Application for Waiver from Construction Standards for Public Water Systems

Revised March 2025

Water System Name: City of Newport PWS ID: OR41 00566
Project or Facility: City of Newport Water Filtration Facility County: Lincoln
Need for waiver identified: ☐ Water System Survey Date of Survey:

☐ Plan Review #

Construction standard requested to be waived: OAR 333-061-0050 (4)(c)(D) 0.5-log disinfection of Giardia

As provided under OAR 333-061-0055, OHA may grant waivers from the construction standards prescribed by these rules:

(a) When it is demonstrated to the satisfaction of OHA that strict compliance with the rule would be highly burdensome or impractical due to special conditions or causes; and
(b) When the public or private interest in the granting of the waiver is found by OHA to clearly outweigh the interest of the application of uniform rules; and
(c) When alternate measures are provided which, in the opinion of OHA, will provide adequate protection to the health and safety of the public including the ability to produce water which does not exceed the maximum contaminant levels listed in rule 333-061-0030.

Describe situation that conflicts with the standard.
City desires temporary disinfection for 4-log virus and 0.11-log Giardia for two months while the existing Clearwell is out of service for repair. See attached memorandum

Describe why meeting the standard is highly burdensome or impractical.
Standard requires 0.28 MG tank. Alternate approach requires 0.08 MG tank. Cost savings anticipated to be $1.4M. Constrained site does not allow large tank. See attached memorandum

Describe proposed alternate measure that provide adequate protection to public health and safety.
Increase membrane filtration effectiveness (LRV) to compensate for any reduction with inactivation of Giardia such that the total WTP achieves 4.5 log Giardia removal/inactivation. Other provisions as noted in the attached memorandum.

EMAIL this form along with plans of proposed waiver request and additional supporting information to your regulator or dws.planreview@odhsoha.oregon.gov. If you are unable to send your documents electronically, please contact OHA before mailing them.

*Signature: Steve Stewart	Date: 7/31/2025

*Use Adobe Acrobat E-sign: https://helpx.adobe.com/acrobat/using/signing-pdfs.html

Continue to page 2

Name: Steve Stewart

Address: 169 SW Coast Highway

City/State/Zip: Newport, OR 97365

Phone Number: 541-265-7421

Email Address: s.stewart@NewportOregon.gov

☐ Comments:

☑ Attachments (describe):

Justification for the waiver and description of the proposed alternative are outlined in the attached memorandum.

OHA Use Only

Waiver ID: 2025-0551

Entered into waiver database ☑

☐ Plan Review Coordinator's notes:

DWS formed a workgroup to review this request. Workgroup comments are summarized below.

After due consideration the above requested waiver from the construction standards of OAR 333-061-0050 is hereby:

☑ Approved

☐ Denied

Comments:

During an 8-week period only, Newport may reduce the pathogen inactivation provided by chlorine and increase the pathogen removal provided by membrane filtration, as follows:

- Chlorine minimum = 1.3 ppm, with a higher target suggested

8/28/2025

Technical Services Unit or Regional Manager
OHA Drinking Water Services

Date

Waiver database updated ☐

Plan Review Coordinator's Comments:

During an 8-week period only, Newport may reduce the pathogen inactivation provided by chlorine and increase the pathogen removal provided by membrane filtration, as follows:

- Chlorine minimum = 1.3 ppm, with a higher target suggested
- Minimum contact time with chlorine = 6.2 min
- Maximum flow = 2500 gpm
- Temporary tank = 80,000 gal, minimum operating depth 14.5 feet
- Minimum giardia inactivation = 0.11-log
- Maximum PDR = 0.06 psi/min (at least daily), primary filtration racks max TMP = 35 psi (continuous), backwash recovery rack(s) max TMP = 9 psi (continuous), minimum LRV ambient 4.39, calculated continuously.
- Consider larger buffer (LRVDIT – min LRVambient) for Backwash recovery
- Newport to provide data upon request, may be more frequently than monthly
- DWS will provide a modified CT reporting form with viral CT req'd, viral CT achived, and giardia CT achieved

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All relay calls accepted | www.healthoregon.org/dws

Stantec

Memo

To:	Baxter Call, PE Regional Engineer	From:	Bryan Black, PE
	Oregon Health Authority Public health Division-Drinking Water Services		Stantec
File:	Newport Clearwell Repair	Date:	July 31, 2025

Reference: Application for Waiver from Construction Standards for Public Water Systems - City of Newport Water Treatment Plant

REVISION

This is a revision to the City's original Waiver request. The revision was requested by Baxter Call of OHA by email on July 7, 2025. The revision addresses items listed in Baxter's email. The memo now includes calculations and operational setpoints (Chlorine residual minimum, maximum pressure decay rate (PDR_{max}), maximum Trans-membrane Pressure) that will ensure these requirements are met under all conditions.

Baxter's email asks us to address the timing of this work. The waiver would be applicable from estimated January 2027 through March 2027 for a period estimated to be about 8 weeks. This timing has been set to allow design and construction of Clearwell bypass piping with an integrated new chlorine contact tank. Constructing these new items requires at least one shutdown and this is planned for Fall 2026 during a low demand period. This City prefers plant shutdowns to not occur during greater water demands occurring April through September. Having the Clearwell out of service during a low demand period also reduces the sizing of the temporary disinfection system because it can be limited to a capacity 2,500 gpm, rather than a higher flow rate that would be required in Summer. The Clearwell is a key piece of treatment infrastructure and its level is used to control the flow rate from the membrane system. If there are control complications that result from taking it out of service, it is preferred that this occur during a low demand period when the City can more comfortably rely on stored finished water in its distribution system tanks.

INTRODUCTION AND BACKGROUND

The City of Newport, Oregon (City) owns and operates a membrane filtration water treatment plant (WTP), the only potable water supply for its residents. Disinfection at the WTP is achieved by chlorination of the filtered water and storage in a baffled Clearwell tank. The Clearwell must be taken out of service (OOS) for repairs. This memorandum describes an alternate temporary approach for disinfection that requires that a waiver be approved by OHA for the period of time that the Clearwell is out of service.

Stantec and the City completed an alternatives analysis for potential solutions to maintain water production during construction and this alternative temporary approach to disinfection was selected to be the most feasible given the constrained WTP site. The selected alternative is to obtain a waiver from the Oregon Health Authority (OHA) to temporarily reduce the requirement for 0.5-log disinfection of Giardia and compensate with a corresponding increase in Giardia Log Removal Value (LRV) from the membrane filtration system.

DESCRIPTION OF SITUATION THAT CONFLICTS WITH THE STANDARD

Temporary disinfection is required to allow the existing Clearwell to be taken OOS for approximately 8 weeks for sealant and other repairs. The Standard, Oregon Administrative Rule (OAR) 330-061-050 (4)(c)(D), states “regardless of the filtration method used, the water system must achieve a minimum of 0.5-log reduction of *Giardia lamblia* and a 1.0-log reduction of viruses from disinfection alone after filtration treatment.” Due to site and financial constraints, it is not possible to construct a temporary Clearwell large enough to meet the Standard. Instead, alternate measures are proposed below to provide adequate protection to public health and safety during this temporary period, including construction of a temporary small Clearwell (0.08 MG) sized to achieve 4-log virus and 0.11-log Giardia inactivations. The shortfall in Giardia disinfection of 0.39-log (0.5-0.11) would be compensated for by increasing protection from the membrane filtration system (increasing the minimum LRV from 4.0- to 4.39-logs).

WHY MEETING THE STANDARD IS HIGHLY BURDENSOME OR IMPRACTICAL

The existing WTP site is highly constrained, and the water utility is facing budget challenges due to the need for dam repair or replacement and other projects. Alternatives considered to meet the standard included building a large temporary Clearwell (0.28 MG) or installing temporary UV disinfection with a smaller tank. These alternatives are estimated to increase project cost by at least $1.4M. Due to site and financial constraints along with operational complexity, it is highly burdensome and impractical to implement a large Clearwell or temporary UV disinfection as short temporary measures.

DESCRIPTION OF PROPOSED ALTERNATE MEASURES TO PROVIDE ADEQUATE PROTECTION OF PUBLIC HEALTH AND SAFETY

The existing membrane filtration system is operated to achieve a Log Removal Value (LRV) of at least 4.0. Adding OHA’s requirement for 0.5-log Giardia inactivation yields a total treatment requirement of 4.5-log Giardia, summarized in **Table 1**. The Waiver request is to temporarily increase the LRV from the membrane system to compensate for the temporary decrease in disinfection. The overall total WTP Giardia removal / inactivation public health protection is equivalent, as shown in **Table 1**.

Table 1 – OHA Requirements - Normal versus Proposed Temporary Waiver Operations

	Giardia Removal or Inactivation	
WTP Process	**Normal Operation**	**Proposed Temporary Operation** (Clearwell OOS, Waiver Active)
Membrane Filtration LRV Removal Requirement	4.0-log Giardia	4.39-log Giardia
Chlorine Disinfection Requirement	0.5-log Giardia	0.11-log Giardia
TOTAL WTP	4.5-log Giardia	4.5-log Giardia

The City proposes to construct a new tank for use when the existing Clearwell is OOS for maintenance. The proposed maximum flow rate during temporary operations is 2,500 gallons per minute. The new tank would be integrated into bypass piping to allow water to be diverted around the Clearwell when it is OOS, similar to **Figure 1**. Chlorine contact time would be obtained in the existing Clearwell inlet and outlet piping and end at the chlorine residual analyzer located at the FWPS, as shown in **Table 2**.

Table 2 – Chlorine Contact Time Available in Existing Pipelines

Pipe	Diameter (inch)	Length (feet)	Volume (gallons)	Contact Time T_{10} (minutes)
Inlet	20	142	2,316	0.93
Outlet	24	98	2,302	0.92
Total	-	-	4,618	1.8

Chlorine contact time would also be achieved in the new tank. The new tank will include baffles to improve disinfection hydraulics, targeting a minimum baffling factor of 0.32. **Table 3** provides preliminary design criteria for chlorine contact time in the new tank.

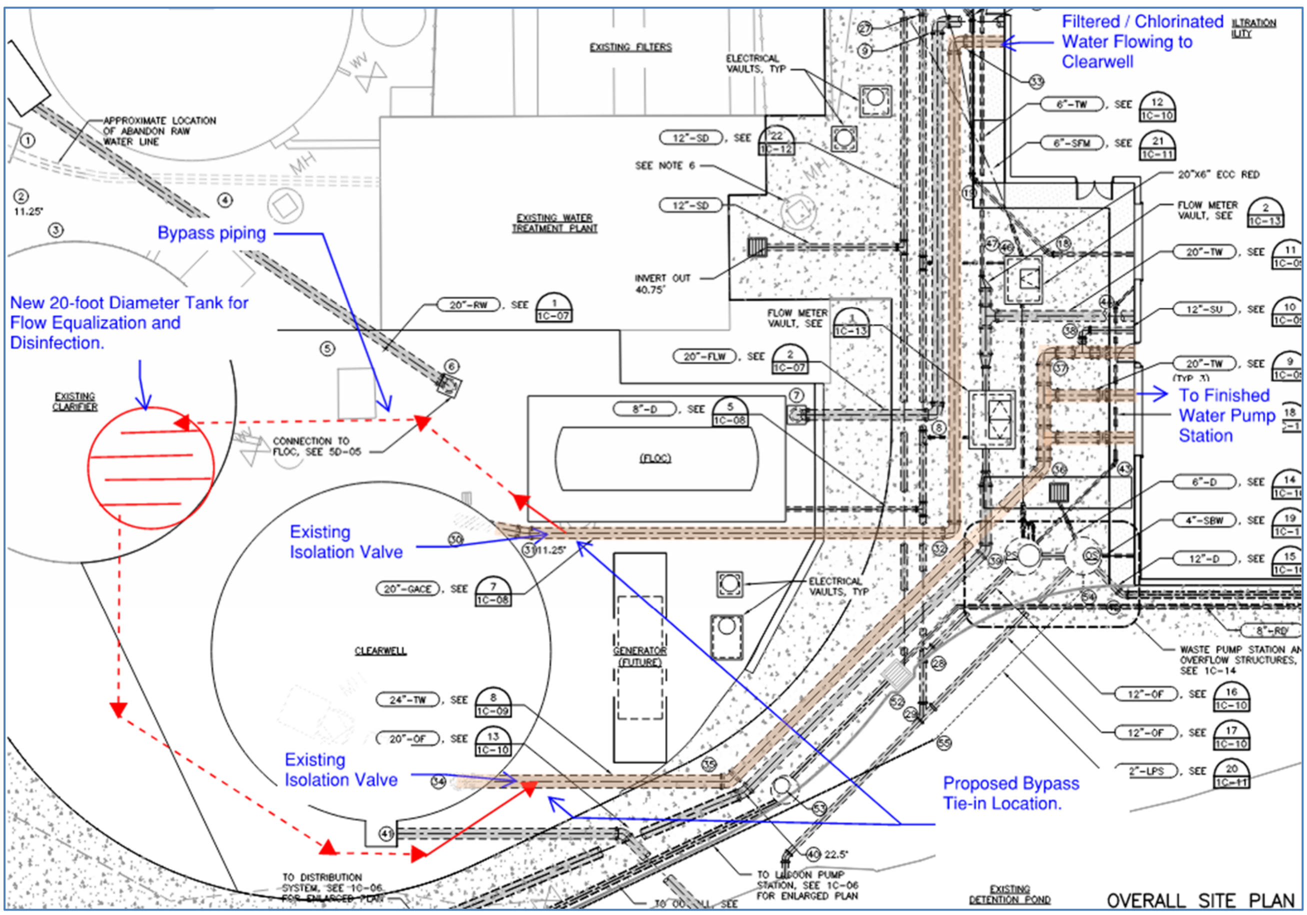

Figure 1. Clearwell Bypass with new Tank

Table 3 – Chlorine Contact Time in New Tank

	Diameter (feet)	**Minimum Depth (feet)**	**Volume (gallons)**	**Minimum Baffling Factor (T_{10}/T)**	**Effective Volume (gallons)**	**Contact Time T_{10} (minutes)**
New Tank	20	14.5	34,000	0.32	10,876	4.4

The total chlorine contact time, the sum of the pipelines and the new tank, is 6.2 minutes. Review of WTP records indicates that the water temperature could be as low as 5 degrees C and the maximum pH during disinfection is 8. Plant operators indicate that chlorine residual can be maintained at 1.3 mg/L during the temporary period when the Clearwell is OOS. **Table 4** provides disinfection calculations showing that the proposed system can achieve 0.11-log inactivation of Giardia and 4-log inactivation of viruses.

Table 4 - Chlorine Disinfection Achieved by Existing Pipelines and New Tank, Clearwell OOS (pH=8, Temperature = 5 degrees C, Flow = 2,500 gpm, chlorine residual = 1.3 mg/L)

	CT Required (mg-min/L)	**Minimum Contact Time T_{10} (minutes)**	**Minimum Chlorine Residual (mg/L)**	**CT Actual (mg-min/L)**	**Log Inactivation**
Giardia	37.5 (0.5-log)	6.2	1.3	8.06	0.11-log
Viruses	8 (4-log)	6.2	1.3	8.06	4-log

The new tank will also be designed to provide flow equalization. Flow equalization is necessary to account for different instantaneous flow rates between the membrane filtration system and the Finished Water Pump Station (FWPS). Discussion with plant operators indicate this flow equalization volume should be approximately 30,000 gallons. The flow equalization zone will be at the top of the new tank and will have a fluctuating water level. The bottom volume of the tank will be reserved for chlorine contact time. The minimum depth of water in the new tank will be 14.5 feet to protect the volume needed for chlorine contact time. **Table 5** summarizes proposed design criteria for the new tank.

Table 5 – Proposed Design Criteria for New Tank

	Diameter (feet)	Height (feet)	Total Volume (gallons)	Baffling Factor	Construction Type
Tank	20	27.25	64,000	0.32	Bolted Steel – Fusion Bonded Epoxy

With the Clearwell OOS, the City proposes to increase the LRV for the membrane system to compensate for the temporary reduction in log inactivation of Giardia with disinfection. The City proposes to increase the membrane system LRV from 4.0 to 4.39-logs, per **Table 1**. The City's membrane system includes primary membrane racks and a backwash recovery membrane rack - the City proposes to operate each type with the minimum 4.39-log LRV during the temporary period. LRV_{dit} calculations are provided in the attachment. During operation with the Clearwell OOS, the WTP will stay within these parameters to achieve a minimum $LRV_{ambient}$ of 4.39-logs.

The LRV_{dit} for the primary racks (Attachment 1) is 4.60 with a maximum pressure decay rate of 0.06 psi/min (pass/fail criteria for the daily direct integrity test) and a maximum trans-membrane pressure (TMP) of 35 psi. This calculation has been previously approved by OHA.

The LRV_{dit} for the Backwash Recovery Rack is 4.40 with a maximum pressure decay rate of 0.06 psi/min (pass/fail criteria for the daily direct integrity test) and a maximum trans-membrane pressure (TMP) of 9 psi. The Backwash Recovery Rack TMP has not been observed to go above 5 psi. If it approaches 9 psi during temporary operation, the membrane rack will be cleaned to restore the TMP to a lower value.

The City proposes the following additional measures to protect public health and safety during the waiver period when the existing Clearwell is OOS:

1. Chlorine residual at Entry Point target 1.3 mg/L; set point for shut off if chlorine residual falls below 1.3 mg/L. The set point will only apply following the daily WTP startup after sufficient time for complete turnover of the new tank volume.

2. Maintaining a combined log inactivation of Giardia of 4.5-log through a combination of filtration and disinfection in the temporary tank. As demonstrated above, the temporary tank will provide a minimum inactivation of 0.11-log Giardia and 4-log viruses through disinfection. To maintain a total WTP removal / inactivation of Giardia of 4.5-log, the membrane system will be operated to maintain a minimum LRV of 4.39-log.

3. Maintaining a minimum $LRV_{ambient}$ for the membrane system of 4.39-log as described above

4. Confirming the intended duration of temporary waiver, the Clearwell is expected to be out of service to be eight weeks.

5. Pressure transducers will be calibrated before planned work.

6. Daily monitoring of CT and turbidity will be consistent with normal operation, DWS will be contacted if there are conditions encountered other than what is planned and described in this memo.

7. Mad Dog Country Tavern (PWS 92052) is Newport's only permanent purchaser. Newport shall give written notice explaining the details of the interruption of normal disinfection, and the measures being taken to ensure drinking water is safe while the Clearwell is out of service.

CONCLUSIONS/NEXT STEPS

The City plans to authorize the start of design for the project in late summer 2025. Construction of the improvements is anticipated to start in late summer/early fall of 2026 with repair of the Clearwell happening during a period in January through March of 2027, after which OHA will be notified and the waiver period can end.

The City and Stantec are looking forward to any discussion and approval of this waiver and appreciate OHA’s willingness to work with the City on this matter.

Stantec Consulting Services Inc.

Bryan Black PE
Regional Practice Leader

Phone: 503-490-2041
Bryan.Black@stantec.com

Cc:

Steve Stewart, Plant Manager

Todd Drage, Assistant City Engineer

ATTACHMENT 1

Resolution and LRV Calculations for Direct Integrity Testing Using the MFGM Method for Water Treatment Plant at Newport, OR MF System, Primary Racks

Objectives

The objective is to determine (1) the testing pressure required to meet the resolution criterion of 3 µm or less as specified in the Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), (2) the pressure decay value (PDR) corresponding to required Log Reduction Value (LRV) for particles with the size of 3 µm at plant design conditions.

Calculation for Resolution and Sensitivity of the Membrane System

1. Determining Testing Pressure for Required Resolution (≤3 µm)

   The testing pressure can be calculated per Equation (4.1)

$$P_{test} = (0.193 * \kappa * \sigma * \cos\theta) + BP_{\max} \qquad \text{Equation (4.1)}$$

Table 1. Calculation Variables (P_{test})

Item	Description	Unit	Value
P_{test}	Test pressure for required resolution	psi	16.95
k	Shape correction factor	dimensionless	1
σ	Surface tension of water @ 5 °C	dynes/cm	72.26
θ	Water contact angle of membrane medium	degree	0.00
BP_{max}	Sum of backpressure and static head	psid	3.00

Since the testing pressure to be used is 25 psi or above and the pressure decay is anticipated lower than 1 psi during the duration of the test for Aria Filtra MF system, the resolution criterion is satisfied.

2. Calculating Sensitivity (LRV_{DIT})

The LRV calculation is performed by using Equation (4.9) in USEPA's Membrane Filtration Guidance Manual (USEPA, 2005):

$$LRV_{DIT} = \log\left(\frac{Q_p * ALCR * P_{atm}}{\Delta P_{test} * V_{sys} * VCF}\right) \qquad \text{Equation (4.9)}$$

The air-liquid conversion ration (ALCR) is calculated using Darcy Equation by assuming that the hollow fiber breaks completely at the interface of potting layer, which results in a shortest flow path for bypass flow. The calculation also uses the highest trans-membrane pressure (TMP) during a filtration cycle. This results in a conservative result that has a low LRV.

Air-to-liquid-conversion ratio (ALCR):

$$ALCR = 170 * Y * \sqrt{\frac{(P_{test} - BP)(P_{test} + P_{atm})}{(460 + T) * TMP}} \qquad \text{Equation (C.4)}$$

$$Y \propto \left[\frac{1}{\frac{(P_{test} - BP)}{(P_{test} + P_{atm})}}, K \right] \qquad \text{Equation (C.5)}$$

K: resistant coefficient

$$K = f * \frac{L}{d_{fiber}} \qquad \text{Equation (C.6)}$$

The parameters used in the LRV calculation are presented in Table 2.

Table 2. Parameters Used for LRV Calculation

Item	Description	Unit	Value
Q_p	design (instantaneous) flow per rack	gpm	1,570
VCF [a]	volumetric concentration factor	dimensionless	1.08
ΔP_{test}	The smallest pressure decay rate associated w/ a breach	psi/min.	0.06
V_{sys} [b]	system hold-up volume	gallons	220.80
P_{atm}	Atmospheric pressure	psi	14.70
BP [b,c]	back-pressure during pressure decay test	psi	0
T [b]	Temperature	°F	74
TMP [b]	terminal trans-membrane pressure during filtration	psi	35.00
f	friction factor	dimensionless	0.025
L [c]	the length of flow path for breach	M	0.06
D	diameter of hollow fiber lumen	M	0.00064
P_{test} [b]	testing pressure for pressure decay test	psi	25.0

Note: a - *Calculated based on the data from AwwaRF Report No. 91032 by Sethi et al., 2004*

b - *Based on the design data*

c - *Assume worst-case fiber breakage (at the top potting layer)*

Find K:

$$K = f * \frac{L}{d_{fiber}} \qquad \text{Equation (C.6)}$$

f: friction factor

L: the length of flow path of the breach (equal to the potting thickness)

d_{fiber}: lumen diameter of the fiber.

$$K = 0.025 * \frac{0.06}{0.00064}$$

Find Y value using the chart on page A-22 from Crane:

$$Y \propto \left[\frac{1}{\frac{(P_{test} - BP)}{(P_{test} + P_{atm})}}, K \right]$$

Substitute Y into Equation (C.4):

Substitute ALCR into Equation (4.9):

Table 3. Additional Parameters Used for LRV Calculation

Item	Description	Unit	Value
K	Resistant coefficient	dimensionless	2.34
Y	Net expansion factor	dimensionless	0.63
$ALCR$	Air to liquid conversion ratio	dimensionless	24.57
LRV_{dit}	Sensitivity of direct integrity test	log	4.60

Therefore, the sensitivity of direct integrity testing is = LRV_{dit} in Table 3.

1. Calculate Upper Control Limit (UCL) and Alert Level (AL) for Direct Integrity Testing. The UCL for direct integrity testing, the pressure decay rate corresponding to the required LRV, is determined by rearranging Equation (4.9):

$$UCL = \frac{Q_p \bullet ALCR \bullet P_{atm}}{10^{LRC*} \bullet V_{sys} \bullet VCF} \quad \text{Equation (4.17)}$$

Where: UCL - upper control limit for pressure decay rate, psi/min.

$LRC*$ - required LRV for the membrane system

If the required LRV for the membrane system is 4-logs, substitute $LRC* = 4$ and the same parameters in Table 2:

The plot of LRV as a function of pressure decay rate is presented in Figure 1 in which the UCL is marked with red dotted line.

Table 4. Results of UCL Calculation

Item	Description	Unit	Value
UCL	Upper control limit	psi/min	0.24

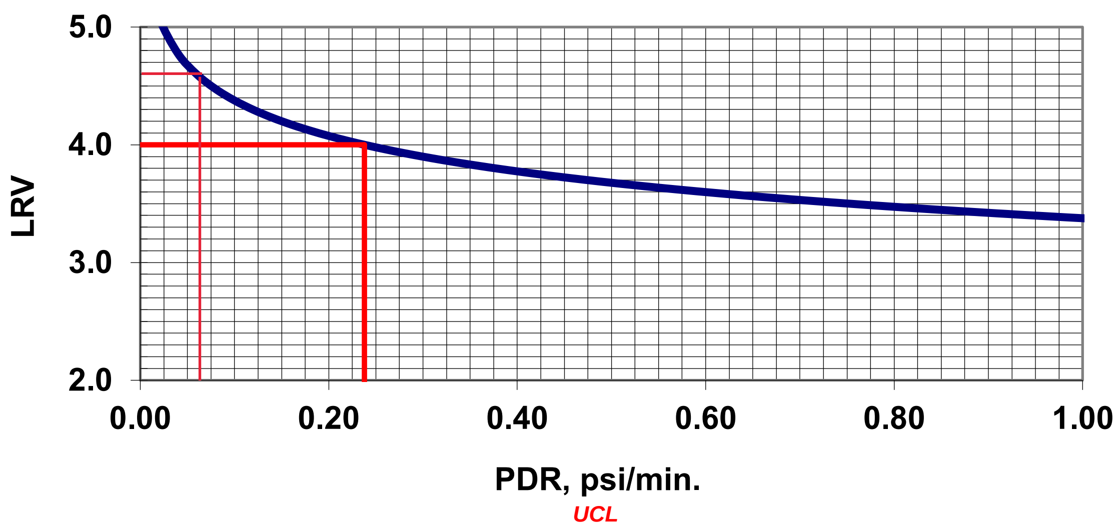

Figure 1: LRV as a function of pressure-decay rate (PDR)

UCL is indicated on the graph corresponding to LRV of 4-logs.

LRVdit ~ 4.6 at PDRmax = 0.06 [psi/min]

References

Sethi, S., G. Crozes, D. Hugaboom, B., Mi, J. M. Curl, and B. J. Mariñas (2004): *Assessment and Development of Low-Pressure Membrane Integrity Monitoring Tools* , AwwaRF Report No. 91032, Denvor, CO.

USEPA: *National Primary Drinking Water regulations: Long Term 2 Enhanced Surface Water Treatment Rule; Final Rule* , Federal Register, January 5, 2006

USEPA: *Membrane Filtration Guidance Manual* , EPA-815-R-06-009, November, 2005

ATTACHMENT 2

Resolution and LRV Calculations for Direct Integrity Testing Using the MFGM Method for Water Treatment Plant at Newport, OR MF System, BWR (Temporary Measure-BWR to reach 4.4)

Objectives

The objective is to determine (1) the testing pressure required to meet the resolution criterion of 3 µm or less as specified in the Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), (2) the pressure decay value (PDR) corresponding to required Log Reduction Value (LRV) for particles with the size of 3 µm at plant design conditions.

Calculation for Resolution and Sensitivity of the Membrane System

1. Determining Testing Pressure for Required Resolution (≤3 µm)

The testing pressure can be calculated per Equation (4.1)

$$P_{test} = (0.193 * \kappa * \sigma * \cos\theta) + BP_{\max} \qquad \text{Equation (4.1)}$$

Table 1. Calculation Variables (P_{test})

Item	Description	Unit	Value
P_{test}	Test pressure for required resolution	psi	16.95
k	Shape correction factor	dimensionless	1
σ	Surface tension of water @ 5 °C	dynes/cm	72.26
θ	Water contact angle of membrane medium	degree	0.00
BP_{max}	Sum of backpressure and static head	psid	3.00

Since the testing pressure to be used is 25 psi or above and the pressure decay is anticipated lower than 1 psi during the duration of the test for Aria Filtra MF system, the resolution criterion is satisfied.

2. Calculating Sensitivity (LRV_{DIT})

The LRV calculation is performed by using Equation (4.9) in USEPA's Membrane Filtration Guidance Manual (USEPA, 2005):

$$LRV_{DIT} = \log(\frac{Q_p * ALCR * P_{atm}}{\Delta P_{test} * V_{sys} * VCF}) \quad \text{Equation (4.9)}$$

The air-liquid conversion ration (ALCR) is calculated using Darcy Equation by assuming that the hollow fiber breaks completely at the interface of potting layer, which results in a shortest flow path for bypass flow. The calculation also uses the highest trans-membrane pressure (TMP) during a filtration cycle. This results in a conservative result that has a low LRV.

Air-to-liquid-conversion ratio (ALCR):

$$ALCR = 170 * Y * \sqrt{\frac{(P_{test} - BP)(P_{test} + P_{atm})}{(460 + T) * TMP}} \quad \text{Equation (C.4)}$$

$$Y \propto \left[\frac{1}{\frac{(P_{test} - BP)}{(P_{test} + P_{atm})}}, K \right] \quad \text{Equation (C.5)}$$

K : resistant coefficient

$$K = f * \frac{L}{d_{fiber}} \quad \text{Equation (C.6)}$$

The parameters used in the LRV calculation are presented in Table 2.

Table 2. Parameters Used for LRV Calculation

Item	Description	Unit	Value
Q_p	design (instantaneous) flow per rack	gpm	500
VCF [a]	volumetric concentration factor	dimensionless	1.08
ΔP_{test}	The smallest pressure decay rate associated w/ a breach	psi/min.	0.06
V_{sys} [b]	system hold-up volume	gallons	220.80
P_{atm}	Atmospheric pressure	psi	14.70
BP [b,c]	back-pressure during pressure decay test	psi	0
T [b]	Temperature	°F	74
TMP [b]	terminal trans-membrane pressure during filtration	psi	9.00
f	friction factor	dimensionless	0.025
L [c]	the length of flow path for breach	M	0.06
D	diameter of hollow fiber lumen	M	0.00064
P_{test} [b]	testing pressure for pressure decay test	psi	25.0

Note: a - *Calculated based on the data from AwwaRF Report No. 91032 by Sethi et al., 2004*

b - *Based on the design data*

c - *Assume worst-case fiber breakage (at the top potting layer)*

Find K:

$$K = f * \frac{L}{d_{fiber}} \qquad \text{Equation (C.6)}$$

f: friction factor

L: the length of flow path of the breach (equal to the potting thickness)

d_{fiber}: lumen diameter of the fiber.

$$K = 0.025 * \frac{0.06}{0.00064}$$

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Find Y value using the chart on page A-22 from Crane:

$$Y \propto \left[\frac{1}{\frac{(P_{test} - BP)}{(P_{test} + P_{atm})}}, K \right]$$

Substitute Y into Equation (C.4):

Substitute ALCR into Equation (4.9):

Table 3. Additional Parameters Used for LRV Calculation

Item	Description	Unit	Value
K	Resistant coefficient	dimensionless	2.34
Y	Net expansion factor	dimensionless	0.63
$ALCR$	Air to liquid conversion ratio	dimensionless	48.46
LRV_{dit}	Sensitivity of direct integrity test	log	4.40

Therefore, the sensitivity of direct integrity testing is = LRV_{dit} in Table 3.

1. Calculate Upper Control Limit (UCL) and Alert Level (AL) for Direct Integrity Testing. The UCL for direct integrity testing, the pressure decay rate corresponding to the required LRV, is determined by rearranging Equation (4.9):

$$UCL = \frac{Q_p \bullet ALCR \bullet P_{atm}}{10^{LRC^*} \bullet V_{sys} \bullet VCF} \qquad \text{Equation (4.17)}$$

Where: UCL - upper control limit for pressure decay rate, psi/min.

LRC^* - required LRV for the membrane system

If the required LRV for the membrane system is 4.4-logs, substitute $LRC^* = 4.4$ and the same parameters in Table 2:

The plot of LRV as a function of pressure decay rate is presented in Figure 1 in which the UCL is marked with red dotted line.

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Table 4. Results of UCL Calculation

Item	Description	Unit	Value
UCL	Upper control limit	psi/min	0.06

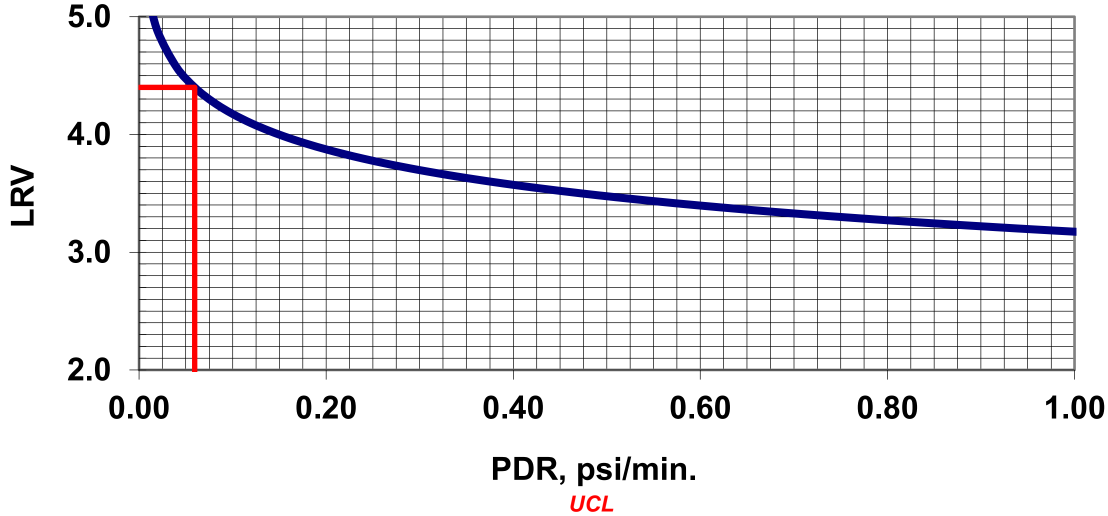

Figure 1: LRV as a function of pressure-decay rate (PDR)

UCL is indicated on the graph corresponding to LRV of 4.4-logs.

References

Sethi, S., G. Crozes, D. Hugaboom, B., Mi, J. M. Curl, and B. J. Mariñas (2004): *Assessment and Development of Low-Pressure Membrane Integrity Monitoring Tools* , AwwaRF Report No. 91032, Denvor, CO.

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