PUBLIC HEALTH DIVISION
Drinking Water Services
Kate Brown, Governor

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10 June 2022

Phil Chick
Arch Cape Water District
32065 East Shingle Mill Lane
Arch Cape Oregon 97102 *via email*

Re: Arch Cape Water District – WS ID# 00802
Membrane Module Replacement (Toray Model: HFU-2020AN)
Conditional Approval – PR# 90-2022

Dear Mr. Chick:

Thank you for your submittal to the Oregon Health Authority's Drinking Water Services (DWS) of plan review information regarding the membrane module replacement project for Arch Cape Water District. On 25 May 2022 we received the 2019 NSF 419 Test Report for the module model HFU-2020AN, and a check for $248.

Note that the lumen inside two membrane module models are identical: So HFU-2020AN effectively is equivalent for our purposes to HFUG-2020AN, which DWS verified in 2019.

Ten new modules are replacing the existing, but discontinued, Toray Torayfil HFS-2020.

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. 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 likely to be set no less than 18 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.

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 flux of 120 gfd, or equivalent flow setpoint. Since the membrane surface area of the HFU-2020AN is 775-ft^2, 120 gfd equates to a flow of 65 $^{gpm}/_{module}$.
b. Maximum transmembrane pressure (TMP) of 29 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 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 filter trains.

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.
4. The operation and maintenance manual is updated, or an addendum added to incorporate the new HFU-2020AN specifications, including any necessary changes to the membrane testing and module fiber repair/pinning procedures.

Lastly, I recommend Arch Cape works with the membrane manufacturer or engineer to explicitly determine parameters to track the long term health of the membrane modules. Whether it is resistance, TMP, or just number of pinned fibers, Arch Cape needs a parameter(s) to track now to assess the durability and reliability of the membranes into the 2030s.

The remainder of this letter includes:

1) Table 1 - Log removal credits (LRC) granted for the HFU-2020AN 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.

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 Toray HFU-2020AN membrane modules.

Table 1 – Filter Log Removal Credit (LRC) – HFUG-2020AN

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

LRCs above are only valid provided operations are within the limits shown in Table 2. Ensure SCADA programming accounts for the operating limits in Table 2 (e.g. set system alarms to ensure limits are met). **Many 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	**TBD**
DIT starting test pressure	**TBD** *(≥ 18 psi)*
Minimum allowed DIT pressure	**17.44 psi** (may change based on BP_{max}) throughout the DIT
Maximum allowable pressure decay rate (PDR) upper control limit (UCL)	**TBD**
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***
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)	**29 psi** at 20°C
Maximum allowed filtrate flux [gfd]	**120** $^{gal/SqFt}/_{day}$ @ 20°C.
Combined filter effluent (CFE)	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:

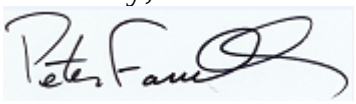
Accuracy in $^{psi}/_{min}$ = (% Accuracy x Max of span in psi) / DIT duration in minutes

[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 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 please contact me using the information above.

Sincerely,



Pete Farrelly, PE
Regional Engineer
Drinking Water Services

ec: Lindsay Housley, PE, WesTech Engineering, LLC
Jay MacPherson & Evan Hofeld, OHA–DWS

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 17.44 psi. **Should the pressure during a DIT drop below 17.44 psi, the DIT is considered invalid or "failed" and must be repeated. A DIT starting test pressure over 18 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	$LRV_{ambient} = \log_{10}\left(\frac{Q_P \bullet ALCR \bullet P_{atm}}{\Delta P_{test} \bullet V_{sys} \bullet VCF}\right)$
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]	0.588
d, Lumen diameter [mm]	0.8 I.D. [1.4 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 [$^{dyne}/_{cm}$]	74.9 dyne/cm @ 5°C water temp.
θ, Liquid-membrane contact angle [degrees]	0°
Q_p, Maximum design flow rate [$^{L}/_{min}$]	244.46 (64.6 gpm)
BP_{max}, Maximum backpressure during the DIT [psi]	2.98 (during 419 Test Report)
P_{Test}, Applied direct integrity test pressure [psi] (*Should be ≥ minimum test pressure in Table 2*)	18 psi target starting DIT pressure 17.44 psi minimum ending DIT pressure
D_{base}, Baseline diffusive loss expected through fully intact membrane filter unit [$^{psi}/_{min}$]	0 was conservatively used in 419 Test

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