent (CFE)[3]	CFE ≤ 0.1 NTU for ≥ 15 consecutive minutes
Combined filter effluent (CFE) turbidity	CFE ≤ 1 NTU in 95% of readings and always less than 5 NTU
Automatic Shutdown Conditions (shut filter train down and conduct a DIT to demonstrate membrane integrity is intact)	○ PDR > UCL ○ $LRV_{ambient}$ < LRC ○ CFE > 0.15 NTU for > 15 min ○ CFE > 5.49 NTU (may prompt boil water notice)

[1] **Pressure transducer accuracy** is based on the manufacturer's stated accuracy (best fit straight line), expressed as % of span. The accuracy calculated in terms of [psi/min] must be less than or equal to the UCL in [psi/min]. Accuracy in terms of [psi/min] is calculated as follows:

Accuracy in psi/min = (% Accuracy x Max of span in psi) / DIT duration in minutes

[2] **$LRV_{ambient}$** is the best metric for demonstrating compliance with the log removal credit (LRC) granted.

- $LRV_{ambient}$ must be equal to or greater than the LRC for *Cryptosporidium* shown in Table 1.
- Ensure that any $LRV_{ambient}$ values displayed in SCADA are calculated using the formulae and variables shown in Appendix B

[3]CFE turbidity is allowed indirect integrity monitoring due to the hydraulic conditions of the plant as per letter from Kari Salis (DWS Engineer) dated May 10, 2012 – see Appendix D.

Thank you for your cooperation during this process and if you have any questions on the information above, or would like this information in an alternate format, please contact me at 971-200-0288 or via e-mail at evan.e.hofeld@dhsoha.state.or.us.

Sincerely,

Evan Hofeld, PE
Regional Engineer
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Appendix A - Explanation of operating limits and terms in Table 2.

The operating limits summarized in Table 2 are further described as follows:

- Upper Control Limit (UCL) – TBD $^{psi}/_{min}$
  Every membrane system has an Upper Control Limit (UCL) measured in $^{psi}/_{min}$. The UCL is the highest **p**ressure **d**ecay **r**ate (PDR) allowed during a direct integrity test (DIT). Exceeding the UCL indicates DIT failure. The failing membrane unit shall not operate until it passes a DIT. Based on a review of Pendleton's specific system and information provided by the membrane manufacturer, the UCL is established to be TBD $^{psi}/_{min}$. Direct integrity tests that pass indicate that the membrane removes pathogens at the rate credited, e.g. 4.0 log (or 99.99%). Ensure that the SCADA/PLC system is programmed to account for this UCL.

- Membrane Performance ($LRV_{ambient}$): The results of the direct integrity test can also be used to determine the log removal value of *Cryptosporidium* that is based on ambient or current operating conditions ($LRV_{ambient}$). The main difference between LRV_{DIT} and $LRV_{ambient}$ is the use of the current operating flow when calculating $LRV_{ambient}$. Lower flows could yield a lower (less conservative) LRV value. **Since your pathogen removal credit is in terms of 4.0-log, membrane performance must be determined to demonstrate compliance with the pathogen credit awarded using the same unit of measure [log]. Formulae and variables used to calculate $LRV_{ambient}$ are included in Appendix B of this letter.** In summary, **$LRV_{ambient}$** is the metric for demonstrating compliance. $LRV_{ambient}$ must be equal to or greater than the log removal credit for *Cryptosporidium* shown in Table 1.

- TMP: **The transmembrane pressure or "TMP" (pressure drop across the membranes) must not exceed 12 psi.**

- Flux: **The flux ($^{flow}/_{filter\ feed\ area}$) must not exceed 60 gallons per square feet per day [$^{gal/SqFt}/_{day}$].**

- DIT Turbidity Trigger (CFE > 0.10 NTU for > 15 min): **A direct integrity test (DIT) must be performed on each of the 4 filter trains if the combined filter effluent (CFE) turbidity is greater than 0.10 NTU for more than 15 minutes. This must be programmed into the SCADA system.**

- DIT Daily Trigger: A DIT is also required each day of operation. If the pressure decay rate (PDR) drops below the upper control limit (UCL) of TBD $^{psi}/_{minute}$, then the DIT is considered to have failed and the unit must be automatically taken off-line, repaired, and retested to show that it passes a DIT before being placed back into service. In other words, should the PDR of the daily PDT (or "air hold test") exceed TBD $^{psi}/_{minute}$, this should indicate a "failed" DIT and the membrane must be taken out of service and may not be placed into service until it passes a DIT. **A new DIT may be immediately run after a DIT failure, or repairs may be needed first (e.g. fibers pinned, leaks at pipe fittings repaired, etc.) followed by passing a new DIT.**

- DIT test pressure: The minimum DIT pressure (i.e., the test pressure at the end of the DIT) must not drop below 10.3 psi. **Should the pressure during a DIT drop below 10.3 psi, the DIT is considered invalid or "failed" and must be repeated. Suez has established a DIT starting test pressure of 11 psi to help ensure that the minimum DIT pressure is met.**

- Automatic Shutdown Conditions: **The filters must be taken off-line or otherwise shut down, repaired and/or re-tested if any of the following occurs:**

    1. PDR > UCL. The DIT PDR exceeds the TBD $^{psi}/_{min}$ UCL.
    2. $LRV_{ambient}$ < LRC. The $LRV_{ambient}$ is less than the 4.0 log removal credit (LRC)
    3. CFE > 0.10 NTU for > 15 min. The combined filter effluent (CFE) turbidity exceeds 0.10 NTU for more than 15 minutes.
    4. Combined Filter Effluent (CFE) turbidity exceeds 5.49 NTU (a boil water notice may be required)

- DIT Sensitivity (LRV_{DIT}): The results of the direct integrity test (pressure decay rate or "PDR") and the design flow can be used to determine the DIT sensitivity, expressed as a log removal value of *Cryptosporidium* (LRV_{DIT}). This LRV_{DIT} must be equal to or greater than the log removal credit (LRC) shown in Table 1 (i.e., LRC = 4.0-log). A PDR of TBD $^{psi}/_{min}$ equates to an LRV_{DIT} of 4.0-log. **Please ensure that any LRV_{DIT} values displayed in SCADA are calculated using the formulae and variables shown in Appendix B. LRV_{DIT} has been calculated to be 4.0-log as shown in Appendix B.**

Appendix B - Formulae and variables used in calculating the log removal value ($LRV_{ambient}$) of each membrane filter train using current ambient operating conditions.

Formulae and variables used in calculating the log removal value ($LRV_{ambient}$) of each membrane filter train using current ambient operating conditions is shown in Table B.

Table B. Formulae and variables used in the $LRV_{ambient}$ programming

Specification	Value
$LRV_{ambient}$ equation	$LRV_{ambient} = \log_{10}(\frac{Q_P \bullet ALCR \bullet P_{atm}}{\Delta P_{test} \bullet V_{sys} \bullet VCF})$
ALCR equation	$ALCR_{Turbulent} = 170 \bullet Y \bullet \sqrt{\frac{(P_{test} - BP) \bullet (P_{test} + P_{atm})}{(460 + T) \bullet TMP}}$
P_{Test} equation	$P_{minend} = [(4.0 \bullet 10^6 \bullet \kappa \bullet \sigma \bullet \cos\theta)/d_{res}] + BP_{max}$ (a form of the formula: $P_{Test} = (0.193 \bullet \kappa \bullet \sigma \bullet \cos\theta) + BP_{max}$ leaving the defect diameter as a variable and using σ in terms of N/m and BP_{max} in terms of Pa)
Volume of pressurized air in module during direct integrity testing [gallons and liters]	TBD gallons/module (TBD liters/module)
V_{sys}, Total volume of pressurized air in the unit during direct integrity testing [gallons and liters]	TBD gallons (TBD liters)
VCF, Volumetric Concentration Factor [dimensionless]	TBD
VCF for backwash units in which filtrate goes to clearwell	N/A – no backwash recovery units
P_{atm}, Atmospheric pressure [psia]	TBD
Y, Net Expansion Factor [dimensionless]	Unk – N/A – use of laminar ALCR (0.588 is lowest from Crane[1] p. A-22)
d, Lumen diameter [mm]	0.8 I.D. [1.9 mm O.D.]
L, Potting depth or defect length [mm]	Unk – N/A – use of laminar ALCR
κ, Pore shape correction factor [dimensionless]	1.0
σ, surface tension at 0°C, N/m [dyne/cm]	0.07564 N/m [75.64 dyne/cm]
ϴ, Liquid-membrane contact angle [degrees]	TBD - 60 (ZW 500 CP5) - 65 (ZW 500 SMC)
Q_p, Maximum design flow rate [L/min]	TBD (TBD gpm)
BP_{max}, Maximum backpressure during the DIT [psi]	TBD (TBD inches of water)
P_{Test}, Applied direct integrity test pressure [psi] (*Should be ≥ minimum test pressure in Table 2*)	11 psi target starting DIT pressure 10.3 psi minimum ending DIT pressure
D_{base}, Baseline diffusive loss expected through fully intact membrane filter unit [psi/min]	TBD psi/min (TBD psi over a 5-min DIT)

Crane Co. 1988. *Flow of fluids through valves, fittings, and pipe*. Technical Paper No. 410. Stamford, CT.

DIT Minimum Test Pressure (P_{test} or P_{minend})

$P_{Test} = (0.193 \cdot \kappa \cdot \sigma \cdot \cos\theta) + BP_{max}$ is the general equation in which the 0.193 factor accounts for units conversion factors using σ in units of dyne/cm and BP_{max} in units of psi as well as the 3 micron defect diameter (d_{res}). Suez uses σ in units of N/m and BPmax in units of pascals and leaves the defect diameter as a variable, therefore, the following equation is used:

$$P_{minend} = \frac{4.0 \times 10^6 \times \kappa \times \sigma \times \cos\theta}{d_{res}} + BP$$

where:

P_{minend}	= minimum test pressure at the end of the pressure decay test (Pa, converted to plant specific units of pressure transmitter)
κ	= pore shape correction factor (dimensionless)
σ	= surface tension at the air-liquid interface (N/m)
θ	= liquid-membrane contact angle (°)
d_{res}	= direct integrity test resolution requirement (μm)
BP	= maximum backpressure on the system during the test (Pa)

In determining the value of P_{minend}, SUEZ assumes a conservative pore shape correction (κ) factor of 1, and a conservative surface tension at the air-liquid interface (σ) of 0.07564 N/m (corresponding to 0°C). The contact angle for ZeeWeed membranes has been verified through third party testing, as described in section 2.4. Section 2.5 describes the calculation of the maximum backpressure.

2.6 how does SUEZ determine the recommended starting test pressure for the MIT resolution?

In order to start the PDT at a test pressure sufficient to allow for decay to occur while remaining above the minimum test pressure (P_{minend}), SUEZ also determines a recommended minimum start pressure ($P_{minstart}$) for the test:

$$P_{minstart} = P_{minend} + 3447$$

where:

$P_{minstart}$	= minimum test pressure at the start of the pressure decay test (Pa, converted to plant specific units of pressure transmitter)
P_{minend}	= minimum test pressure at the end of the pressure decay test (Pa, converted to plant specific units of pressure transmitter)
3447	= selected as a reasonable minimum pressure drop during the test of 3447 Pa or 0.5 psi

2.7 how does SUEZ measure the actual test pressures?

The actual test pressures at the start ($P_{MITstart}$) and end (P_{MITend}) of the MIT are measured by a pressure transmitter on the permeate header which is pressurized with air during the test. In some membrane plants, there may be backpressure on the pressure transmitter due to water remaining in the piping above the pressure transmitter ($H_{verticalpipe}$), as shown in figure 2.5.1 and figure 2.5.2. In such cases, the actual pressure transmitter readings must be corrected for this backpressure by subtracting $H_{verticalpipe}$ from the pressure transmitter reading.

$$P_{MITend} = P - H_{verticalpipe} \times \text{conversion factor from plant specific units of level transmitter to Pa}$$

where:

P_{MITend}	= pressure on the side of the membranes that is pressurized with air at the end of the MIT, corrected for backpressure on the pressure transmitter (Pa)
P	= reading from pressure transmitter including backpressure on the pressure transmitter (Pa)
$H_{verticalpipe}$	= height of water remaining in the piping above the pressure transmitter tap (plant specific units of level transmitter)

Maximum Backpressure (BP_{max})

2.5 how is the maximum backpressure on the membranes calculated?

The backpressure on the system is taken as the backpressure at the bottom-most fibers, where the backpressure is the highest. The backpressure on the system is calculated differently for immersed and pressurized membranes. The calculations used for each type of membrane system are described below.

2.5.1 backpressure for immersed membranes

For an immersed membrane system, the MIT is performed by pressurizing the inside of the membrane fibers. Typically, the membrane tank remains full of water. The backpressure on the system is due to the water column in the membrane tank during the MIT. As the water level in the membrane tank may vary, SUEZ calculates the maximum backpressure (BP = BP_{max}) on the system during the test for each MIT using the water level measured in the tank following the pressurization of the system.

The backpressure is calculated as follows:

$$BP = \left(H_{fibers} - H_{topfibers} + BP\_Level\right) \times 9.80638 \ \ Pa/mm$$

where:

BP	= backpressure on the system during the test (Pa)
H_{fibers}	= distance between top-most and bottom-most membrane fibers (mm, see section 5.2 for values)
$H_{topfibers}$	= water level at the top of the membrane fibers, measured by the membrane tank level transmitter (mm)
BP_Level	= Purge Level = water level in the membrane tank following pressurization with air (mm)

The relevant water levels are illustrated in figure 2.5.1 below.

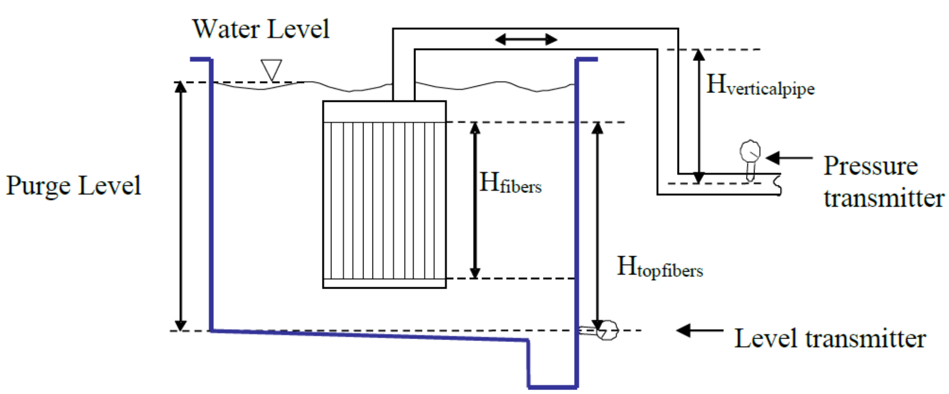


figure 2.5.1: water levels for backpressure calculation for immersed membranes

DIT Sensitivity (LRV_{DIT})

$$LRV_{DIT} = \log_{10}\left(\frac{Q_{pmax} \times ALCR\_{sensitivity} \times P_{atm}}{\Delta P_{test\_sensitivity} \times V_{sys\_sensitivity} \times VCF\_{sensitivity}}\right)$$

In the context of sensitivity, the inputs to the LRV equation are therefore selected as follows:

LRV_{DIT}	= direct integrity test sensitivity in terms of LRV (dimensionless)
Q_{pmax}	= maximum design filtrate flow rate (m^3/s)
$ALCR\_{sensitivity}$	= air-liquid conversion ratio used for sensitivity calculation (dimensionless)
P_{atm}	= atmospheric pressure (Pa, absolute)
$\Delta P_{test\_sensitivity}$	= smallest rate of pressure decay rate that can be reliably measured and associated with a known integrity breach during the integrity test (Pa/s)
$V_{sys\_sensitivity}$	= maximum volume of pressurized air in the membrane unit during the test used for sensitivity calculation (m^3)
$VCF_{sensitivity}$	= average volumetric concentration factor based on design conditions used for sensitivity calculation (dimensionless)

$$LRV_{DIT} = \log \bullet \left(\frac{Q_p \bullet ALCR \bullet P_{atm}}{\Delta P_{test} \bullet V_{sys} \bullet VCF}\right)$$

$Q_{p\ actual}$	TBD	gpm
Actual $ALCR_{DP}$	TBD	-
P_{atm}	TBD	psia
Corrected Operational ΔP_{test}	TBD	psi/min
V_{sys}	TBD	gallons
VCF	TBD	-

$LRV_{DIT\ (DP)}$ =	TBD

Air-Liquid Conversion Ratio (ALCR)

$$T = \frac{9}{5} \times T_{airCelcius} + 32$$

Substituting the Fahrenheit to Celsius relationship into the ALCR equation for the Hagen-Poiseuille Model modifies the equation as shown below:

$$ALCR = \frac{527 \times \Delta P_{eff} \times \mu_w}{TMP \times \mu_{air} \times (460 + T)}$$

$$ALCR = \frac{527 \times \Delta P_{eff} \times \mu_w}{TMP \times \mu_{air} \times \left(460 + \frac{9}{5} \times T_{airCelsius} + 32\right)}$$

The equation for ΔP_{eff} can be simplified as follows:

$$\Delta P_{eff} = \left[(P_{test} - BP)\right] \times \left[\frac{(P_{test} + P_{atm}) + (BP + P_{atm})}{2 \times (BP + P_{atm})}\right] \times \left[\frac{(BP + P_{atm})}{P_{atm}}\right]$$

$$\Delta P_{eff} = \left[(P_{test} + P_{atm}) - (BP + P_{atm})\right] \times \left[\frac{(P_{test} + P_{atm}) + (BP + P_{atm})}{2}\right] \times \left[\frac{1}{P_{atm}}\right]$$

$$\Delta P_{eff} = \left[\frac{(P_{test} + P_{atm})^2 - (BP + P_{atm})^2}{2 \times P_{atm}}\right]$$

$$ALCR = \frac{293 \times (P_{testa}{}^2 - BP_a{}^2) \times \mu_w}{2 \times P_{atm} \times TMP \times \mu_{air} \times (273.15 + T_{airCelcius})}$$

where:

μ_w	= viscosity of water at the time that the flow and TMP data is captured (Pa-s)
TMP	= transmembrane pressure (Pa)
μ_{air}	= viscosity of air at the time of the MIT (Pa-s)
$T_{airCelsius}$	= air temperature at the time of the MIT (°C)

Upper Control Limit (psi/min)

$$UCL = \frac{Qp \bullet ALCR \bullet P_{atm}}{10^{LRV} \bullet V_{sys} \bullet VCF}$$

(Equation 4.17 EPA Manual)

Q_p	TBD	gpm	
$ALCR_{DP}$	TBD		
P_{atm}	TBD	psia	Atmospheric Pressure
V_{sys}	TBD	gallons	
LRC	4	-	Minimum log removal credit (LRC) value to be accepted
VCF	TBD	-	Deposition mode configuration standard value

UCL_{DP} = TBD psi / min

$LRV_{ambient}$

$$LRV = \log_{10}\left(\frac{Q_p \times ALCR \times P_{atm}}{\Delta P_{test} \times V_{sys} \times VCF_{avg}}\right)$$

where:

LRV	= log removal value (dimensionless)
Q_p	= membrane unit filtrate flow (plant specific units of flow transmitter, converted to m^3/s)
ALCR	= air-liquid conversion ratio (dimensionless)
P_{atm}	= atmospheric pressure (plant specific units of pressure transmitter, converted to Pa, absolute)
ΔP_{test}	= rate of pressure decay measured and associated with integrity breaches (Pa/s)
V_{sys}	= volume of pressurized air in the membrane unit during the test (m^3)
VCF_{avg}	= VCF = average volumetric concentration factor (dimensionless)

ΔP_{test}

4.5 how does SUEZ calculate ΔP_{test}?

The pressure decay rate measured during the membrane integrity test is not entirely attributable to integrity breaches. ZeeWeed membranes allow diffusion of compressed air through the membrane pores. In order to account for this, the pressure decay rate associated with integrity breaches is calculated as follows:

$$\Delta P_{test} = \Delta P_m - D_{base}$$

where:

ΔP_{test} = pressure decay rate associated with integrity breaches (Pa/s)

ΔP_m = pressure decay rate measured during the membrane integrity test (Pa/s)

D_{base} = pressure decay rate associated with diffusion (Pa/s)

The pressure decay rate measured during the membrane integrity test (ΔP_m) is calculated as follows:

$$\Delta P_m = \frac{P_{MITstart} - P_{MITend}}{t_{PDT}}$$

where:

$P_{MITstart}$ = pressure at the beginning of the pressure decay test (Pa)

P_{MITend} = pressure at the end of the pressure decay test (Pa)

t_{PDT} = duration of pressure decay (s)

Appendix C – Product specifications for the ZeeWeed® 500C and Ds modules.

Characteristics regarding the membrane modules are provided in Table A.

Table A. Membrane Filter Module Specifications

Specification	Value	
Membrane Manufacturer	Suez	
Membrane Model Number	ZW 500C	ZW 500Ds (s = short)
Challenge test standard (ANSI/NSF 419-YY, ETV, etc.)		
Challenge test report date		
$LRV_{C\text{-}Test}$	-log	
OHA-DWS Challenge Study Verification Information Assumes a __psi maximum backpressure (BP_{max}) =>	Date Verified = Oct 2013 LRC = 4.0-log (Giardia/Crypto) Max Flux = 60 GFD @ 20°C Max TMP = 12 psi Minimum DIT Pressure = 10.29 psi	
ANSI/NSF Standard 61 certification (yes/no)	Yes	
Membrane type (*e.g.*, hollow fiber, etc.)	Hollow fiber	
Number of fibers per module		
Fiber inside (lumen) diameter	0.8 I.D. [1.9 mm O.D.]	
Fiber wall thickness	0.55 mm	
Active fiber length (length of fibers not in potting)	mm	
Potting depth	mm	
Membrane classification (*e.g.,* ultra- or micro-filtration)	Ultrafiltration	
Nominal membrane pore size (*e.g.*, 0.01 µm, etc.)	0.04 µm	
Membrane material (*e.g.*, PVDF, polysulfone, etc.)	PVDF	
Roughness coefficient	0.75 µm (0.00075 mm)	
Feed side membrane filtration area (ft^2)	250 (23.2 m^2)	350 (32.5 m^2)
Filtration Flow Direction (*i.e.*, inside-out or outside-in)	Outside-in	
Hydraulic configuration (*i.e.*, deposition or suspension)	Deposition	
Submerged or Pressurized	Submerged	

table 2.4: summary of liquid-membrane contact angles (θ) and bubble point pressures ($P_{bubblept}$)

membrane (fiber)	liquid-membrane contact angle (θ) used by SUEZ	$P_{bubblept}$ (Pa)
ZW500 (CP5)	60°	50,427
ZW500 (SMC)	65°	42,622
ZW1000 (CP3)	60°	50,427
ZW1000 (CP5)	65°	42,622
ZW1000 (CPX)	53°	60,695
ZW1500 (CPX)	53°	60,695

ZeeWeed® 500C and 500D listed on verified list of membrane modules (9-29-21):

Alternative Treatment Technology Units Meeting Challenge Study Criteria

Oregon Health Authority

Oregon Administrative Rule 333-061-0050(4)(c)(I)

Oregon Health Authority, Drinking Water Services (DWS)

» MEMBRANE FILTERS «

(Other models not on this list may meet the criteria.
Contact DWS for details on verifications for units not listed.)

Manufacturer	Model	Log_{10} Removal Credit			Maximum Flux (gfd @ 20°C)	Maximum TMP (psi @ 20°C)	Maximum Flow/Module (gpm)	Minimum Static DIT[B] Pressure (psi)	Date Verified
		Crypto.	*Giardia*	Virus[A]					
Dow	XUSV-5203	3.5	3.5	0	60	30	23	30	2010 Feb
	SFD-2880XP	4.0	4.0	0	70	24	41	19	2010 Dec[C]
	SFD-2860XP	4.0	4.0	0	62	30	26	19	2010 Dec
	DW102-1100	4.0	4.0	0	70	30	50.2	30.25	2013 Jan[C]
GE Zenon	ZeeWeed 500C	4.0	4.0	0	60	12	10.4	10.29	2013 Oct
	ZeeWeed 500D	4.0	4.0	0	60	12	18.3	10.29	2013 Oct
	ZeeWeed 1000 V3	4.0	4.0	0	30	13	17	10	2009 July
	ZeeWeed 1000 V4	4.0	4.0	0	60	13	17.4	10	2013 Oct
DuPont inge (formerly BASF)	dizzer XL 0.9 MB 60 W	4.0	4.0	0	105	22	47	17.5	2015 Sept[C]
	dizzer XL 0.9 MB 70 WT	4.0	4.0	0	105	22	55	17.8	2015 Sept[C]
	dizzer XL 0.9 MB 80 WT	4.0	4.0	0	105	22	55	17.8	70 WT equiv.
Pall	UNA-620A	4.0	4.0	0	120	35	44	17.5	2010 Feb
	USV-6203	4.0	4.0	0	120	35	44	17.5	2010 Feb
	XUSV-5203	4.0	4.0	0	120	35	33	17.5	2010 Feb
Scinor	SMT 600-P50	4.0	4.0	0	120	43.5	46	21	2015 June[C]
	SMT 600-P80	4.0	4.0	0	120	43.5	72	21	P50 equivalent
	SMT 600-S26	4.0	4.0	0	106	11	23.5	15.9	2016 June[C]

[A] Virus removal credits are not available in Oregon due to lack of a direct integrity test for virus-sized particles. All approvals and removal credits are subject to change should information indicate the model is not capable of meeting regulatory requirements.

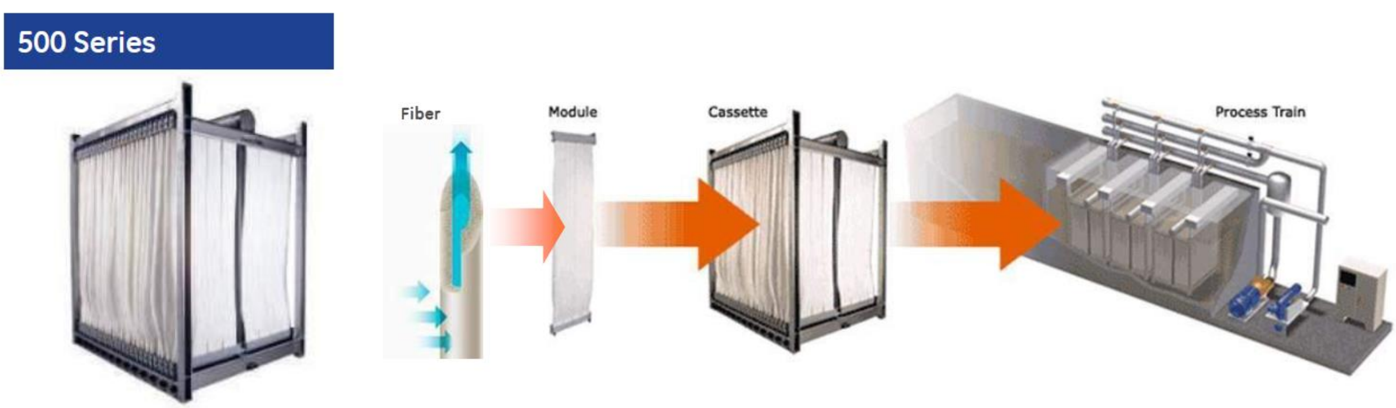
[B] DIT = Direct Integrity Test. Acceptable pressure decay rates during a DIT are, in part, a function of system volume and must be confirmed with DWS during plan review for each installation. Additionally, minimum static pressure may be higher than listed here if backpressure is above minimums.

[C] Verification via NSF 'Public Drinking Water Equipment Performance'

For more information, please call the OHA Drinking Water Services at ph. 971-673-0405 (8am-5pm PT, Mon-Fri)

Updated: 16 October 2020

Page 1 of 3



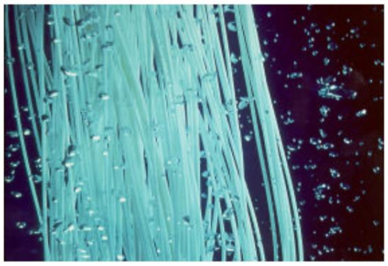


Figure 1 Photo of ZeeWeed Hollow Fibre Membrane Bundle

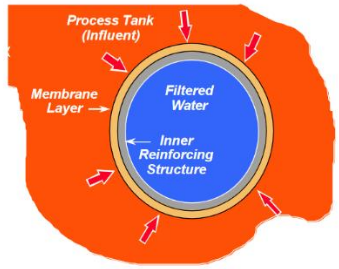


Figure 2 Cross Section of ZeeWeed® Fibre

Figure 3 ZeeWeed® Membrane Module

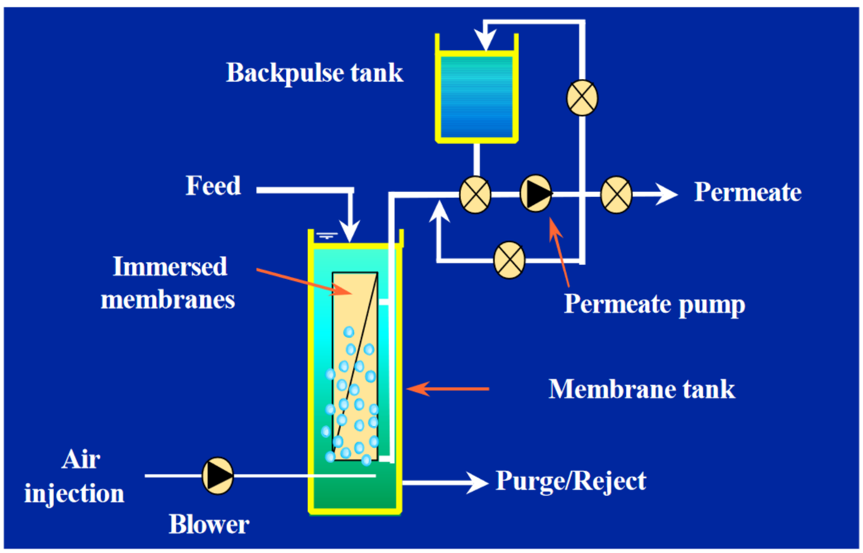


Figure 5 ZeeWeed® Process Flow Diagram

Figure 4 ZeeWeed® Membrane Module Cassette

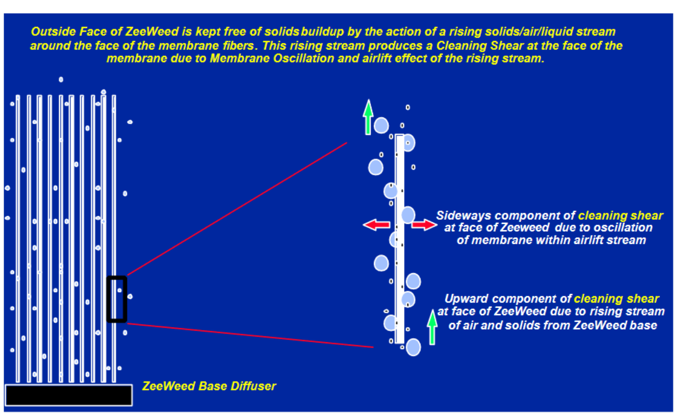


Figure 6 ZeeWeed® Air Scour

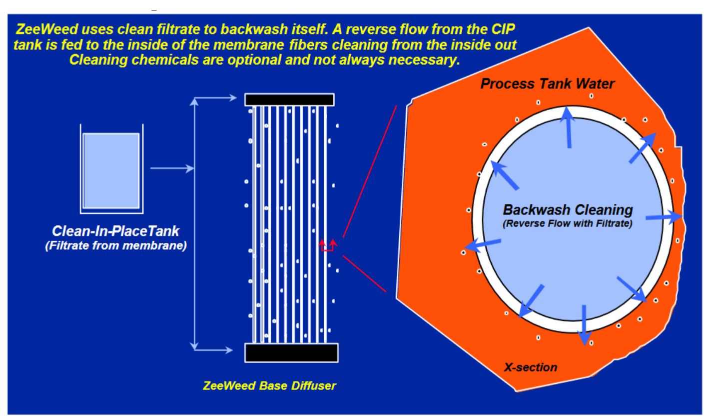
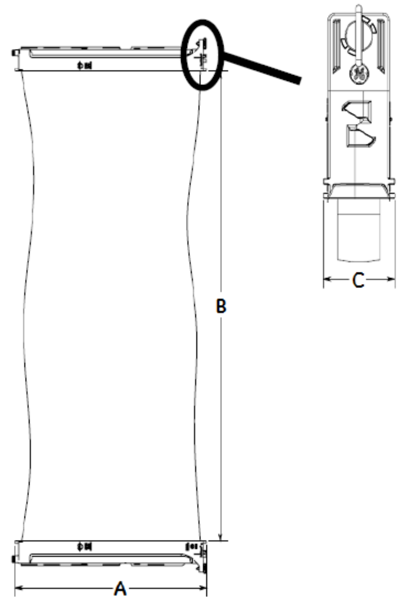


Figure 7 ZeeWeed® Backpulse

Suez ZeeWeed® 500Ds Hollow Fiber PVDF Ultrafiltration Module for Submerged Applications
Outside-in flow operated in dead-end deposition mode

membrane	H_{fibers} (mm)
ZW500c	1,710
ZW500d (short)	1,555

ZeeWeed* 500D Module



Module Dimensions				
Applica-tion	Product	Width (A) mm (in)	Header-to-Header Length (B) mm (in)	Depth (C) mm (in)
MBR	500D	844 (33.2)	1,940 (76.4)	49 (1.9)
Water	500D			52 (2.1)
	500Ds		1,577 (62.1)	52 (2.1)

	Module Properties								
Application	Membrane Surface Area m² (ft²)	Max. Shipping Weight [1] kg (lb)	Lifting Weight [2] kg (lb)	Material	Nominal Pore Size (μm)	Fibre Diameter (mm)	Surface Properties	Fibre Tensile Strength (N)	Flow Path
MBR	40.0 (430)	28 (61)	28 – 75 (61 – 164)	PVDF	0.04	2.2	Non-ionic & Hydrophilic	> 600	Outside-In
Water	40.9 (440)	32 (70)	30 – 74 (66 – 163)			1.9			
	32.5 (350)	26 (57)	26 - 72 (57 – 159)			1.9			

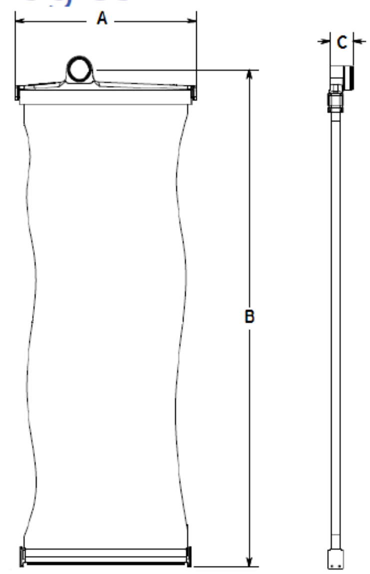
[1] Packaged
[2] Varies with solids accumulation

Operating & Cleaning Specifications						
Application	TMP Range kPa (psig)	Max. Operating Temp. °C (°F)	Operating pH Range	Max. Cleaning Temp. °C (°F)	Cleaning pH Range	Max. Cl_2 Conc'n (ppm)
MBR	-55 to 55 (-8 to 8)	40 (104)	5.0-9.5	40 (104)	2.0 – 10.5 (<30°C) 2.0 -10.0 (30-40°C)	1,000
Water	-90 to 90 (-13 to 13)					

Suez ZeeWeed® 500C Hollow Fiber PVDF Ultrafiltration Module for Submerged Applications
Outside-in flow operated in dead-end deposition mode

GE Power & Water
Water & Process Technologies

ZeeWeed* 500C Module



membrane	H_{fibers} (mm)
ZW500c	1,710
ZW500d (short)	1,555

Module Dimensions

Product	Width (A) mm (in)	Height (B) mm (in)	Depth (C) mm (in)
250	720 (28.3)	1,888 (74.3)	93 (3.7)

Module Properties

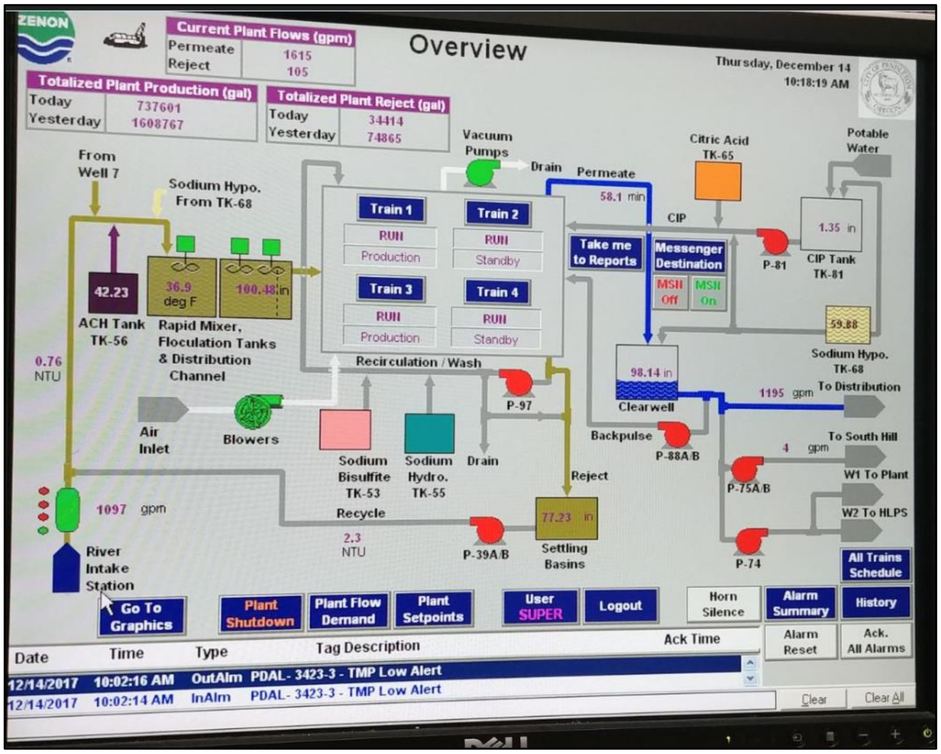
Application	Product	Nominal Membrane Surface Area m^2 (ft^2)	Max. Shipping Weight* kg (lb)	Lifting Weight** kg (lb)	Material	Nominal Pore Size (µm)	Surface Properties	Fiber Diameter (mm)	Flow Path
MBR	250	23.2 (250)	22 (48)	18-60 (39-135)	PVDF	0.04	Non-ionic & Hydrophilic	OD: 1.9 ID: 0.8	Outside-In
Non-MBR	250	23.2 (250)	22 (48)	18-60 (39-135)					

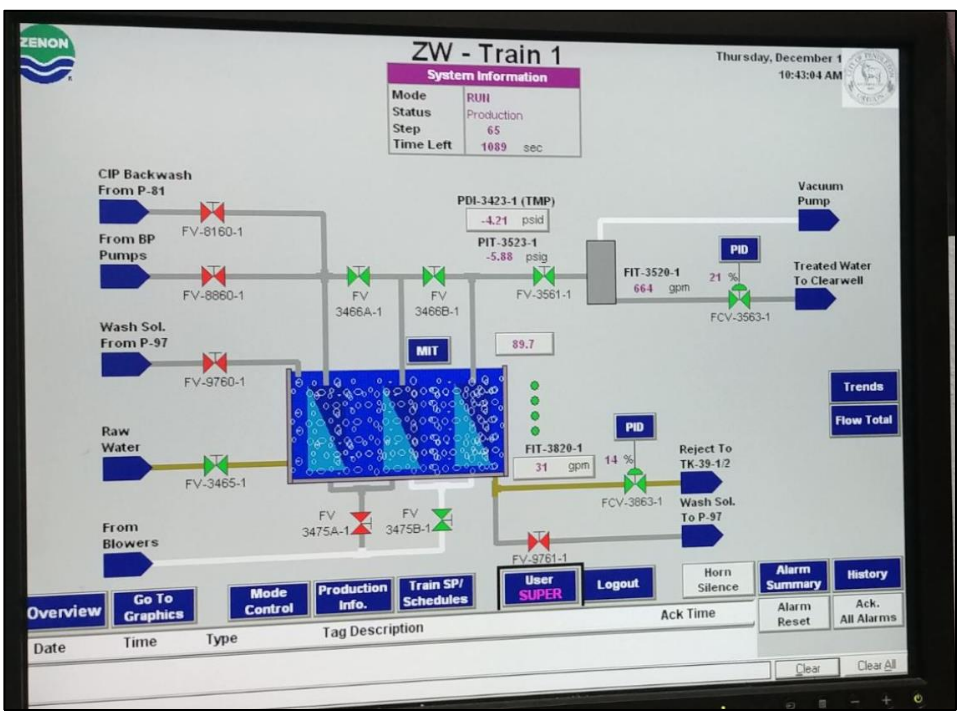
* Packaged
** Varies with solids accumulation

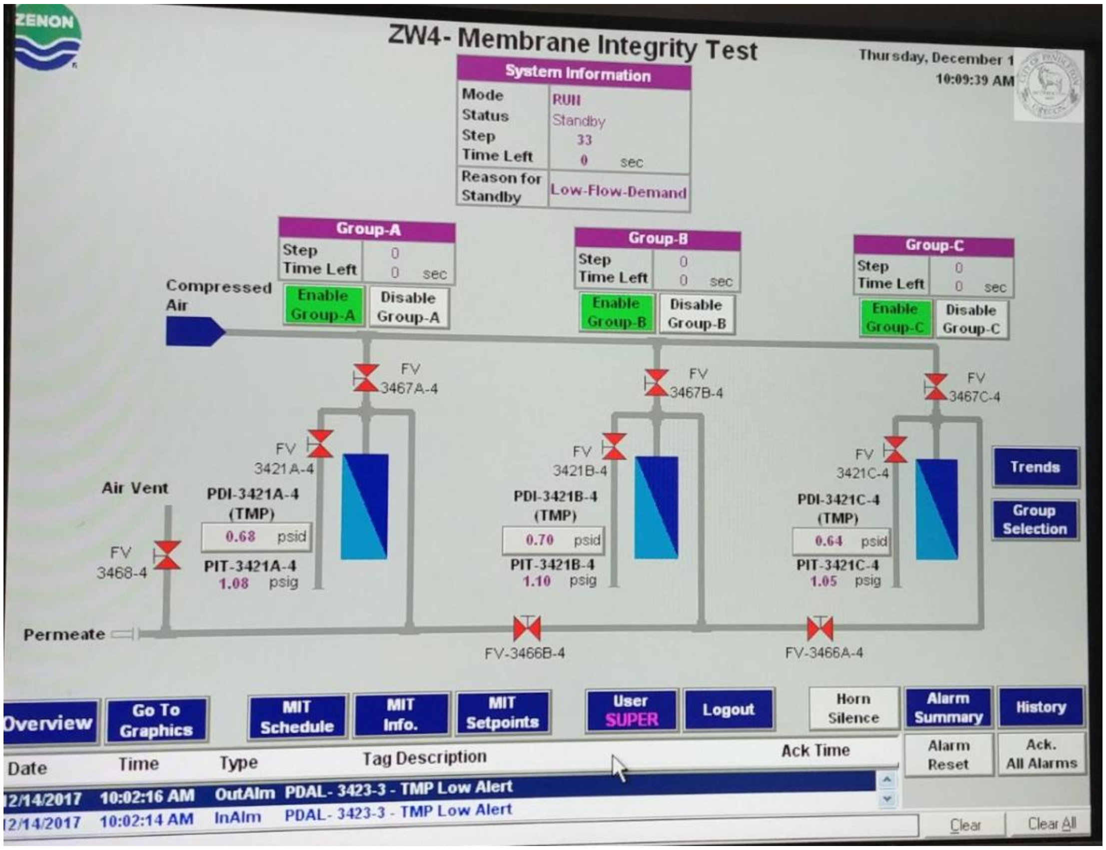
Operating & Cleaning Specifications

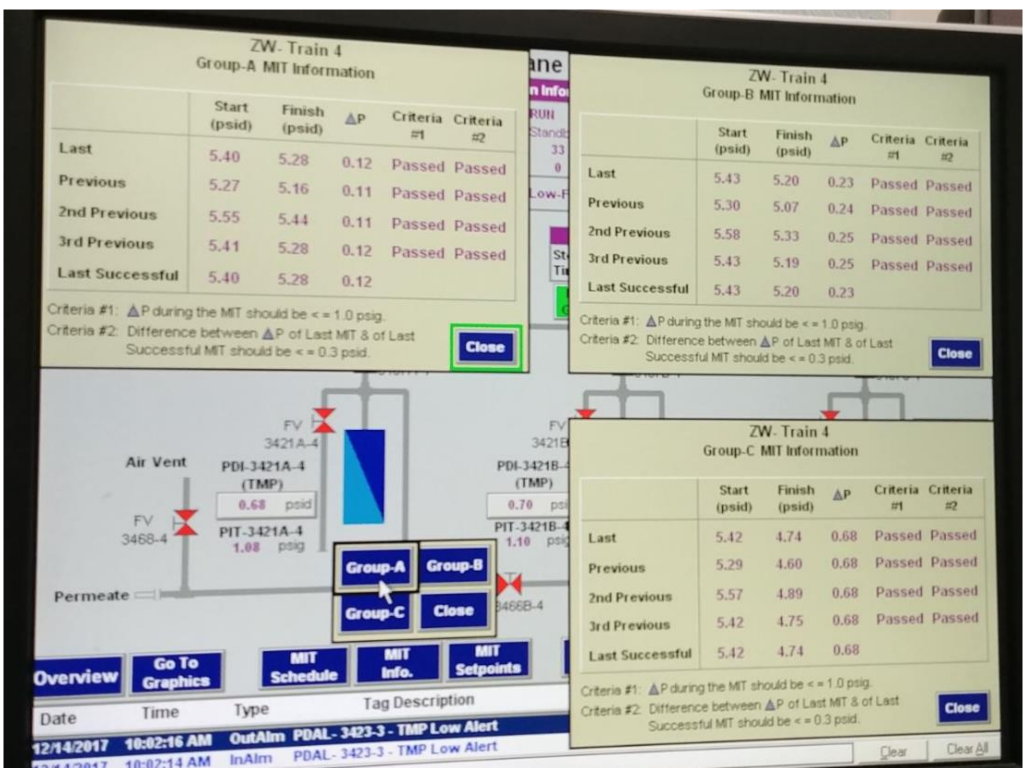
Application	Product	TMP Range kPa (psig)	Max. Operating Temp. °C (°F)	Operating pH Range	Max. Cleaning Temp. °C (°F)	Cleaning pH Range	Max. Cl_2 Conc'n (ppm)
MBR	250	-55 to 55 (-8 to 8)	40 (104)	5.0-9.5	40 (104)	2.0 – 10.5 (<30°C) 2.0 -10.0 (30-40°C)	1,000
Non-MBR	250	-90 to 90 (-13 to 13)					

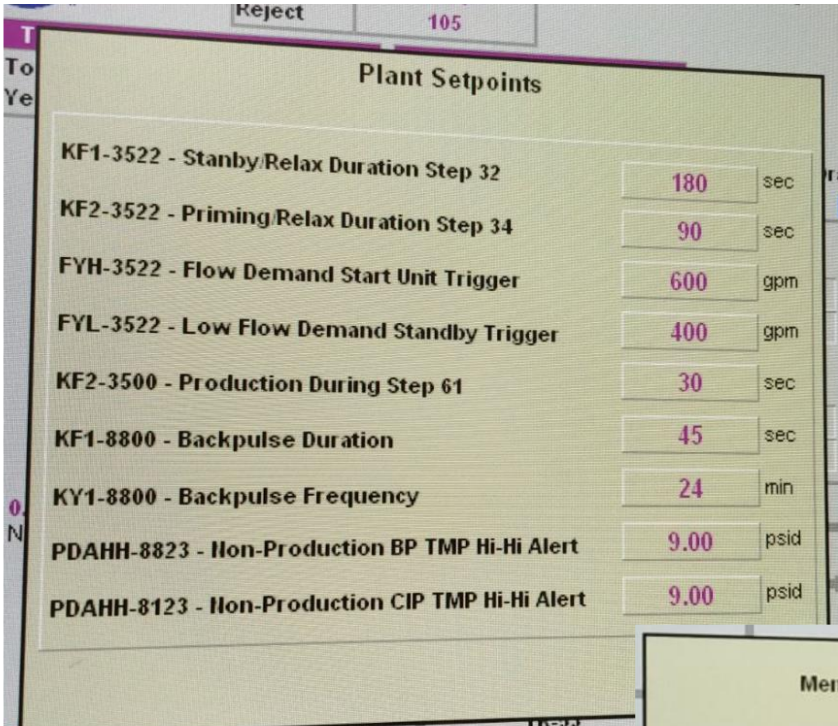
Pendleton SCADA Screens (2017)

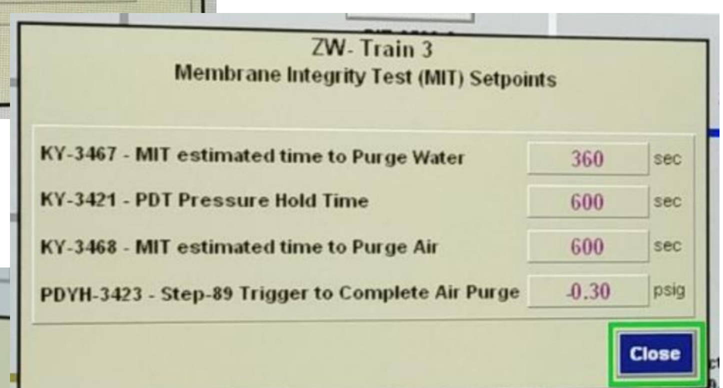


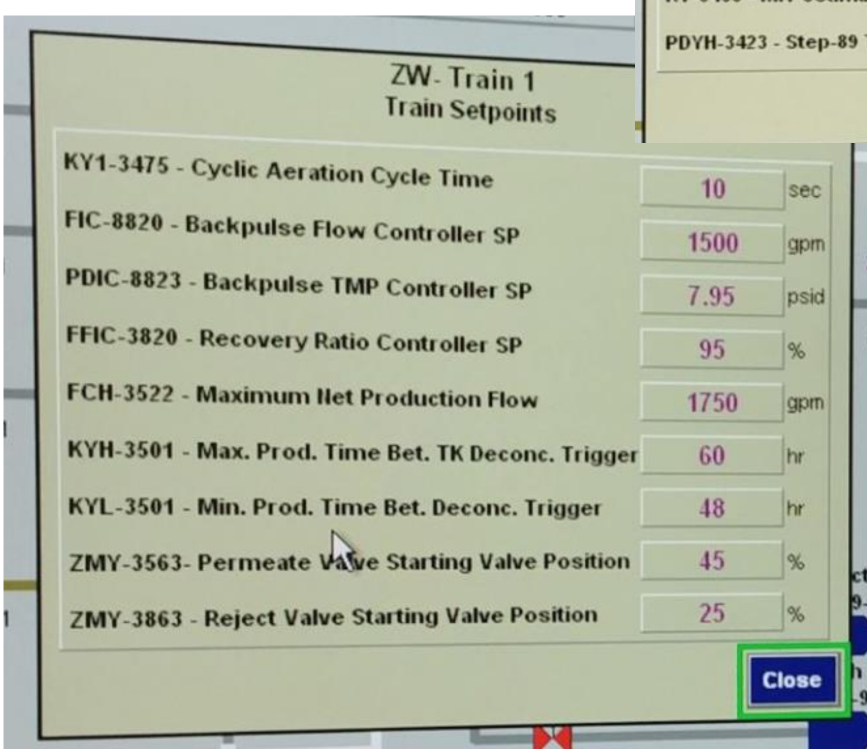



ZENON
ZW4- Membrane Integrity Test
Thursday, December 1
10:09:39 AM
System Information
Mode RUN
Status Standby
Step 33
Time Left 0 sec
Reason for Standby Low-Flow-Demand
Group-A
Step 0
Time Left 0 sec
Enable Group-A
Disable Group-A
Group-B
Step 0
Time Left 0 sec
Enable Group-B
Disable Group-B
Group-C
Step 0
Time Left 0 sec
Enable Group-C
Disable Group-C
Compressed Air
FV 3467A-4
FV 3467B-4
FV 3467C-4
FV 3421A-4
FV 3421B-4
FV 3421C-4
Air Vent
PDI-3421A-4 (TMP)
0.68 psid
PDI-3421B-4 (TMP)
0.70 psid
PDI-3421C-4 (TMP)
0.64 psid
FV 3468-4
PIT-3421A-4
1.08 psig
PIT-3421B-4
1.10 psig
PIT-3421C-4
1.05 psig
Trends
Group Selection
Permeate
FV-3466B-4
FV-3466A-4
Overview
Go To Graphics
MIT Schedule
MIT Info.
MIT Setpoints
User SUPER
Logout
Horn Silence
Alarm Summary
History
Date
Time
Type
Tag Description
Ack Time
Alarm Reset
Ack. All Alarms
12/14/2017 10:02:16 AM OutAlm PDAL- 3423-3 - TMP Low Alert
12/14/2017 10:02:14 AM InAlm PDAL- 3423-3 - TMP Low Alert
Clear
Clear All


ZW- Train 4
Group-A MIT Information
	Start (psid)	Finish (psid)	ΔP	Criteria #1	Criteria #2
Last	5.40	5.28	0.12	Passed	Passed
Previous	5.27	5.16	0.11	Passed	Passed
2nd Previous	5.55	5.44	0.11	Passed	Passed
3rd Previous	5.41	5.28	0.12	Passed	Passed
Last Successful	5.40	5.28	0.12		
Criteria #1: ΔP during the MIT should be <= 1.0 psig.
Criteria #2: Difference between ΔP of Last MIT & of Last Successful MIT should be <= 0.3 psid.
Close
ZW- Train 4
Group-B MIT Information
	Start (psid)	Finish (psid)	ΔP	Criteria #1	Criteria #2
Last	5.43	5.20	0.23	Passed	Passed
Previous	5.30	5.07	0.24	Passed	Passed
2nd Previous	5.58	5.33	0.25	Passed	Passed
3rd Previous	5.43	5.19	0.25	Passed	Passed
Last Successful	5.43	5.20	0.23		
Criteria #1: ΔP during the MIT should be <= 1.0 psig.
Criteria #2: Difference between ΔP of Last MIT & of Last Successful MIT should be <= 0.3 psid.
Close
ZW- Train 4
Group-C MIT Information
	Start (psid)	Finish (psid)	ΔP	Criteria #1	Criteria #2
Last	5.42	4.74	0.68	Passed	Passed
Previous	5.29	4.60	0.68	Passed	Passed
2nd Previous	5.57	4.89	0.68	Passed	Passed
3rd Previous	5.42	4.75	0.68	Passed	Passed
Last Successful	5.42	4.74	0.68		
Criteria #1: ΔP during the MIT should be <= 1.0 psig.
Criteria #2: Difference between ΔP of Last MIT & of Last Successful MIT should be <= 0.3 psid.
Close
Air Vent
PDI-3421A-4 (TMP)
0.68 psid
FV 3468-4
PIT-3421A-4
1.08 psig
Permeate
Group-A
Group-B
Group-C
Close
Overview
Go To Graphics
MIT Schedule
MIT Info.
MIT Setpoints
Date
Time
Type
Tag Description
12/14/2017 10:02:16 AM OutAlm PDAL- 3423-3 - TMP Low Alert
InAlm PDAL- 3423-3 - TMP Low Alert


Reject
105
Plant Setpoints
KF1-3522 - Stanby/Relax Duration Step 32 | 180 | sec
KF2-3522 - Priming/Relax Duration Step 34 | 90 | sec
FYH-3522 - Flow Demand Start Unit Trigger | 600 | gpm
FYL-3522 - Low Flow Demand Standby Trigger | 400 | gpm
KF2-3500 - Production During Step 61 | 30 | sec
KF1-8800 - Backpulse Duration | 45 | sec
KY1-8800 - Backpulse Frequency | 24 | min
PDAHH-8823 - Non-Production BP TMP Hi-Hi Alert | 9.00 | psid
PDAHH-8123 - Non-Production CIP TMP Hi-Hi Alert | 9.00 | psid


ZW- Train 3
Membrane Integrity Test (MIT) Setpoints
KY-3467 - MIT estimated time to Purge Water | 360 | sec
KY-3421 - PDT Pressure Hold Time | 600 | sec
KY-3468 - MIT estimated time to Purge Air | 600 | sec
PDYH-3423 - Step-89 Trigger to Complete Air Purge | -0.30 | psig
Close


ZW- Train 1
Train Setpoints
KY1-3475 - Cyclic Aeration Cycle Time | 10 | sec
FIC-8820 - Backpulse Flow Controller SP | 1500 | gpm
PDIC-8823 - Backpulse TMP Controller SP | 7.95 | psid
FFIC-3820 - Recovery Ratio Controller SP | 95 | %
FCH-3522 - Maximum Net Production Flow | 1750 | gpm
KYH-3501 - Max. Prod. Time Bet. TK Deconc. Trigger | 60 | hr
KYL-3501 - Min. Prod. Time Bet. Deconc. Trigger | 48 | hr
ZMY-3563- Permeate Valve Starting Valve Position | 45 | %
ZMY-3863 - Reject Valve Starting Valve Position | 25 | %
Close

Appendix D
Letters regarding allowing CFE in lieu of IFE turbidity for indirect integrity testing

OREGON PUBLIC HEALTH DIVISION
Office of Environmental Public Health
John A. Kitzhaber, MD, Governor

Oregon Health Authority
800 NE Oregon St., Suite 640
Portland, OR 97232-2162
Voice – (971) 673-0405
FAX – (971) 673-0694
www.oregon.gov/DHS/ph/dwp

May 10, 2012

Bob Patterson, P.E.
City of Pendleton, PWS #4100613
500 SW Dorion Avenue
Pendleton, Oregon 97801

Dear Bob:

Thank you for your February 24, 2012 letter regarding the results of the pilot test for continuous indirect integrity monitoring by measuring turbidity on each individual membrane train's effluent. The results of the pilot test have been reviewed. The City has adequately demonstrated the operational difficulties of performing this monitoring due to the siphon design of the water treatment plant.

In lieu of measuring effluent turbidities of each individual membrane train, **the City is allowed to measure the combined filter effluent (CFE) turbidity using a control limit of 0.10 NTU**. Anytime two consecutive 15-minute readings exceed 0.10 NTU, all four trains must be shut down and direct integrity tests must be performed each unit. Water production may only resume for those membrane units that pass the direct integrity test. In any case, direct integrity tests must be performed no less than daily on each unit that is in use. The treatment plant's programming must be revised to incorporate the CFE control limit no later than June 15, 2012. Please let Bill Goss or I know when this has been done.

If you have any questions please call Bill Goss at 541-966-0900, or me at 971-673-0423.

Sincerely,

Kari Salis, P.E.
Technical Services Region 1 Manager
OHA Drinking Water Program

cc: Bill Goss, P.E., OHA Drinking Water Program, Pendleton

CITY OF PENDLETON

Public Works Department
500 S.W. Dorion Avenue
Pendleton, Oregon 97801-2090
Telephone (541) 966-0202
FAX (541) 966-0251
TDD Phone (541) 966-0230

February 24, 2012

RECEIVED
FEB 2 7 2012
FIELD SERVICES
DRINKING WATER PROGRAM

Kari Salis, PE
OHA – Drinking Water Program
800 NE Oregon Street
Portland, OR 97232-2162

RE: Results of Membrane Filtration Turbidity Pilot Test – Siphon Design

Dear Kari:

This letter is to notify you of the results of the City of Pendleton, PWS 4100613, pilot test for continuous turbidity monitoring under a siphon design at our membrane filtration plant.

As stated in our letter dated August 20, 2010, regarding the continuous indirect integrity testing, City worked with Paul Berg, PE, of CH2M Hill to determine the feasibility of various means of meeting this requirement. City's membrane filtration system is a vacuum-driven system that utilizes a gravity-based siphon to create negative pressure for all four of our membrane trains. In addition to our turbidimeter and particle counter installed at a downstream location of combined permeate under positive pressure, we have installed and have been operating individual turbidity monitoring for each train under negative pressure to meet the new continuous turbidity monitoring requirement.

We installed small sample pumps for each membrane train to direct a sample stream to a de-aeration chamber from which a steady stream is fed to the turbidity equipment. The additional turbidity monitoring equipment was installed in October 2010 and went on-line in early January 2011. We have since operated for over 12 months.

We have now burned out 13 pumps due to cavitation caused by entrained air from the siphon and air scour system for the membranes. We increased size of the sample pumps, but still continue to have the issue of burning out the pumps from cavitation related issues.

We have had multiple membrane trains shut down numerous times by turbidity monitoring due to the pumps burning out and no longer feeding the de-aeration chamber. Staff must then respond to the call-out and replace the pump and conduct an MIT in order to put the membrane train back into service. We have yet to identify a bad membrane or bad element header, where the membranes are potted into the main housing, from use of turbidity meters. We are able to identify bad membranes or bad elements when we perform the MIT.

None of this additional monitoring that we have performed in our pilot test has provided for an increase in public health protection for our customers. It has added to our burden for maintenance and operation of our facility – affecting staff time and overall production.

We have had Bill Goss from OHA – DWP Pendleton office at the plant. He reviewed the installation of the turbidity monitoring equipment. We have kept him apprised of our findings throughout our pilot test period. We conveyed that we would give this pilot test 12 months of operation to determine our next course of action. We are now past 12 months.

We attest, as before conducting the pilot test, that the additional turbidity monitoring provides no net public health protection and is not suitable for a membrane treatment plant operating with a siphon design operating under negative pressure for permeate from individual membrane trains.

We hereby request consideration to discontinue our pilot test and turbidity monitoring for each individual membrane train. We will continue to perform daily MIT which has meaningful public health implications and utilize our turbidity and particle count monitoring equipment for combined permeate under positive pressure.

If you have specific questions about the results of our pilot test, please contact Tim Smith, Control Systems Manager, at 541-966-4518. I can be reached at 541.966.0202.

Sincerely,

Bob Patterson, PE
Public Works Director

BP:bp:jh
copy: Bill Goss, PE, OHA—DWP, Pendleton Office
Tim Smith, Control Systems Manager
Karen King, Regulatory Specialist
File: WTP Regulatory Requirements