# THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

# ETV Joint Verification Statement

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|---|---|---|
| TECHNOLOGY TYPE: | **NANOFILTRATION USED IN PACKAGED DRINKING WATER TREATMENT SYSTEMS** | |
| APPLICATION: | **REMOVAL OF PRECURSORS TO DISINFECTION BY-PRODUCTS IN BARROW, ALASKA** | |
| TECHNOLOGY NAME: | **FYNE PROCESS MODEL ROP 1434 WITH AFC-30 NANOFILTRATION MEMBRANES** | |
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The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by substantially accelerating the acceptance and use of improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations; stakeholders groups which consist of buyers, vendor organizations, and permitters; and with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

NSF International (NSF) in cooperation with the EPA operates the Drinking Water Treatment Systems (DWTS) Pilot, one of 12 technology areas under ETV. The DWTS Pilot recently evaluated the performance of a nanofiltration system used in package drinking water treatment system applications. This verification statement provides a summary of the test results for PCI Membrane Systems Inc.'s Fyne Process nanofiltration system equipped with a C10 module containing tubular polyamide AFC-30 membranes. The University of Alaska Anchorage in cooperation with the University of New Hampshire, a NSF-qualified field-testing organization (FTO), performed the verification testing.

## ABSTRACT

Equipment testing and verification of PCI Membrane Systems Inc. Fyne Process nanofiltration systems Model ROP 1434 equipped with a C10 module containing AFC-30 tubular membranes was conducted from March 16 to May 11, 2000 in Barrow, Alaska. The source water was a moderate alkalinity, moderately turbid surface water with a pH near neutral and a total organic carbon (TOC) concentration of approximately 15 mg/l. The average feed water temperature was 14.4°C. The skid produced an average of 0.87 gpm of permeate when operated so that 80% of the raw water supplied to the test skid was recovered as permeate. The average transmembrane pressure and specific flux during the verification study were 88 psig, and 0.14 gfd/psi, respectively. The membrane removed more than 95% of TOC and reduced $UV_{254}$ absorbance by an average of 97%. The test skid reduced the average total trihalomethane (TTHM) formation potential from 535 µg/l in the source water to 31 µg/l in the permeate. The average haloacetic acid (HAA5) formation potential was reduced from 398 µg/l in the source water to 6.2 µg/l in the permeate. All disinfection by-product formation potentials were evaluated using the U.S. EPA's Uniform Formation Conditions. The EPA Stage 1 Disinfectants/Disinfection By-Products (D/DBP) Rule requires TTHM and HAA5 concentrations not exceed 80 µg/l and 60 µg/l, respectively.


## TECHNOLOGY DESCRIPTION

The Fyne Process refers to a family of treatment systems offered by PCI Membrane Systems that were originally developed in the United Kingdom to treat waters with high concentrations of organic materials. The Fyne Process is designed to remove both microbial contaminants and reduce the organic content as precursors to form disinfection byproducts. One unique aspect of the Fyne Process is the use of an automated foam ball cleaning process to remove accumulated organic and inorganic foulants. In this process, a small foam ball is forced through the tubular filter elements via water pressure flowing in the opposite direction of normal flow. The foam ball scrubs the tubular membrane surface removing the accumulated foulants. "Filter-catchers" (small, perforated plates installed in the module inlet and outlet lines) retain the foam-balls in the system. Cleaning frequency is adjustable and the entire process is fully automated.

The specific system verified in this study was equipped with a C10 module that contained 72 AFC-30 tubular polyamide nanofiltration membranes connected in series. The total membrane surface area available was 114 $ft^2$. The test skid contained two pumps: a raw water pump that supplied source water to the skid and a recirculation pump that introduced source water and recycled concentrate to the inside of the tubular membrane elements housed in the module. Permeate passing through the membranes was collected in the module shroud and discharged at atmospheric pressure.

## VERIFICATION TESTING DESCRIPTION

### Test Site

The verification test was conducted at a site owned and operated by Barrow Utilities Electric Cooperative Incorporated (BUECI) in Barrow, Alaska. Barrow is an Inupiat Eskimo village that draws raw water year round from Isatkoak Reservoir, a surface water source that has a moderate alkalinity, moderate turbidity and an elevated organic content.

### Methods and Procedures

Water quality data were collected on all source water, permeate and concentrate streams produced by the PCI process and analyzed using *Standard Methods for the Examination of Water and Wastewater, 20th Edition* (1998) or EPA approved methods. The analysis of pH, turbidity, conductivity, color and temperature were conducted on-site using field instrumentation. Analysis for TOC, total suspended solids (TSS), total dissolved solids (TDS), chloride, bromide, sulfate, ortho-phosphate, total phosphate,

magnesium, manganese, calcium, total hardness, alkalinity, iron, total silica and dissolved silica were performed by a state-certified laboratory. $UV_{254}$ analysis was performed at the University of Alaska Anchorage. $UV_{254}$, pH, turbidity, conductivity and color analyses were conducted daily. The laboratory performed semiweekly (twice a week) analysis for TOC and biweekly (every two weeks) analysis for all other analytes. Flow rate and pressure data were obtained from skid instrumentation. All flow rate and pressure readings were manually verified during the verification study.

TTHM and HAA5 disinfection by-product formation potential for both the source water and the permeate was evaluated using the Uniform Formation Conditions (UFC) protocol specified EPA's Information Collection Rule (ICR). Biweekly feed and permeate samples were dosed with free chlorine and incubated for 24 hours at 20°C. All incubations were completed within 24 hours of sample collection. A sample with a free chlorine residual of 0.6 - 1.4 mg/l and final pH of 7.8 - 8.2 was quenched and sent to the laboratory for TTHM and HAA analysis.

## VERIFICATION OF PERFORMANCE

### System Operation

The test skid operated for 57 consecutive days from March 16 to May 11, 2000 with an average recovery of 80%. Feed and permeate flow rates averaged 1.08 gpm and 0.87 gpm, respectively, during the verification study. The test skid operated with an average transmembrane pressure 88 psig and the temperature corrected specific flux of 0.14 gfd/psi.

The system operated for the entire test period without requiring a chemical cleaning. A chemical cleaning was completed at the end of the verification test to evaluate cleaning efficiency using a caustic solution with an initial pH of approximately 10. The single high pH chemical cleaning recovered over 100% of the transmembrane pressure and specific flux values measured at the start of the verification study. Foam ball cleaning occurred at 5-hour intervals throughout the verification test.

### Water Quality Results

The test skid effectively removed organic compounds and particulates from the source water during the verification study. The raw water TOC, which averaged 15 mg/l, was reduced by over 95%. As a result, the treatment system was able to reduce the source water TTHM and HAA5 concentration produced under the Uniform Formation Conditions by 94% and 98%, respectively, and produced a permeate that contained an average of 31 µg/l TTHM and 6.2 µg/l HAA5. Permeate turbidity was consistently less than 0.1 NTU.

The test skid also removed 47%-99% of iron, manganese, calcium and sulfate from solution. (Note: Iron can foul membranes and should be considered for all membrane installations. However, the specific flux data indicates that significant fouling did not occur during this verification study). Modest reductions in source water alkalinity (10%) and total dissolved solids concentration (34.5%) were also observed. The other water quality parameters monitored during the test were not significantly altered by membrane treatment.

**Feed Water Quality/Permeate Water Quality**

**PCI Membrane System Inc. Fyne Process Model # ROP 1434**

| | Turbidity (NTU) | $UV_{254}$ Absorbance | TOC (mg/l) | HAA5 (µg/l) | TTHM (µg/l) |
|---|---|---|---|---|---|
| Average | 3.4/0.056 | 0.52/0.012 | 15/0.7 | 405/6.7 | 544/31 |
| Minimum | 2.8/0.039 | 0.41/0 | 9.3/0.4 | 306/4 | 400/21 |
| Maximum | 4.5/0.165 | 1.53/0.032 | 16/1.2 | 480/11 | 605/46 |
| Standard Deviation | 0.5/0.019 | 0.19/0.0078 | 1.5/0.2 | 72/3.1 | 97/11 |
| 95% Confidence Interval | (3.3,3.6)/ (0.051,0.061) | (0.44,0.60)/ (0.009,0.016) | (14,15)/ (0.6,0.8) | (290,520)/ (1.7,12) | (389,699)/ (15,48) |

**Operation and Maintenance Results**

The test system evaluated in this study was highly automated (with the exception of chemical cleaning) making day-to-day operation straightforward and simple. On most days (51 out of the 57 days of testing), test skid operators performed only the routine checks required for the verification study. The operators also made minor adjustments to the concentrate control valve to maintain target flow rates. When both routine operation and system repairs are considered, the average time required to operate the test system was 20 minutes per day. Power consumed by the test skid was 12.3 kW-hr per thousand gallons of permeate produced. The feed pump, which was external to the skid and not designed specifically for this project, consumed an additional 21.3 kW-hr per thousand gallons of permeate produced.

The operation and maintenance manual was well-written, effectively organized and contained appropriate information for most of the tasks required during the verification study. The information required to recalibrate the concentrate flow meter that was not in the original O&M manual supplied with the skid but was subsequently supplied by PCI.

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**Availability of Supporting Documents**

Copies of the *ETV Protocol for Equipment Verification Testing for Removal of Precursors to Disinfection By-Products* dated August 9, 1999, the Verification Statement, and the Verification Report (NSF Report #00/19/EPADW395) are available from the following sources:

(NOTE: Appendices are not included in the Verification Report. Appendices are available from NSF upon request.)

1.) Drinking Water Treatment Systems ETV Pilot Manager (order hard copy)
NSF International
P.O. Box 130140
Ann Arbor, Michigan 48113-0140

2.) NSF web site: http://www.nsf.org/etv (electronic copy)

3.) EPA web site: http://www.epa.gov/etv (electronic copy