August 14, 2025

Jeremy Wolford - jwolford@gawsa-or.org
Green Area Water & Sanitary Authority
5585 Grange Road
Roseburg, OR 97470

Sent by email only

Re: Membrane Replacement – PR#2021-84
Green Area Water & Sanitary Authority – PWS # 00717
Conditional Approval

Dear Jeremy Wolford:

Thank you for submitting information to Oregon Health Authority's Drinking Water Services (DWS) regarding the membrane module replacement for Green Area Water & Sanitary Authority. On May 25, 2021, we received plans for replacing the existing Memcor S10V membrane modules with Memcor S10N modules. A plan review fee payment of $825 was also received.

The proposed work is to replace the existing Memcor S10V membrane modules with the newer Memcor S10N modules, and program the ambient log removal value ($LRV_{ambient}$) calculations into SCADA for both membrane units.

Membrane Filtration Process

1. Direct Integrity Testing (DIT) parameters will need to be verified and programmed into the PLC/SCADA system. These parameters include:
    a. An ongoing **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 and the most recent DIT result. In summary, $LRV_{ambient}$ is the performance indicator used to demonstrate the minimum 4.0-log (99.99%) *Cryptosporidium* removal that the membrane filters have been credited with.

   b. A **maximum pressure decay rate (PDR_{max})**, which is set no higher than 0.95 $^{psi}/_{min}$ that indicates a failure of the DIT and prompts an automatic shut-down of the filtration skid.

2. Indirect Integrity Testing is performed by continuously monitoring individual filter effluent (IFE) turbidity on each membrane unit. If IFE turbidity readings are above 0.15 NTU for a period of greater than 15 minutes, the associated membrane unit must immediately be taken off-line and a DIT performed.
3. The operations and maintenance manual is updated to include a diagnosis and repair plan for the new modules such that the ability to remove pathogens is not compromised.

When final approval is granted, the membrane modules 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 Report for the Evoqua Memcor S10N membrane modules.

Table 1 – Filter Log Removal Credit (LRC)

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

In summary, **$LRV_{ambient}$** is the best metric for demonstrating compliance with the log removal credit (LRC) granted. To remain in compliance, $LRV_{ambient}$ must be equal to or greater than the log removal credit for *Cryptosporidium* shown in Table 1. $LRV_{ambient}$ values displayed in SCADA should be calculated using the formulas and variables shown in the membrane supplier's calculations, and its use as a compliance parameter are included in Appendix B – Demonstrating Compliance and Performance using $LRV_{ambient}$.

Until we receive verification that the conditions have been met and final approval has been issued, the new membranes is not approved for use. Upon completion of the project, the engineer must verify in writing that construction was completed according to the submitted plans. If substantial changes are made, a set of as built drawings must be submitted. Documentation demonstrating how the above conditions were met should reference Plan Review #2021-84 and can be emailed to me at rebecca.a.templin@oha.oregon.gov.

Thank you for your cooperation during this process and if you have any questions about the above information, or would like this information in an alternative format, please feel free to email me or call me at 541-650-4868.

Sincerely,

Rebecca Templin, PE
Regional Engineer
OHA-Drinking Water Services

ec: Zach Golik, OHA-DWS: ZACHARIAH.CUNNINGHAM-GOLIK@oha.oregon.gov

Enclosures:

- Appendix A – Explanation of Operating Limits and Terms
- Appendix B – Demonstrating Compliance and Performance using $LRV_{ambient}$

Appendix A
Operating Limits and Definition of Terms

The operating limits are listed in Table A, followed by definitions of the terms in this Appendix. Table A should be confirmed once plan review has been finaled.

Table A – Operating Limits

Operating Parameter	Limit
DIT frequency	Conduct at least 1 DIT on each unit for each day of operation
DIT starting test pressure[1]	16.5 psi
Minimum allowed DIT pressure	11.4 psi throughout the DIT duration
PDR_{max}	0.95 $^{psi}/_{min}$
Minimum DIT pressure transducer accuracy for the established PDR_{max}[2]	± 0.2% of span (indicate span in psi)
LRV_{max}	4.8-log. LRV_{max} is the maximum LRV that can be reliably demonstrated by the DIT
Maximum TMP	22 psi at 20°C
Maximum allowed filtrate flux	80 $^{gal/SqFt}/_{day}$ @ 20°C

[1] DIT starting pressure will be specified in the membrane supplier's test protocol and calculations.

[2] **Pressure transducer accuracy** is typically based on the manufacturer's stated accuracy (best-fit straight line), expressed as % of span. A pressure transducer accuracy of $^{+}/_{-}$ 10% of the DIT pressure span is recommended. The accuracy calculated in terms of [$^{psi}/_{min}$] must be less than or equal to the PDR_{max}.

Accuracy in terms of [$^{psi}/_{min}$] is calculated as follows:

$$\text{Accuracy in } {}^{psi}/_{min} = {}^{(\%\text{ Accuracy x Max of span in psi})} / {}_{\text{DIT duration in minutes}}$$

The ability of membranes to filter out pathogens (referred to as **membrane integrity**) is to be tested in two ways:

Direct Integrity Testing

1) Once a day using a more direct pressure decay or "air hold" test, often called a **"Direct Integrity Test" (DIT)** because the air hold test is a direct test for leaks or broken membrane fibers.

Indirect Integrity Testing

2) Continuously using a turbidimeter that monitors the effluent turbidity from each membrane unit, often called **individual filter effluent (IFE)** turbidity monitoring.

Direct Integrity Testing (DIT):

Like checking for leaks in a car tire, the membranes are pressurized with air and held for a set amount of time. Air hold times are generally 2 – 10 minutes. A pressure sensor then detects a drop in the held pressure. This pressure drop is called a pressure decay, measured in psi [$^{lbs.}/_{sq.\ in.}$]. How fast the pressure drops (or decays) is called the **pressure decay rate (PDR)**, expressed in $^{psi}/_{minute}$. The PDR is the drop in pressure [psi] divided by the air hold time [minutes]. In some cases, the SCADA will display only the pressure decay in psi, and it is up to the operator to know the hold time and determine the decay rate in $^{psi}/_{minute}$.

Direct Integrity Testing using P_{Test}:

For a DIT to be able to demonstrate that the membranes are intact (do not have holes or broken fibers) –

1. the membrane first needs to be pressurized to a certain minimum pressure (the **minimum DIT pressure – sometimes called P_{Test}**) and
2. the PDR needs to be under a specified upper limit or **"maximum pressure decay rate" (PDR_{max})**.

Indirect Integrity Testing (DIT):

Turbidity monitoring is “indirect integrity testing.”

Should IFE turbidity exceed 0.15 NTU for more than 15 consecutive minutes, the membrane unit needs to be taken out of service and undergo a DIT. Turbidity is an indirect indicator of membrane integrity, and a DIT is needed to explicitly determine membrane integrity.

$LRV_{ambient}$ – Demonstrating continuous pathogen removal:

The results of the daily DIT can be used to calculate a pathogen removal efficiency under ambient operating conditions achieved by the membranes. This log removal value is termed **“$LRV_{ambient}$”** and can be used to demonstrate compliance by directly comparing this performance metric to the log removal credit (**LRC**) *Cryptosporidium* awarded in Table 1 in the letter.

More detail on the terms introduced above and the operating limits (*e.g.*, PDR_{max}) in Table A are further described as follows:

Glossary

- DIT Turbidity Trigger (IFE > 0.15 NTU for > 15 min):
  A DIT must be performed on each filter unit if the IFE turbidity is greater than 0.15 NTU for more than 15 minutes. This must be programmed into the SCADA system. Should the IFE turbidity exceed 0.15 NTU for more than 15 minutes, the membrane unit must be taken out of service and undergo a DIT. The membrane unit must not be placed back into service unless it passes the DIT (see PDR_{max} below). Membrane fiber repair/pinning is often needed to remedy this situation.

- DIT Daily Trigger:
  A DIT is also required each day of operation. If the resulting PDR exceeds the PDR_{max}, then the DIT is considered to have failed and the unit must remain 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 pressure decay test (PDT or "air hold test") exceed the PDR_{max}, 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 (P_{Test}):
  As mentioned above on Page 2, the minimum DIT pressure (*i.e.*, the test pressure at the end of the DIT) must not drop below the minimum DIT pressure stated in Table A. **Should the pressure during a DIT drop below the level in Table A, the DIT is considered invalid or "failed" and must be repeated.**

- PDR_{max}:
  Every membrane system has a maximum pressure decay rate (PDR_{max}) measured in $^{psi}/_{min}$. This is the highest PDR allowed during a DIT. Exceeding the PDR_{max} indicates DIT failure. The failing membrane unit shall not operate until it passes a DIT. Ensure that the SCADA/PLC system is programmed to account for this PDR_{max}.

- DIT Sensitivity (can be used to determine "LRV_{max}"):
  The results of a DIT and the design flow can be used to determine the DIT sensitivity, expressed as a log removal value of *Cryptosporidium* (LRV_{max}). This LRV_{max} must be equal to or greater than the log removal credit (LRC) shown in Table 1.

- Membrane Performance ($LRV_{ambient}$):
  The results of the DIT will be used to determine the log removal value of *Crypto.* that is based on ambient or current operating conditions ($LRV_{ambient}$). The main difference between LRV_{max} and $LRV_{ambient}$ is the use of the current operating flow when calculating $LRV_{ambient}$. Lower flowrates could yield a lower $LRV_{ambient}$ value.
  Variables used to calculate $LRV_{ambient}$ are included in Table A. In summary, $LRV_{ambient}$ is the metric for demonstrating compliance. $LRV_{ambient}$ must be equal to or greater than the LRC for *Crypto.* shown in Table 1.

- Transmembrane Pressure (TMP):
  The TMP is the pressure drop across the membranes and must not exceed the maximum value indicated in Table A.

  Flux:
  The flux ($^{flow}/_{filter\ feed\ area}$) is the flow per square feet of membrane surface area on the feed or inlet side of the membranes per day [$^{gal/SqFt}/_{day}$]. The flux must not exceed that indicated in Table A.

- 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. $PDR > PDR_{max}$.
     The DIT PDR exceeds the PDR_{max} in Table A.

  2. $LRV_{ambient} < LRC$.
     The $LRV_{ambient}$ is less than the LRC in Table 1.

  3. IFE > 0.15 NTU for > 15 min.
     The IFE turbidity exceeds 0.15 NTU for more than 15 minutes.

  4. Combined Filter Effluent (CFE) turbidity exceeds 5.49 NTU (your regulator should be contacted as a boil water notice may be required)

Appendix B – Demonstrating Compliance and Performance using $LRV_{ambient}$

The Oregon Health Authority will more directly assess pathogen removal efficiencies of membrane filter treatment plants. The current practice of determining compliance using pressure decay rates (PDR) alone is insufficient. Monitoring a decay rate just once per day by itself is not as representative of filter performance as continuously calculating the log removal value based on current operating conditions (**$LRV_{ambient}$**) for the filter.

Rather than relying solely on pressure decay rates obtained during direct integrity testing as the indicator of filter performance, Oregon is also requiring continuously monitoring the log removal value. The following explains this rationale:

1) Log removal values using ambient operating conditions (**$LRV_{ambient}$**) should be calculated to assure filter performance for the following reasons:
   - $LRV_{ambient}$ is the clearest way to 'demonstrate a removal efficiency' equal to or greater than the log removal credit (**LRC**) awarded. (The LRC is typically set by Oregon at 4.0.)
   - $LRV_{ambient}$ is the closest approximation to quantifying *Cryptosporidium* removal efficiency.
     - Reliance on staying below the maximum allowable pressure decay rate in a Direct Integrity Test means relying on a fixed limit established based on the LRC and the design flow rate, not current conditions. Therefore, the PDR alone does not represent current continuous performance as well as $LRV_{ambient}$.
   - The actual, ambient, removal efficiency is dependent on the most recent direct integrity test results, transmembrane pressure (TMP), temperature, and flow rate which may result in an $LRV_{ambient}$ lower than the LRC. $LRV_{ambient}$ gives a more accurate picture of ongoing performance.

2) Operators will need to be able to easily view parameters on their SCADA to:
   - verify current values that accurately characterize installed membranes and their performance; and
   - facilitate programming changes needed when the type or number of membrane modules changes or during SCADA and other programming upgrades

How do I add $LRV_{ambient}$ to my SCADA/PLC programming?

Water systems using a membrane filter are also now required to clearly demonstrate how $LRV_{ambient}$ is calculated. This means SCADA must display $LRV_{ambient}$ and the variables and equations used in its calculation. This allows an operator (or regulator) to quickly review the performance of the filters.

There are only a few equations, which may be displayed in SCADA using a graphic such as the ones shown below.

$$LRV_{ambient} = \log_{10}\left(\frac{Q_P \bullet ALCR_{ambient} \bullet P_{atm}}{\Delta P_{test} \bullet V_{sys} \bullet VCF}\right)$$

$$P_{test} = \left(0.193 \bullet \kappa \bullet \sigma \bullet \cos\theta\right) + BP$$

$$ALCR_{Turbulent} = 170 \bullet Y \bullet \sqrt{\frac{(P_{test} - BP) \bullet (P_{test} + P_{atm})}{(460 + T) \bullet TMP}}$$

The example SCADA screen below shows how these formulas were added at the top of the city of Lebanon's SCADA screen.

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

Equation 4.9 from MFGM

$$ALCR = 170 \bullet Y \bullet \sqrt{\frac{(P_{test} - BP) \bullet (P_{test} + P_{atm})}{(460 + T) \bullet TMP}}$$

Equation C.4 from MFGM (Turbulent Flow ALCR Calc)

Last MIT Results

LRV Parameters	UF1	UF2	UF3	UF4
Y:	0.7500	0.7500	0.7500	0.7500
P(test), psi:	21.22	20.91	20.86	20.64
BP, psi:	3.82	3.82	3.82	3.82
P(atm), psi:	14.70	14.70	14.70	14.70
T, °F:	52.97	52.97	48.67	49.74
TMP, psi:	1.44	1.80	3.78	2.12
ALCR:	64.65	66.47	71.57	84.49
Q(p), gpm:	191.7	264.0	491.1	443.0
ΔP(test), psi/min:	-0.005	-0.005	0.0040	-0.006
V(sys), gal:	1083.2	1083.2	1083.2	1083.2
VCF:	1.00	1.00	1.00	1.00
LRV:	5.30	5.30	5.07	5.30
Timestamp:	04/08 10:56	04/08 11:21	04/08 12:40	04/08 12:10

Calculated Current LRV

Real Time LRV:	5.30	5.30	5.30	5.30

<u>SCADA Screen Example</u>

The equations in the EPA's <u>Membrane Filtration Guidance Manual</u> are complex. The example below provides a template for programmers/integrators to use when setting up a SCADA system. DWS can provide guidance for other examples (e.g., turbulent condition calculations, rather than the laminar equation, are provided below).

Direct Integrity Test (DIT) Results	
Filter Unit ID	
PDR_{Max} (aka Upper Control Limit, UCL) [$^{psi}/_{min}$]	
DIT Interval or Frequency [hrs; must be at least once each day that water is filtered]	
Most Recent DIT Decay Rate [$^{psi}/_{min}$]	
Date of last DIT	mm/dd/yyyy
Time of last DIT	hh:mm
DIT Duration [min]	
DIT Starting Test Pressure [psi]	
DIT Ending Test Pressure [psi]	
Minimum Required Direct Integrity Test Pressure (P_{test})	
Minimum Required DIT Ending Test Pressure, P_{test} [psi]	
Equation for minimum required test pressure to achieve a resolution of 3µm breach [psi]: $P_{test} = (0.193 \bullet \kappa \bullet \sigma \bullet \cos\theta) + BP$	
Pore Shape Correction Factor, κ	
Air-liquid interface Surface tension, σ [$^{dynes}/_{cm}$]	
Liquid-membrane contact angle, ϴ [degrees]	
Maximum Back Pressure During the DIT, BP [psi]	
Ambient LRV Using Most Recent DIT Results ($LRV_{ambient}$)	
Filter Unit ID	
Log Removal Credit (LRC)	**4.0**
$LRV_{ambient}$	
General $LRV_{ambient}$ Equation $LRV_{ambient} = \log_{10}\left(\frac{Q_P \bullet ALCR_{ambient} \bullet P_{atm}}{\Delta P_{test} \bullet V_{sys} \bullet VCF}\right)$	
Current Filtrate Flow, Q_p [gpm]	
Atmospheric Pressure, P_{atm} [psi]	
Most Recent DIT decay rate, ΔP_{test} [$^{psi}/_{min}$]	
Volume of module [$^{gal}/_{module}$]	
Total Volume of modules [gal]	
Total System Volume, V_{sys} [gal]	
Volumetric Concentration Factor, VCF [dimensionless]	

Ambient Air to Liquid Conversion Ratio, $ALCR_{ambient}$ [dimensionless]	
Air-Liquid Coversion Ratio (ALCR)[1]	
$ALCR_{ambient}$ Equation (turbulent example) $ALCR_{Turbulent} = 170 \bullet Y \bullet \sqrt{\frac{(P_{test} - BP) \bullet (P_{test} + P_{atm})}{(460 + T) \bullet TMP}}$	
Current Feed Temperature, T [°F]	
Current Transmembrane Pressure, TMP [psi]	
Net Expansion Factor, *Y* [dimensionless]	0.588

[1] ALCR should be calculated using the Darcy equation for turbulent flow through hollow fiber membranes, and use a net expansion factor of 0.588. There are several approaches to calculating ALCR outlined in the *Membrane Filtration Guidance Manual* (EPA, 2005). OHA recommends the combination of the turbulent Darcy model with a fixed net expansion factor as the most conservative approach to calculating $LRV_{ambient}$.