



July 16, 2021

Bill Palmaymesa
PO Box 220
Antelope, OR 97001

**Re: Young Life (PWS ID#01246)
Membrane Module Replacement with 8 Toray HFUG-2020AN Modules
Conditional Approval – PR# 75-2021**

Dear Mr. Palmaymesa:

Thank you for submitting information regarding the membrane module replacement project for Young Life. On May 12, 2021, our office received information on a project to replace the 8 existing Toray HFS-2020 membrane modules originally installed in 2013 with a total of 8 Toray HFUG-2020AN ultrafiltration PVDF hollow fiber membrane modules (4 modules per skid in two WesTech AP-VI filtration skids with capacity for up to 6 modules each). A plan review fee of \$248 was also received on May 12, 2021. The Oregon Health Authority grants **Conditional Approval** for this project with the following conditions that will need to be met prior to granting Final Approval:

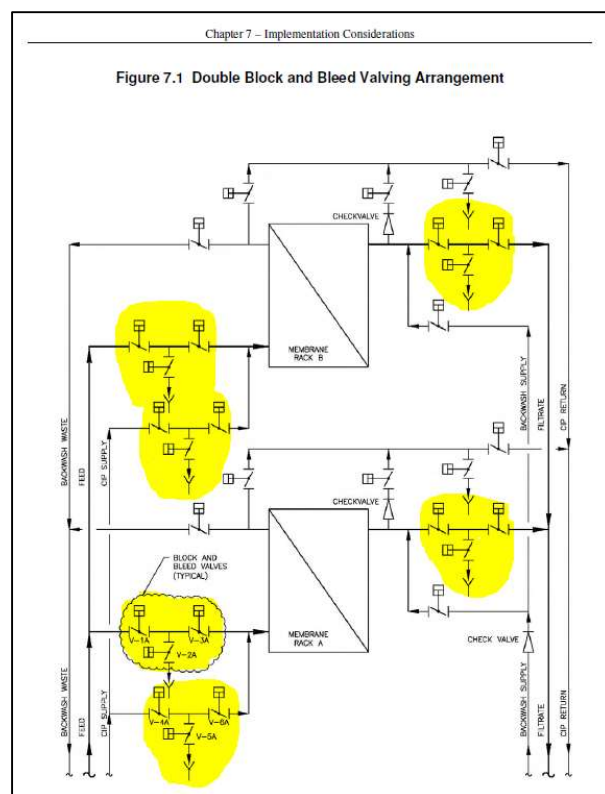


1. Direct integrity testing parameters will need to be determined and programmed into the SCADA system. These parameters include:
 - a. A **direct integrity test pressure**, which is to be set no less than 18.21 psi. It is understood that the starting direct integrity test pressure is designed to be 20 psi;
 - b. An **upper pressure decay control limit** of 0.09 psi/min 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 routinely calculated based on current ambient operating conditions (a metric commonly referred to as LRV_{ambient}). In summary, LRV_{ambient} is the metric for demonstrating 4.0-log (99.99%) Cryptosporidium removal credited for the membrane filters. Since the 0.09 psi/min control limit is to be set up in SCADA as soon as the new membrane modules are installed, it is acceptable to add LRV_{ambient} as part of a previously planned upgrade of the SCADA system in October 2021.

2. 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 flow of 323 gpm per filter skid containing 4 membrane modules, maximum flow of 80.75 gpm per membrane module, and/or a maximum flux of 120 gfd. Per WesTech, each filter skid has a design capacity of 115.9 gpm, therefore, an alarm set point set to 115.9 gpm or less would fulfill this requirement.
 - b. Maximum transmembrane pressure (TMP) of 29 psi.
 - c. Minimum $LRV_{ambient}$ of 4.0-log (added w/ SCADA upgrades in October 2021)
 - d. Maximum direct integrity test pressure decay rate of 0.09 psi/min.
 - e. An alarm set point established to trigger a filter skid shut-down when the individual filter effluent turbidity exceeds 0.15 NTU for more than 15 minutes so that a direct integrity (pressure decay) test can be performed.
3. 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 (see images at the end of Appendix A for examples).
4. Measures are taken to ensure that the membrane filter unit 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 =>
5. The Operation and maintenance manual is updated, or an addendum added to incorporate the new HFUG-2020AN specifications, including any necessary changes to the membrane testing and module fiber repair/pinning procedures. (see images at the end of Appendix A for examples)

The remainder of this letter includes:

- 1) Table 1 - Log removal credits (LRC) granted for the Toray HFUG-2020AN module.
- 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 (WesTech AP-VI skid containing four Toray HFUG-2020AN modules) using current ambient operating conditions.
- 5) Appendix C – Product specifications for the Toray HFUG-2020AN module.



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 from the National Sanitation Foundation (NSF) dated August 15, 2019 (NSF job #J-00320592) for the installed Toray HFUG-2020AN membrane modules.

Table 1 – Filter Log Removal Credit (LRC)

Pathogen	Removal Credit (log ₁₀)
<i>Giardia lamblia</i>	4.0
<i>Cryptosporidium sp.</i>	4.0
Viruses	0.0

The LRCs above are only valid provided operations are within the limits shown in Table 2 below. Ensure SCADA/PLC programming accounts for the operating limits (e.g. set system alarms to ensure operating limits are met):

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 minutes
DIT starting test pressure	20 psi
Minimum allowed DIT pressure	18.21 psi throughout the DIT duration (starting test pressure is anticipated to be 20 psi)
Maximum allowable pressure decay rate (PDR) upper control limit (UCL)	UCL = 0.09 psi/min
Minimum DIT pressure transducer accuracy for the established UCL ¹	± 0.5% of span (0-50 psi), 0.05 psi/min (equal to the stated accuracy of the Wika-A10 pressure transducer installed).
Membrane Minimum Performance (LRV _{ambient}) ²	LRV _{ambient} = 4.0-log (must be ≥ 4.0-log LRC)
DIT Sensitivity (LRV _{DIT})	4.27-log at PDR = 0.05 psi/minute and flow of 115.9 gpm. (4.0-log at PDR = 0.09 psi/min and flow of 115.9 gpm. 4.49-log at PDR = 0.03 psi/min and flow of 115.9 gpm.)
Maximum transmembrane pressure (TMP)	29 psi at 20°C
Maximum allowed filtrate flux [gfd]	120 gal/SqFt/day @ 20°C. This max flux yields a peak plant production of 323 gpm using 4 out of 6 possible modules per skid (80.75 gpm/module). 115.9 gpm is programmed into the PLC as the maximum design flow per skid (43 gal/SqFt/day)
Individual filter effluent (IFE)	IFE ≤ 0.15 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)	<ul style="list-style-type: none">○ PDR > UCL○ LRV_{ambient} < LRC○ IFE > 0.15 NTU for > 15 min○ CFE > 5.49 NTU (may prompt boil water notice)
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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:

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

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

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
Oregon Health Authority - Drinking Water Services

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) – 0.09 psi/min
Every membrane system has an Upper Control Limit (UCL) measured in psi/min . The UCL is the highest **pressure decay rate (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 Young Life’s specific system and information provided by the membrane manufacturer, the UCL is established to be 0.09 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 ($\text{LRV}_{\text{ambient}}$): 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 ($\text{LRV}_{\text{ambient}}$). The main difference between LRV_{DIT} and $\text{LRV}_{\text{ambient}}$ is the use of the current operating flow when calculating $\text{LRV}_{\text{ambient}}$. 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 $\text{LRV}_{\text{ambient}}$ are included in Appendix B of this letter.** In summary, $\text{LRV}_{\text{ambient}}$ is the metric for demonstrating compliance. $\text{LRV}_{\text{ambient}}$ 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 29 psi.
- Flux: The flux ($\text{flow}/\text{filter feed area}$) must not exceed 120 gallons per square feet per day [$\text{gal}/\text{SqFt}/\text{day}$]. This equates to a peak plant production of 646 gpm with all 8 modules in service (80.75 gpm/module, 324 gpm/skid), which is based on the flows tested during the Challenge Study for the HFUG-2020AN commensurate with the 4.0-log credit granted. **WesTech has established a maximum design flow of 115.9 gpm per skid.**
- DIT Turbidity Trigger ($\text{IFE} > 0.15 \text{ NTU}$ for $> 15 \text{ min}$): **A direct integrity test (DIT) must be performed if the turbidity is greater than 0.15 NTU for more than 15 minutes. This must be programmed into the SCADA system.**

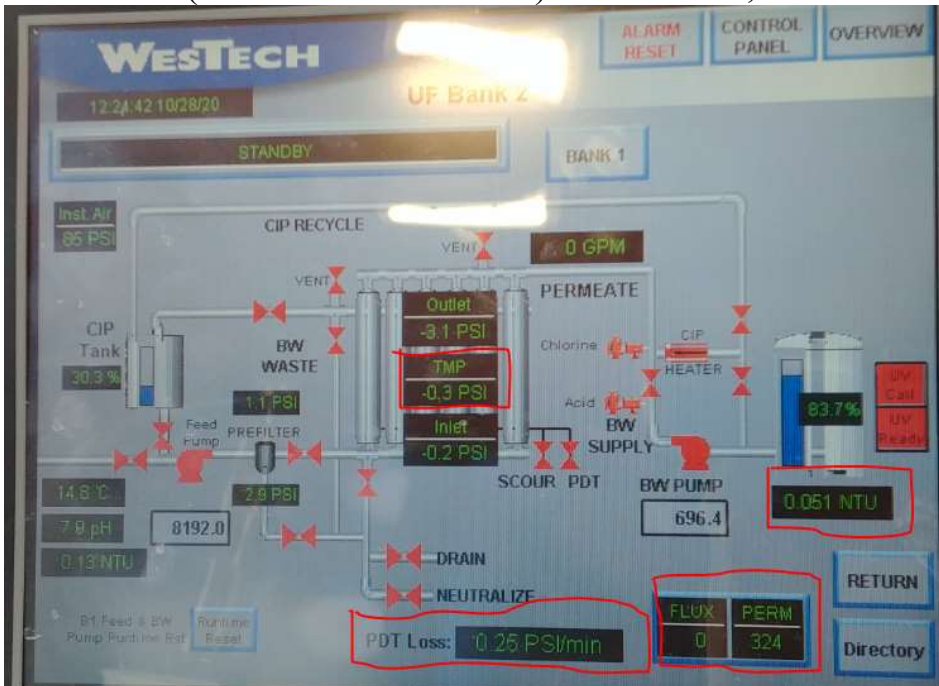
- **DIT Daily Trigger**: A DIT is also required each day of operation. If the pressure decay rate (PDR) drops below the upper control limit (UCL) of 0.09 psi/minute , then the DIT is considered to have failed and the unit must be automatically taken off-line, repaired, and retested to show that it passes a DIT before being placed back into service. In other words, should the PDR of the daily PDT (or “air hold test”) exceed 0.09 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 18.21 psi. **Should the pressure during a DIT drop below 18.21 psi, the DIT is considered invalid or “failed” and must be repeated. WesTech has established a DIT starting test pressure of 20 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. $\text{PDR} > \text{UCL}$. The DIT PDR exceeds the 0.09 psi/min UCL.
 2. $\text{LRV}_{\text{ambient}} < \text{LRC}$. The $\text{LRV}_{\text{ambient}}$ is less than the 4.0 log removal credit (LRC)
 3. $\text{IFE} > 0.15 \text{ NTU}$ for $> 15 \text{ min}$. The individual filter effluent (IFE) turbidity exceeds 0.15 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., $\text{LRC} = 4.0\text{-log}$). A PDR of 0.09 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.**

Images on the following pages show Young Life’s SCADA screens and sections of the operation and maintenance manual that may need to be updated to reflect the new membrane modules.

Alarms for inlet high pressure, TMP, and PDT pressure and pressure decay rate (PDR):



UF Bank 2 (also check *UF Bank 1*) for PDT loss, IFE turbidity, flux and permeability:



Rated Operating Specifications

WESTECH RATED OPERATING SPECIFICATIONS

Rated Operating Specifications

The following limits, set forth by the membrane manufacturer, must be observed at all times in order to maintain the warranty for the membrane modules. WestTech may request operating logs from the Owner in the event of a membrane module warranty claim to demonstrate that the modules have been operated in accordance with WestTech's operating instructions.

Raw Water Quality:

- Particulate..... < 200 microns
- Temperature Range..... 0-40 °C
- Turbidity, Intermittent Peak (<48 hrs)..... 100 NTU (or 100 mg/L)
- Turbidity, Continuous Maximum..... 30 NTU (or 30 mg/L)
- pH Range..... 1-13

Production Limits

- Max. Inlet Pressure..... 43.5 psi
- Filtration TMP Limit..... <29.0 psid
- Max. Feed Flow Rate (per module)..... 53 gpm
- Max. Normalized Flux..... 130 gfd
- Integrity Test, Max. Initial Pressure..... 18 psi
- Integrity Test, Upper Control Limit..... 0.998 psi/min

Backwash Limits

- Max. Backwash Pressure..... 63.5 psi
- Max. TMP..... 29.0 psid
- Max. BW Flow Rate (per module)..... 59 gpm
- Max Air Scour Pressure..... 6 psi
- Max Air Scour Flow Rate (per module)..... 5.3 scfm
- Min Air Scour Flow Rate (per module)..... 2.8 scfm

System Process Summary

System Process Summary

The WestTech AltaFlex® Filtration System has been designed with the following process parameters:

Table 3. AP-VL Process Parameters

Parameter	200 gpm (14°C)	160 gpm (10°C)	150 gpm (8°C)
Membrane Modules	8	8	8
Banks	1	1	1
Membrane Area per Module	775 ft ²	775 ft ²	775 ft ²
Membrane Area per System	6,200 ft ²	6,200 ft ²	6,200 ft ²
Design Temperature	14 °C	10 °C	8 °C
Flux at Design Temperature	53.56 gfd	42.98 gfd	40.34 gfd
Normalized Flux (20°C) at Design Temperature	62.51 gfd	56.27 gfd	56.04 gfd
Approx. Flow Rates			
Instantaneous	230.6 gal/min	185.1 gal/min	173.7 gal/min
Average Gross	208.1 gal/min	167.1 gal/min	156.8 gal/min
Average Net Permeate	200.0 gal/min	160.0 gal/min	150.0 gal/min
Approx. Net Permeate Production per Day	0.288 MGD	0.230 MGD	0.216 MGD
Backwash Waste Volume per Day	5,739 gal/day	4,592 gal/day	4,305 gal/day
Influent Used for Rinsing/Draining per Day	5,926 gal/day	5,586 gal/day	5,500 gal/day
Estimated Water Recovery	96.1 %	95.8 %	95.7 %
Estimated CIP Frequency	> 30 Days	> 30 Days	> 30 Days

Appendix B - Formulae and variables used in calculating the log removal value ($LRV_{ambient}$) of each membrane filter unit (WesTech AP-VI skid containing four Toray HFUG-2020AN modules) using current ambient operating conditions.

Formulae and variables used in calculating the log removal value ($LRV_{ambient}$) of each membrane filter unit (WesTech AP-VI skid containing four Toray HFUG-2020AN modules) 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	$LRV_{ambient} = \log_{10} \left(\frac{Q_p \cdot ALCR \cdot P_{atm}}{\Delta P_{test} \cdot V_{sys} \cdot VCF} \right)$
ALCR equation	$ALCR_{Turbulent} = 170 \cdot Y \cdot \sqrt{\frac{(P_{test} - BP) \cdot (P_{test} + P_{atm})}{(460 + T) \cdot TMP}}$
P_{Test} equation	$P_{Test} = 0.193 \cdot \kappa \cdot \sigma \cdot \cos\theta$
Volume of pressurized air in module during direct integrity testing [gallons and liters]	9.24 gallons/module (34 liters/module)
V_{sys} , Total volume of pressurized air in the unit during direct integrity testing [gallons and liters]	45.71 gallons (173 liters)
VCF, Volumetric Concentration Factor [dimensionless]	1
VCF for backwash units in which filtrate goes to clearwell	N/A – no backwash recovery units
P_{atm} , Atmospheric pressure [psia]	14.7
Y, Net Expansion Factor [dimensionless]	0.74 (0.588 is lowest from Crane ¹ p. A-22)
d, Lumen diameter [mm]	0.7
L, Potting depth or defect length [mm]	80
κ , Pore shape correction factor [dimensionless]	1.0
σ , surface tension at 5°C [dynes/cm]	75.6
θ , Liquid-membrane contact angle [degrees]	0
Q_p , Maximum design flow rate [l/min]	438.7 (115.9 gpm)
BP_{max} , Maximum backpressure during the DIT [psi]	3.62 (100.28 inches of water)
P_{Test} , Applied direct integrity test pressure [psi] (Should be \geq minimum test pressure in Table 2)	20 psi target starting DIT pressure 18.21 psi minimum ending DIT pressure
D_{base} , Baseline diffusive loss expected through fully intact membrane filter unit [psi/min]	0.002 psi/min (0.01 psi over a 5-min DIT)

Calculations:

$$P_{\text{Test}} = 0.193 \cdot \kappa \cdot \sigma \cdot \cos\theta + BP_{\text{max}}$$

(Equation 4.1 EPA Manual)

K	1	-	Most conservative value
σ	75.6	dynes/cm	Surface tension of water at 5 deg C
θ	0	degrees	Most conservative value
BP_{max}	3.62	psi	Converted from inches of water
Constant	0.193		Constant that includes the defect diameter (i.e. 3 μm resolution requirement) and unit conversion factors

$$P_{\text{test min}} = 18.21 \text{ psi}$$

$$125.6 \text{ kPa}$$

P_{test} is the minimum starting pressure for a Pressure Decay Test (PDT)

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

(Equation C.4 EPA Manual)

P_{test}	20.0	psi	Initial applied test pressure
BP_{max}	3.62	psi	Converted from inches of water
P_{atm}	14.7	psia	
T_{actual}	57.2	$^{\circ}\text{F}$	Actual water temperature
TMP_{actual}	29.00	psi	Actual TMP before most recent PDT
Y	0.74		Does not change from above

$$ALCR = 24.49$$

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

Q _{p actual}	115.90	gpm
Actual ALCR _{DP}	24.49	-
P _{atm}	14.7	psia
Corrected Operational ΔP _{test}	0.09	psi/min
V _{sys}	45.71	gallons
VCF	1	-

LRV_{DIT} (DP) =	4.00
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$$UCL = \frac{Q_p \cdot ALCR \cdot P_{atm}}{10^{LRV} \cdot V_{sys} \cdot VCF}$$

(Equation 4.17 EPA Manual)

Q _p	115.90	gpm	
ALCR _{DP}	24.49		
P _{atm}	14.7	psia	Atmospheric Pressure
V _{sys}	45.71	gallons	
LRC	4	-	Minimum log removal credit (LRC) value to be accepted
VCF	1	-	Deposition mode configuration standard value

UCL_{DP} =	0.09 psi / min	by Darcy Pipe method
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Appendix C – Product specifications for the Toray HFUG-2020AN module.

Characteristics regarding the membrane modules are provided in Table A.

Table A. Membrane Filter Specifications

Specification	Value
Membrane Manufacturer	Toray Industries, Inc.
Membrane Model Number	HFUG-2020AN
Challenge test standard (ANSI/NSF 419-YY, ETV, etc.)	ANSI/NSF 419-18
Challenge test report date	August 15, 2019
LRV _{C-Test}	5.17-log
OHA-DWS Challenge Study Verification Information Assumes 2.98 psi maximum backpressure (BP _{max}) =>	Date Verified = November 2019 LRC = 4.0-log (Giardia/Crypto) Max Flux = 120 GFD @ 20°C Max TMP = 29 psi Minimum DIT Pressure = 17.44 psi Max Flow = 80.75 gpm @ 20°C
ANSI/NSF Standard 61 certification (yes/no)	Yes
Membrane type (e.g., hollow fiber, etc.)	Hollow fiber
Number of fibers per module	14,000
Fiber inside (lumen) diameter	0.7 mm
Fiber wall thickness	0.2 mm
Active fiber length (length of fibers not in potting)	1,816 mm
Potting depth	80 mm
Membrane classification (e.g., ultra- or micro-filtration)	Ultrafiltration
Nominal membrane pore size (e.g., 0.01 µm, etc.)	150,000 daltons MWCO
Membrane material (e.g., PVDF, polysulfone, etc.)	PVDF
Roughness coefficient	0.75 µm (0.00075 mm)
Feed side membrane filtration area (ft ²)	969
Filtration Flow Direction (i.e., inside-out or outside-in)	Outside-in
Hydraulic configuration (i.e., deposition or suspension)	Deposition
Submerged or Pressurized	Pressurized

ANSI/NSF Standard 419-18 Challenge Study Report from the National Sanitation Foundation (NSF) dated August 15, 2019 (NSF job #J-00320592) for the installed Toray HFUG-2020AN membrane modules



NSF International
750 N. Dixboro Rd., Ann Arbor, MI 48105, USA
1-800-NSF-MARK | +1-734-769-3010 | www.nsf.org

TEST REPORT

<p>Send To: 53110 Mr. Yosei Fujita Toray Industries, Inc. 1-1-2, Nihonbaishi-Muromachi Chuo-Ku, Tokyo 103-8606 Japan</p>	<p>Facility: C53111 Toray Chemical Korea, Inc. 300, Spongden 2-ro, Gumi Gyeongsangbuk-do 730350 Korea, Republic of</p>
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Result: PASS
Report Date: 15-AUG-2019

Customer Name: Toray Industries, Inc.
Tested To: NSF/ANSI Standard 419-2018: Public Drinking Water Equipment Performance – Filtration
Location of Testing: NSF International, 750 N. Dixboro Rd., Ann Arbor, MI 48105
Description: Ultrafiltration Membrane Modules, Model Number HFUG-2020AN
Test Type: Qualification
Job Number: J-00320592
Project Number: W0526739
Project Manager: Sangho Lee

Thank you for having your product tested by NSF International.
Please contact your Project Manager if you have any questions or concerns.

Report Authorization:  Digitally signed by Kevin Schaefer – Group Leader, Engineering Lab on 08/15/2019 10:30:00 AM

Authority:  Paul Anderson – Director, Engineering Lab

This report replaces the report with serial number FT20190718103612. It is a retest. This does not change the overall status of the report.

FD0190615145247 J-00320592

This report shall not be reproduced, except in its entirety, without the written approval of NSF International. Authorization to use the NSF Mark is limited to product identification only. The results relate only to those items tested, in the conditions specified at the time of testing.

Table 1 – Challenge Test Summary Results

Membrane manufacturer	Toray Industries, Inc.
Membrane model number	HFUG-2020AN
Membrane type	Hollow fiber
Membrane classification	Ultrafiltration
Challenge test date	04/01/2019 – 6/27/2019
Challenge particle or organism	MS2 and <i>Bacillus atrophaeus</i>
LRV _{C-Test} (log)	5.17
Challenge test feed water temperature (°C)	16.11 – 21.94
Challenge test flux (gfd)	120.14 - 120.57
Challenge test flux normalized to 20°C (gfd) ¹	113.78- 132.79
Challenge test TMP (psi)	15.19– 18.29
Revised Non-Destructive Performance Test (NDPT) Method	Pressure decay test from 18.85 psi
Revised Quality Control Release Value (QCRV)	0.048 psi/min
Equation for Air-Liquid Conversion Ratio (ALCR)	$ALCR_{turbulent} = 170 \times Y \times \sqrt{\frac{(P_{test} - BP)(P_{test} + P_{atm})}{((460 + T) \times TMP)}}$
Equation for LRV _{DIT}	$LRV_{DIT} = \log_{10} \left[\frac{Q_P \times ALCR \times P_{atm}}{\Delta P_{test} \times V_{sys} \times VCF} \right]$

¹Test flux normalized to 20°C using equation 2.10 from the Membrane Filtration Guidance Manual, USEPA 2005

A summary of the Toray HFUG-2020AN modules is shown below in Table 3.

Table 3 - Manufacturer and Model Specifications

Description	
Membrane Make	Toray
Membrane Model Number	HFUG-2020AN
ANSI/NSF Standard 61 certification	Certified
Membrane type	Hollow Fiber
Membrane classification	Ultrafiltration
Nominal & max pore size, or molecular weight cutoff rating	150,000 daltons
Membrane media symmetry	-
Membrane material	PVDF
Feed side membrane filtration area (ft ²)	969
Membrane module specifications	
Module outside diameter (mm)	216
Length (mm)	2,160
Module volume (gallons and liters)	Feed side, lumen, end caps: 45.0 Liters, 11.88 gallons
Potting depth (mm)	-
Potting material	Epoxy and/or equivalent
Module weight – full/dry (kg)	110 / 67
Module casing material – if pressurized	PVC and/or equivalent
Membrane fiber characteristics	
Number of fibers per module	14,000
Inside fiber diameter (mm)	0.7
Fiber wall thickness (mm)	0.2
Active fiber length (mm)	1,816
Filtration Flow Direction (i.e., inside-out or outside-in)	Outside – In
Hydraulic configuration (i.e., deposition or suspension)	Dead End

Operating Limits	
Maximum design filtrate flux at 20°C (gfd)	120
Maximum inlet module pressure (psi)	43.5
Maximum design transmembrane pressure (TMP) at 20°C	43.5 psi max, 29.0 psi normal operation
Maximum TMP at any temperature	29 psi
Max oxidant tolerance (cleaning; oxidant(s))	3000 mg/L Cl ₂
Max oxidant tolerance (normal operation; oxidant(s))	-
pH tolerance range (cleaning)	0.0 – 12.0 (0.0-40°C)
pH tolerance range (normal operation)	1.0 – 10.0 (0.0 – 40°C)
Temperature tolerance range	0.0 – 40°C

Table 21 - Membrane Integrity Summary Information

Revised NDPT method and QCRV	
NDPT method (e.g., pressure decay, etc.)	10-minute pressure decay from 18.85 psi
QCRV (include units)	0.048 psi/min
Equations for use in determining LRV _{DIT} , ALCR, and DIT pressures	
LRV _{DIT} equation	$LRV_{DIT} = \log_{10} \left[\frac{Q_p \times ALCR \times P_{atm}}{\Delta P_{test} \times V_{sys} \times VCF} \right]$
ALCR equation	$ALCR_{Turbulent} = 170 \times Y \times \sqrt{\frac{(P_{test} - BP)(P_{test} + P_{atm})}{(460 + T) \times TMP}}$
DIT pressure equation	$P_{test} = (0.193 \times K \times \sigma \times \cos\theta) + BP_{max}$
Constants for use in determining LRV _{DIT} , ALCR, and DIT pressures	
Volume of pressurized air in module during DIT (liters)	34.0
Volumetric concentration factor (VCF, dimensionless)	1
Net expansion factor (Y)	0.588
Lumen diameter (d, mm)	1.1 outside, 0.7 inside
Potting depth or defect length (l, mm)	-
Pore shape correction factor (K, dimensionless)	1
Liquid membrane contact angle (θ, degrees)	0°
Maximum design flow rate per module (L/min)	305.67

Note: The "revised" nondestructive performance test (NDPT) method and quality control release value (QCRV) are the NDPT and QCRV established as a result of the challenge study that will demonstrate meeting the 3 μ resolution requirement (with calculations and variables used) and that the modules will meet the removal efficiency demonstrated by the challenge test (LRV_{C-Test}). These may not have changed from what the manufacturer was already using, however, the term "revised" is used to denote the NDPT and QCRV reviewed/revised as a result of the challenge test.

Toray HFUG-2020AN Hollow Fiber PVDF Ultrafiltration Module

Outside-in flow operated in dead-end deposition mode

Molecular weight cutoff = 150,000 daltons

14,000 PVDF hollow fibers per module

Fiber interior (lumen) diameter = 0.7 mm

Active fiber length = 1,816 mm

Filter area = 969 ft²

Maximum flux = 120 ft²/day

Maximum flow = 80.75 gpm/module @ 20°C (challenge test flow)

Maximum TMP = 29 psi

Minimum end-of-test direct integrity test pressure = 17.44 psi (assumes 2.98 psi BP_{max})

