June 2004
NSF 04/12/EPADWCTR

Environmental Technology Verification Report

Physical Removal of Microbial Contamination Agents in Drinking Water

Watts Premier
Ultra 5 Reverse Osmosis Drinking Water Treatment System

Prepared by

NSF International

Under a Cooperative Agreement with
U.S. Environmental Protection Agency

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**POINT-OF-USE REVERSE OSMOSIS DRINKING WATER TREATMENT SYSTEM**	
APPLICATION:	**REMOVAL OF MICROBIAL CONTAMINATION AGENTS IN DRINKING WATER**	
PRODUCT NAME:	**WATTS PREMIER ULTRA 5**	
COMPANY:	**WATTS PREMIER, INC.**	
ADDRESS:	**1725 WEST WILLIAMS STREET**	PHONE: **800-752-5582**
	PHOENIX, AZ 85027	FAX: **623-931-0191**

NSF International (NSF) manages the Drinking Water Systems (DWS) Center under the U.S. Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) Program. The DWS Center recently evaluated the performance of the Watts Premier, Inc. Ultra 5 point-of-use (POU) reverse osmosis drinking water treatment system. NSF performed all of the testing activities, and also authored the verification report and this verification statement. The verification report contains a comprehensive description of the test.

EPA created the 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 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, stakeholder groups (consisting 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.

ABSTRACT

The Watts Premier Ultra 5 was tested for removal of bacteria and viruses at NSF's Drinking Water Treatment Systems Laboratory. Watts Premier submitted ten units, which were split into two groups of five. One group received 25 days of conditioning prior to challenge testing, while the second group was tested immediately. Due to an incorrectly installed shut-off valve on one of the unconditioned units, only four in this group were tested. Both groups were challenged identically. The challenge organisms were the viruses fr, MS2, and Phi X 174, and the bacteria *Brevundimonas diminuta* and *Hydrogenophaga pseudoflava*. The test units were challenged at two different inlet pressures – 40 and 80 pounds per square inch, gauge (psig). The virus challenges were conducted at three different pH settings (6, 7.5, and 9) with the intent to assess whether pH influenced the performance of the test units. The bacteria challenges were only conducted at pH 7.5.

In most cases, the test units significantly reduced the challenge organisms, with reductions greater than 4.0 $\log_{10}$. The $\log_{10}$ reduction data is shown in Tables 3 through 6. Overall, the performance of the conditioned units was better than that of the unconditioned units. Also, the unconditioned units exhibited wider unit-to-unit performance variation than the conditioned units. The $\log_{10}$ reduction data does not conclusively show that inlet pressure or pH influenced test unit performance.

TECHNOLOGY DESCRIPTION

The following technology description was provided by the manufacturer and has not been verified.

The Watts Premier Ultra 5 is a five-stage POU drinking water treatment system. It employs carbon filtration and reverse osmosis processes to remove contaminants from drinking water. It is sold with a faucet that is installed at the kitchen sink, and the system itself is installed either under the kitchen sink or in another location.

During operation, inlet water first passes through a sediment filter, and then through two carbon block filters. The fourth stage is passage through the reverse osmosis membrane. The portion of the inlet water that passes through the membrane travels to the product water storage tank. When the user opens the faucet, the water leaves the storage tank and travels through a final carbon filter before exiting the faucet. The system is designed to produce approximately 12 gallons of reject water for each gallon of treated water produced.

The test units were evaluated without the carbon filters or sediment filter in place to eliminate the possibility that these filters could temporarily trap a portion of the challenge organisms, causing a positive bias of system performance during testing.

VERIFICATION TESTING DESCRIPTION

Test Site

The testing site was the Drinking Water Treatment Systems Laboratory at NSF in Ann Arbor, Michigan. A description of the test apparatus can be found in the test/quality assurance (QA) plan and verification report. The testing was conducted in September and October of 2003.

Methods and Procedures

The testing methods and procedures are detailed in the *Test/QA Plan for Verification Testing of the Watts Premier Ultra 5 Point-of-Use Reverse Osmosis Drinking Water Treatment System for Removal of Microbial Contamination Agents.* Nine test units were verified for bacteria and virus removal

performance using the bacteriophage viruses fr, MS2, and Phi X 174, and the bacteria *B. diminuta* and *H. pseudoflava*. The challenge organisms were chosen because they are smaller than most other viruses and bacteria, and so provide a conservative estimate of performance.

Watts Premier submitted ten units, which were split into two groups of five according to the performance of each membrane in the manufacturer's quality control testing. One group was conditioned for 25 days prior to challenge testing by operating the units daily using the test water without challenge organisms. The second group was challenged without receiving the 25-day conditioning period. Due to an incorrectly installed shut-off valve on one of the unconditioned units, only four in this group were tested.

The test units were challenged at both 40 and 80 psig inlet pressure. The test water for the bacteria challenges was set to pH 7.5 ± 0.5. The test water for the virus challenges was set at pH 6.0 ± 0.5, 7.5 ± 0.5, and 9.0 ± 0.5. However, it had a low buffering capacity, so the lab technicians had difficulty maintaining the pH within the 9.0 ± 0.5 range. As a result, the pH for the conditioned units pH 9, 80 psig challenge was only 7.9. The test water pH values for all other challenges were within the allowable ranges. These challenge conditions were intended to evaluate whether inlet pressure or pH influences bacteria and virus removal. Table 1 shows the challenge schedule for the conditioned units, while Table 2 shows the schedule for the unconditioned units. The challenge levels ranged from 3.4 to 6.4 $\log_{10}$ for the viruses, and 6.7 to 8.4 $\log_{10}$ for the bacteria.

Table 1. Conditioned Units Challenge Schedule

Day	Challenge Organism(s)	pH (± 0.5 units)	Inlet Pressure (± 3 psig)
1	All Viruses	6.0	40
2	All Viruses	6.0	80
3	All Viruses	7.5	40
4	All Viruses	7.5	80
5	All Viruses	9.0	40
6	All Viruses	9.0	80
7	*H. pseudoflava*	7.5	80
8	*H. pseudoflava*	7.5	40
9	*B. diminuta*	7.5	40
10	*B. diminuta*	7.5	80

Table 2. Unconditioned Units Challenge Schedule

Day	Challenge Organism(s)	pH (± 0.5 units)	Inlet Pressure (± 3 psig)
1	*H. pseudoflava*	7.5	80
2	*H. pseudoflava*	7.5	40
3	*B. diminuta*	7.5	40
4	*B. diminuta*	7.5	80
5	All Viruses	6.0	40
6	All Viruses	6.0	80
7	All Viruses	7.5	40
8	All Viruses	7.5	80
9	All Viruses	9.0	40
10	All Viruses	9.0	80

On each challenge day, the test units were operated for one tank-fill period (approximately six to eight hours). The end of this period was evident through engagement of the system's automatic shutoff mechanism, which causes the flow of reject water to cease. At 40 psig, not all of the shut-off mechanisms engaged after 8 hours of operation due to the low pressure. The storage tanks were nearly full in these instances, so operation of the units was stopped manually.

Influent water samples were collected at the beginning and end of the challenge period. After each test unit ceased operation, the entire contents of the product water storage tank were emptied into a sterile container, and a subsample was collected for microbiological analysis. All samples were enumerated in triplicate. Following each challenge period, the test units were flushed by operating them for one tank-fill period using the test water without challenge organisms.

VERIFICATION OF PERFORMANCE

The bacteria reduction data are presented in Tables 3 and 4, and the virus reduction data in Tables 5 and 6. An examination of the bacteria reduction data shows that for the five conditioned test units, in only one case (unit 4 for *B. diminuta* at pH 7.5, 40 psig) was one of the bacteria species detected in the effluent samples. In contrast, for the unconditioned units, there were 13 cases out of 16 where the challenge bacteria were detected in the effluents.

An evaluation of the virus reduction data shows that overall, the conditioned units performed better than the unconditioned units. The mean $\log_{10}$ reductions and mean $\log_{10}$ effluent counts are shown in the bottom right corner of Tables 5 and 6. A comparison of the mean $\log_{10}$ effluent counts for the unconditioned versus conditioned units shows that the conditioned units performed approximately 0.3 to 1.7 $\log_{10}$ better than the unconditioned units.

The unit-to-unit performance variation for the unconditioned units was wider than for the conditioned units, and the performance of each unconditioned unit also varied more from day-to-day. Also, the unconditioned units had many cases where bacteria reduction performance was less than virus reduction performance. The reasons for these observations are not known, but the data suggest that conditioning the systems improves and/or stabilizes their performance. The data does not conclusively show whether inlet pressure or pH influenced test unit performance.

Table 3. Bacteria Log Reduction Data for Unconditioned Units

pH	Pressure (psig)	Challenge Organisms	$\log_{10}$ Influent Challenge	Geometric Mean $\log_{10}$ Reduction Unit 1	Unit 2	Unit 3	Unit 4
7.5	40	*H. pseudoflava*	6.9	4.4	4.9	2.2	1.6
		B. diminuta	8.2	8.2	3.0	2.0	8.2
7.5	80	*H. pseudoflava*	6.9	4.6	6.6	1.9	3.0
		B. diminuta	8.1	3.5	2.2	3.3	8.1

Table 4. Bacteria Log Reduction Data for Conditioned Units

pH	Pressure (psig)	Challenge Organisms	$\log_{10}$ Influent Challenge	Geometric Mean $\log_{10}$ Reduction Unit 1	Unit 2	Unit 3	Unit 4	Unit 5
7.5	40	*H. pseudoflava*	6.7	6.7	6.7	6.7	6.7	6.7
		B. diminuta	8.3	8.3	8.3	8.3	7.2	8.3
7.5	80	*H. pseudoflava*	6.7	6.7	6.7	6.7	6.7	6.7
		B. diminuta	8.4	8.4	8.4	8.4	8.4	8.4

Table 5. Virus Log Reduction Data for Unconditioned Units

Challenge Conditions				Log_{10}	Geometric Mean Log_{10} Reduction					Log_{10}
Target pH	Actual pH	Pressure (psig)	Challenge Organisms	Influent Challenge	Unit 1	Unit 2	Unit 3	Unit 4	Mean[1]	Mean Effluent Count
6.0 ± 0.5	6.5	40	fr	6.3	4.8	3.1	2.9	4.6	3.8	2.5
			MS2	6.1	5.6[2]	3.0	2.8	4.7	4.0	2.1
			Phi X 174	5.0	5.0	2.4	2.3	5.0[2]	3.7	1.3
6.0 ± 0.5	6.2	80	fr	5.9	4.5	3.2	3.3	5.9	4.2	1.7
			MS2	5.8	4.5	3.0	3.3	5.8	4.2	1.6
			Phi X 174	4.9	4.6[2]	2.8	2.4	4.9	3.7	1.2
7.5 ± 0.5	7.6	40	fr	5.9	4.0	2.9	4.9	4.4	4.1	1.8
			MS2	5.6	3.8	2.7	5.0	4.3	4.0	1.6
			Phi X 174	5.7	3.7	2.3	5.7[2]	4.3	4.0	1.7
7.5 ± 0.5	7.7	80	fr	5.8	4.6	2.5	4.3	5.5	4.2	1.6
			MS2	5.7	4.4	2.6	4.3	5.4[2]	4.2	1.5
			Phi X 174	5.9	4.3	2.6	3.7	5.1	3.9	2.0
9.0 ± 0.5	8.7	40	fr	5.8	4.4	2.9	4.2	4.8	4.1	1.7
			MS2	5.6	4.1	2.7	4.1	4.8	3.9	1.7
			Phi X 174	5.7	3.8	2.6	3.3	4.1	3.5	2.2
9.0 ± 0.5	9.0	80	fr	6.0	4.6	3.5	3.7	5.1	4.2	1.8
			MS2	5.7	4.7	3.4	3.8	5.1	4.3	1.4
			Phi X 174	5.6	4.1	3.5	3.5	4.5	3.9	1.7
				fr mean[3]	4.5	3.0	3.9	5.1	4.1	1.9
				MS2 mean[3]	4.5	2.9	3.9	5.0	4.1	1.7
				Phi X 174 mean[3]	4.3	2.7	3.5	4.7	3.6	1.7

[1] The arithmetic mean of all test units for each challenge.
[2] Triplicate count had two "non-detect" agar plates.
3 The arithmetic mean for all challenges against each test unit.

Table 6. Virus Log Reduction Data for Conditioned Units

Challenge Conditions				Log_{10}	Geometric Mean Log_{10} Reduction						Log_{10} Mean
Target pH	Actual pH	Pressure (psig)	Challenge Organisms	Influent Challenge	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Mean[1]	Effluent Count
6.0 ± 0.5	6.5	40	fr	5.1	3.6	4.1	4.0	4.8	4.0	4.1	1.0
			MS2	4.8	3.2	3.7	3.8	4.1	3.2	3.6	1.2
			Phi X 174	3.4	3.4	3.4	3.4	3.4	3.4	3.4	0.0
6.0 ± 0.5	6.4	80	fr	6.1	4.6	4.2	4.3	4.7	4.6	4.5	1.6
			MS2	6.0	4.6	4.2	4.2	4.8	3.7	4.3	1.7
			Phi X 174	3.8	3.8	3.8	3.8	3.8	3.8	3.8	0.0
7.5 ± 0.5	7.5	40	fr	6.4	4.2	4.8	4.7	4.8	4.2	4.5	1.9
			MS2	6.2	4.2	4.5	4.8	4.7	4.3	4.5	1.7
			Phi X 174	4.0	3.7	4.0[2]	4.0[2]	4.0	3.7	3.9	0.1
7.5 ± 0.5	7.3	80	fr	6.3	4.8	5.6	5.6	5.3	4.8	5.2	1.1
			MS2	6.1	5.2	5.5	5.6	4.9	5.0	5.2	0.9
			Phi X 174	4.1	4.1	4.1[2]	4.1	4.1	4.1[2]	4.1	0.1
9.0 ± 0.5	8.9	40	fr	6.2	4.4	4.2	4.3	4.3	4.3	4.3	1.9
			MS2	5.8	4.2	4.0	4.2	4.1	4.2	4.1	1.7
			Phi X 174	4.1	4.1	4.1	4.1	4.1	4.1	4.1	0.0
9.0 ± 0.5	7.9[3]	80	fr	6.0	4.4	4.9	4.7	4.7	4.6	4.7	1.3
			MS2	5.9	4.3	5.9	4.8	4.9	4.6	4.9	1.0
			Phi X 174	4.0	4.0	4.0	4.0	4.0	4.0	4.0	0.0
				fr mean[4]	4.3	4.6	4.6	4.8	4.4	4.6	1.5
				MS2 mean[4]	4.3	4.6	4.6	4.6	4.2	4.4	1.4
				Phi X 174 mean[4]	3.9	3.9	3.9	3.9	3.9	3.9	0.0

[1] The arithmetic mean of all test units for each challenge.
[2] Triplicate count had two "non-detect" agar plates.
[3] See section 5.8.3 of verification report for discussion of pH variance.
[4] The arithmetic mean for all challenges against each test unit.

QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

NSF personnel conducted a technical systems audit during testing to ensure that the testing was in compliance with the test plan. NSF also conducted a data quality audit of 100% of the data. Please see the verification report referenced below for more QA/QC information.

Original signed by	*Original signed by*
E. Timothy Oppelt *07/12/04*	*Gordon Bellen* *07/16/04*
E. Timothy Oppelt Date	Gordon Bellen Date
Director	Vice President
National Homeland Security Research Center	Research
United States Environmental Protection Agency	NSF International

NOTICE: Verifications are based on an evaluation of technology performance under specific, predetermined criteria and the appropriate quality assurance procedures. EPA and NSF make no expressed or implied warranties as to the performance of the technology and do not certify that a technology will always operate as verified. The end user is solely responsible for complying with any and all applicable federal, state, and local requirements. Mention of corporate names, trade names, or commercial products does not constitute endorsement or recommendation for use of specific products. This report is not a NSF Certification of the specific product mentioned herein.

Availability of Supporting Documents

Copies of the test protocol, the Verification Statement, and the Verification Report (NSF Report # NSF 04/12/EPADWCTR) are available from the following sources (NOTE: Appendices are not included in the Verification Report. Appendices are available from NSF upon request.):

1. ETV Drinking Water Systems Center Manager (order hard copy)
   NSF International
   P.O. Box 130140
   Ann Arbor, Michigan 48113-0140
2. NSF web site: http://www.nsf.org/etv/dws/dws_reports.html and from http://www.nsf.org/etv/dws/dws_project_documents.html (electronic copy)
3. EPA web site: http://www.epa.gov/etv (electronic copy)

June 2004

Environmental Technology Verification Report

Physical Removal of Microbial Contamination Agents in Drinking Water

Watts Premier
Ultra 5 Reverse Osmosis Drinking Water Treatment System

Prepared by:

NSF International
Ann Arbor, MI 48105

Under a cooperative agreement with the U.S. Environmental Protection Agency

Jeffrey Q. Adams, Project Officer
National Risk Management Research Laboratory
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Cincinnati, Ohio 45268

Notice

The U.S. Environmental Protection Agency (EPA) through its Office of Research and Development has financially supported and collaborated with NSF International (NSF) under Cooperative Agreement No. R-82833301. This verification effort was supported by the Drinking Water Systems (DWS) Center, operating under the Environmental Technology Verification (ETV) Program. This document has been peer reviewed, reviewed by NSF and EPA, and recommended for public release.

Foreword

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The Environmental Technology Verification (ETV) Program has been established by EPA to verify the performance characteristics of innovative technologies, and to report this objective information to permitters, buyers, and users of the technologies. Verification organizations oversee and report verification activities based on testing and quality assurance protocols developed with input from major stakeholders and customer groups associated with the technology area. ETV consists of seven environmental technology centers. Information about each of these centers can be found on the internet at http://www.epa.gov/etv/.

Under a cooperative agreement, NSF International is partnering with EPA to plan, coordinate, and conduct verification tests for point-of-use, point-of-entry, and small community water treatment systems. Further information can be found on the internet at http://www.epa.gov/etv/centers/center2.html, or http://www.nsf.org/etv.

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Abbreviations and Acronyms

ANSI	American National Standards Institute
ASTM	American Society of Testing Materials
ATCC	American Type Culture Collection
°C	Degrees Celsius
CFU	Colony Forming Unit
cm	Centimeter
DWS	Drinking Water Systems
EPA	U. S. Environmental Protection Agency
ETV	Environmental Technology Verification
°F	Degrees Fahrenheit
L	Liter
mg	Milligram
ml	Milliliter
nm	Nanometer
NSF	NSF International (formerly known as National Sanitation Foundation)
PBDW	Phosphate-Buffered Dilution Water
PFU	Plaque Forming Unit
POU	Point-of-Use
psig	Pounds per Square Inch Gauge
QA	Quality Assurance
QC	Quality Control
QA/QC	Quality Assurance/Quality Control
RPD	Relative Percent Deviation
RO	Reverse Osmosis
SOP	Standard Operating Procedure
TDS	Total Dissolved Solids
TSA	Tryptic Soy Agar
TSB	Tryptic Soy Broth
µg	Microgram
µl	Microliter
µm	Micrometer
µS	MicroSieman

Acknowledgments

NSF International was responsible for all elements in the testing sequence, including collection of samples, calibration and verification of instruments, data collection and analysis, data management, data interpretation and the preparation of this report.

The Manufacturer of the Equipment was:

Watts Premier Incorporated
1725 West Williams Street
Phoenix, AZ 85027

NSF wishes to thank the members of the expert technical panel for their assistance with development of the test plan.

Chapter 1
Introduction

1.1 Environmental Technology Verification (ETV) Purpose and Program Operation

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 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; with stakeholder groups consisting 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; by conducting field or laboratory testing, collecting and analyzing data; and by 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.

The EPA has partnered with NSF International (NSF) under the ETV Drinking Water Systems (DWS) Center to verify performance of drinking water systems that benefit the public and small communities. It is important to note that verification of the equipment does not mean the equipment is "certified" by NSF or "accepted" by EPA. Rather, it recognizes that the performance of the equipment has been determined and verified by these organizations for those conditions tested by the FTO.

1.2 Development of Test/Quality Assurance (QA) Plan

As part of the national Homeland Security effort, NSF has developed a test/QA plan under the EPA ETV program for evaluating point-of-use (POU) reverse osmosis (RO) drinking water treatment systems for removal of biological contamination agents. This test/QA plan uses surrogate bacteria and viruses in place of testing with the actual agents of concern.

To assist in this endeavor, NSF assembled an expert technical panel, which recommended the experimental design and surrogate choices prior to the initiation of testing. Panel members included experts from the EPA, United States Army, and United States Centers for Disease Control and Prevention, Division of Parasitic Diseases, as well as a water utility microbiologist, a university professor, and an independent consultant in the POU drinking water treatment systems industry.

By participating in this ETV test, vendors obtain EPA and NSF verified third–party test data indicating potential user protection against intentional biological contamination of potable water. POU RO systems are not typically marketed as water purifiers that remove bacteria and viruses from drinking water, but they may still remove significant numbers of the microorganisms, thus offering the user a significant level of protection. The verifications serve to notify the public of the possible level of protection against biological contamination agents afforded to them by the use of verified systems.

The test/QA plan called for testing ten Watts Premier Ultra 5 units with a standard test water containing bacterial or viral surrogates. The virus challenges were conducted with the water set to pH values of 6, 7.5, and 9, while the bacteria challenges were conducted at pH 7.5 only. The systems were also challenged at both 40 and 80 pounds per square inch, gauge (psig). The test units were subjected to challenge scenarios that were unique combinations of the challenge organisms, pH, and inlet water pressure. Five units were challenged immediately after completion of the manufacturer's installation and conditioning instructions, while the other five underwent a 25-day conditioning period prior to being challenged with the surrogates.

1.2.1 Bacteria and Virus Surrogates

The expert technical panel recommended that NSF and the EPA use the bacteria *Brevundimonas diminuta* (American Type Culture Collection (ATCC) strain 19146, formerly *Pseudomonas diminuta*), and *Hydrogenophaga pseudoflava* (ATCC strain 33668) as surrogates for bacterial agents. These surrogates were chosen based on their small sizes, as the smallest identified bacterium of concern can be as small as 0.2 μm in diameter. *H. pseudoflava* has a minimum diameter of 0.1 to 0.2 μm, while *B. diminuta* has a minimum diameter of 0.2 to 0.3 μm (please note that these minimum diameters were not obtained during this study. See Section 5.4.2 for discussion). *B. diminuta* is the accepted bacteria of choice for testing filters and membranes designed to remove bacteria. It is used in the American Society of Testing Materials (ASTM) "Standard Test Method for Retention Characteristics of 0.2-μm Membrane Filters Used in Routine Filtration Procedures for the Evaluation of Microbiological Water Quality" (2001).

The virus surrogates were the bacteriophages MS2, Phi X 174, and fr. The ATCC designation and host *Escherichia coli* strain for each virus is given Table 1-1.

Table 1-1. Virus and Host ATCC Designations

Virus	ATCC Designation	Host *E. coli* ATCC Strain
MS2	15597-B1	15597
Phi X 174	13706-B1	13706
fr	15767-B1	19853

The expert technical panel recommended these viruses based on their small sizes and isoelectric points. The isoelectric point is the pH at which the virus surface is neutrally charged. MS2 is 24

nm in diameter with an isoelectric point at pH 3.9, Phi X 174 is 27 nm in diameter with an isoelectric point at pH 6.6, and fr is 19 nm in diameter with an isoelectric point at pH 8.9. With varying isoelectric points, the viruses have different surface charges, or different strengths of negative or positive charge, depending on the pH. In solutions above the isoelectric point, the virus is negatively charged. Below the isoelectric point, the virus is positively charged. Using different pH settings for the virus challenges allowed an evaluation of whether electrostatic forces enhance virus retention in mechanical filtration scenarios. The pH 6 and 9 settings were chosen because they are just beyond the upper and lower boundaries for allowable pH in the EPA National Secondary Drinking Water Regulations. The pH 7.5 setting was chosen because it is the midpoint between the boundaries.

The bacteria reduction challenges were performed only at pH 7.5, because the expert panel believed that bacteria cell size and mass are too large for electrostatic interactions to play a significant role.

1.2.2 Inlet Pressure

The bacteria and virus challenge tests were performed at dynamic inlet pressures of both 40 and 80 psig to evaluate whether inlet pressure affects microorganism rejection by RO membranes. Forty psig is a worse case scenario for ionic rejection mechanisms, while 80 psig represents a poorer mechanical filtration scenario. In a typical mechanical filtration scenario, the higher pressure could push suspended particles further into, and perhaps all the way through, the filtration media, and it could also distort seals to the point that they leak. However, this may or may not be the case with RO membranes, since they operate by a different principle.

1.2.3 Long-Term Conditioning

The expert technical panel was presented with anecdotal evidence that RO membrane performance could be erratic for approximately the first month of operation, so they recommended that NSF split the test units into two groups, one group to be tested immediately after installation and completion of the manufacturer's conditioning instructions (hereafter referred to as "unconditioned units"), and a second group to be tested after a 25 working day conditioning period (hereafter referred to as "conditioned units").

1.3 Testing Participants and Responsibilities

The ETV testing of the Watts Premier Ultra 5 RO system was a cooperative effort between the following participants:

NSF
Watts Premier
EPA

The following is a brief description of each of the ETV participants and their roles and responsibilities.

1.3.1 NSF

NSF is a not-for-profit organization dedicated to public health and safety, and to the protection of the environment. Founded in 1946 and located in Ann Arbor, Michigan, NSF has been instrumental in the development of consensus standards for the protection of public health and the environment. The EPA partnered with NSF to verify the performance of drinking water treatment systems through the EPA's ETV Program.

NSF performed all verification testing activities at its Ann Arbor location. NSF prepared the test/QA plan, performed all testing, managed, evaluated, interpreted, and reported on the data generated by the testing, and reported on the performance of the technology.
Contact Information:

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1.3.2 Watts Premier

The verified system is manufactured by Watts Premier, a division of Watts Water Technologies. Watts Premier manufactures industrial, food service, point-of-entry, and point-of-use water treatment systems.

The manufacturer was responsible for supplying the RO systems in accordance with the equipment selection criteria given in Section 3.1.1, and for providing logistical and technical support as needed.

Contact Information:

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1.3.3 U.S. Environmental Protection Agency

The EPA, through its Office of Research and Development, has financially supported and collaborated with NSF under Cooperative Agreement No. R-82833301. This verification effort was supported by the DWS Center operating under the ETV Program. This document has been peer-reviewed and reviewed by NSF and EPA, and recommended for public release.

Chapter 2
Equipment Description

2.1 RO Membrane Operation

Membrane technologies are among the most versatile water treatment processes with regard to their ability to effectively remove the widest variety of contaminants at the lowest costs. RO membranes operate by the principal of cross-flow filtration. In this process, the influent water flows over and parallel to the filter medium and exits the system as reject water. Under pressure, a portion of the water in the bulk solution diffuses through the membrane becoming "permeate". Membrane pore sizes are small enough to reject bacteria and viruses, but the organisms may still pass through imperfections in the membrane, or pass around the membrane due to microscopic leaks in the seals

2.2 Equipment Capabilities

The Watts Premier Ultra 5 system is certified by NSF to NSF/ANSI Standard 58 – *Reverse Osmosis Drinking Water Treatment Systems*. The system has a certified production rate of 9.06 gallons per day, and an efficiency rating of 8.35%. Efficiency rating as defined in NSF/ANSI Standard 58 is "a percentage measure of the amount of influent water that is delivered as permeate under a closed permeate discharge set of actual use conditions." These measurements are based on system operation at 50 psig inlet pressure, a water temperature of 77 °F, and a total dissolved solids (TDS) level of 750 mg/L. The amount and quality of treated water produced varies depending on the inlet pressure, water temperature, and level of TDS. These measurements were not subject to verification during this study.

2.3 Trade Names

The Ultra 5 is sold under different names at various retail outlets. All of the following models are identical to the Ultra 5 except in name:

- RO-TFM-5SV
- PUR-TEK
- WATTS-25
- CRO-TFM-5SV
- WATTS PURE WATER RO-5
- DELUXE PLUS
- DELUXE
- AQUA-RITE 5.0

2.4 System Components

The Ultra 5 is a five-stage treatment system. The inlet water first passes through a sediment filter, and then through two sequential carbon block filters. The fourth stage is passage through

the RO membrane element. The permeate is sent to a three gallon maximum capacity storage tank, and the reject water is sent to a drain. The system has an automatic shut-off valve to shut down the flow of water through the system when the storage tank is nearly full. The fifth stage of treatment is a granular activated carbon filter downstream of the storage tank. A schematic drawing of the system is provided in Figure 2-1, and a photo of the system in Figure 2-2.

2.5 System Operation

When the flow of water into the system is started, it will continually produce treated water until the storage tank is nearly full. When the storage tank is almost full, back-pressure causes an automatic shut-off device to activate, stopping the flow of water into the system. After a portion of the product water is dispensed from the storage tank, the shut-off device deactivates, allowing water to again flow into the system until the storage tank is nearly full. The operational capacity of the storage tank will vary slightly from unit to unit, and is also affected by the inlet water pressure.

2.6 Rate of Waste Production

The Ultra 5 system produces approximately 11 gallons of reject water for each gallon of product water produced, as defined by the efficiency rating parameter in NSF/ANSI Standard 58.

2.7 Equipment Operation Limitations

Watts Premier gives the following limitations for the drinking water to be treated by the system:

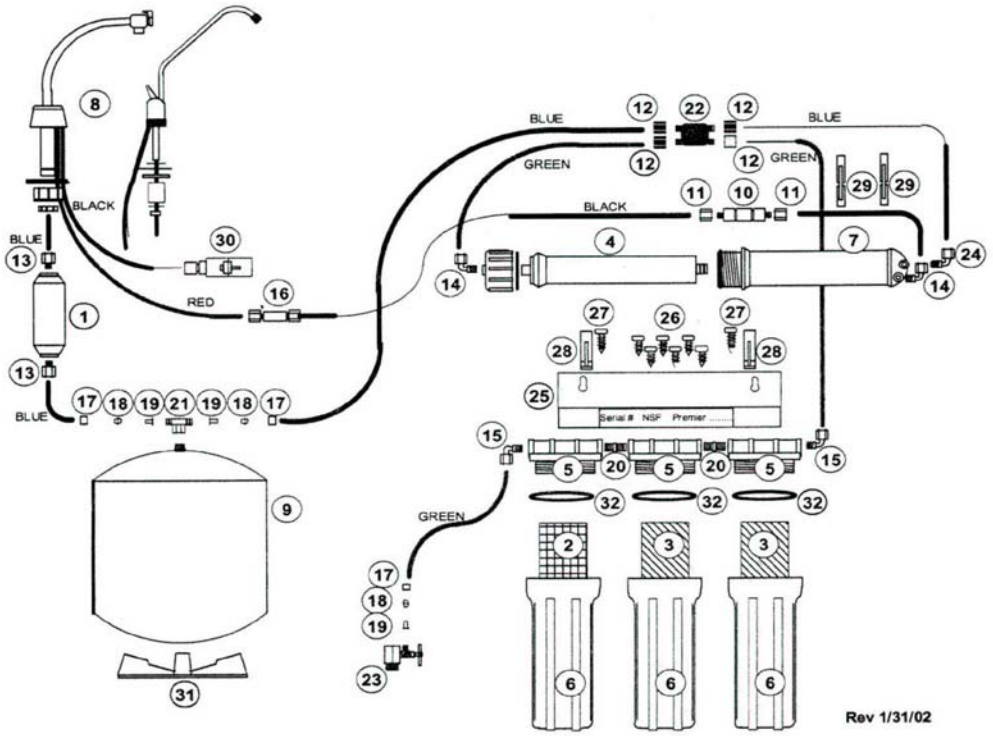
- temperature of 40 – 100°F;
- pressure of 40 – 100 psig;
- pH of 3 – 11;
- Non-detectable iron level;
- hardness of more than 120 mg/L may reduce membrane life expectancy; and
- TDS level should be less than 1800 mg/L.

2.8 Operation and Maintenance Requirements

Watts Premier recommends the following maintenance steps:

- Replacement of the filters upstream from the RO membrane every 6 months;
- Replacement of the carbon filter located downstream of the storage tank annually;
- Annual sanitization of the system with hydrogen peroxide;
- Replacement of the membrane every two to five years, depending on the quality of the product water (Watts Premier offers free water testing, or a TDS monitor for purchase, to monitor the product water quality); and
- Periodic storage tank air pressure check.

Figure 2-1. Schematic Diagram of the Watts Premier Ultra 5 RO System



* The reverse osmosis system contains a replaceable treatment component, critical for the effective reduction of total dissolved solids and that the product water shall be tested periodically to verify that the system is performing properly

Item #		Part #	Description
1	a	100004	GAC-IL-6"-1/4 F (1M-6)
1	b	100014	GAC-IL-10"-1/4 F (PREMIER)
2		104017	SED-SPUN-10"-5M-CTG(5M-10)
3	a	101009	CARBONBLOCK-10"-5M-CTG
3	b	100036	GAC 10" - 56 Cu In CPG
4	a	110004	*MEM-TFM-18 GPD
4	b	110005	*MEM-TFM-25 GPD-DRY
5	a	113004	LID-BLACK 1/4" FPT UNASSEMBLED
5	b	113007	LID-WHITE 1/4" FPT UNASSEMBLED
6	a	113017	HOUSING-FILTER 10" BLUE
6	b	113024	HOUSING-FILTER 10" WHITE
7		113032	VESSEL-MEM-HOUSING-RES
8	a	116001	FAUCET-AG-CHROME (TF)
8	b	116002	FAUCET-AG-WAVE BLK ON SS
8	c	116007	FAUCET-AG-WAVE WHT ON SS
9	a	119004	TANK-PRES-3 GAL-BLUE
9	b	119007	TANK-PRES-3 GAL WHITE
10	a	122004	FLOW RESTRICTOR 150 ML
10	b	122017	FLOW RESTRICTOR 250 ML
11		125002	NUT-PL-1/4C-WHITE-CELCON
12		125005	NUT-PL-1/4C-BLACK-NYLON
13		125017	CON-PL-1/4CX1/4M
14		125031	ELB-PL-1/4CX1/8M-90
15		125034	ELB-PL-1/4CX1/4M-90

Item #		Part #	Description
16		125041	UNI-PL-1/4CX1/4C
17		131002	NUT-BR-1/4C"
18		131012	SLEEVE-DELRIN-1/4"
19		131017	INSERT-BR-1/4"
20		131021	HEX NIPPLE-BR-1/4 HEAVY DUTY
21		131023	TEE-TANK-BR-1/4CX1/4CX1/4F
22		134002	VALVE-SHUT OFF 1/4MPT (RES.)
23	a	134007	VALVE-ADAPTA VALVE
24		134011	VALVE-CHECK-PLA-ELBOW1/4CX1/8M
25	a	137013	BRACKET-4SV-STEEL-WHITE
25	b	137026	BRACKET-5SV-STEEL-WHITE
26		146001	SCREW-#10-3/4" PHIL PANHEAD
27		146004	SCREW-#10-1" PHIL PANHEAD
28		164006	CLIP-MTG-MEM-VESSEL
29		164010	CLIP-DOUBLE-MEM TO IL (OPTIONAL)
30		164016	DRAIN SADDLE 3/8"
31		119028	TANK STAND
32		113029	O-RING FILTER HOUSING
33		199328	MANUAL 4SV & 5SV PR-14
34		140007	GREEN TUBING
35		140005	BLACK TUBING
36		140004	BLUE TUBING

Figure 2-2. Photograph of the Watts Premier Ultra 5 RO System

Chapter 3
Methods and Procedures

3.1 Test Equipment

3.1.1 Equipment Selection

Equipment selection criteria were developed to ensure that the test units were representative of product variability. Watts Premier supplied ten units from three different production runs. The RO membranes themselves were also chosen to be representative of product variability. All membranes are quality control (QC) tested for TDS rejection performance by the membrane manufacturer. Six membranes were chosen from the middle of the allowable QC performance range as specified by Watts Premier, two were chosen from the high end of the QC performance range, and the last two were chosen from the lower end. Note that the actual QC values used by the manufacturer to establish the range of allowable performance are confidential, and so are not reported. The ten systems were split into two groups of five as discussed in Section 1.2.3, such that each group had one high end and one low end membrane, and three membranes from the middle range.

3.1.2 Test Unit Configuration

The Ultra 5 is sold as a five-stage treatment system, as described in Section 2.4. However, for the tests described in this report, all filter elements other than the RO membrane were removed from the units. The pre-membrane and post-membrane filters do not have pore sizes small enough to remove bacteria or viruses, but could temporarily retain significant numbers of the organisms through electrostatic interactions, giving a positive bias to the performance data. Otherwise the systems were operated as sold to the consumer.

3.2 Verification Test Procedure

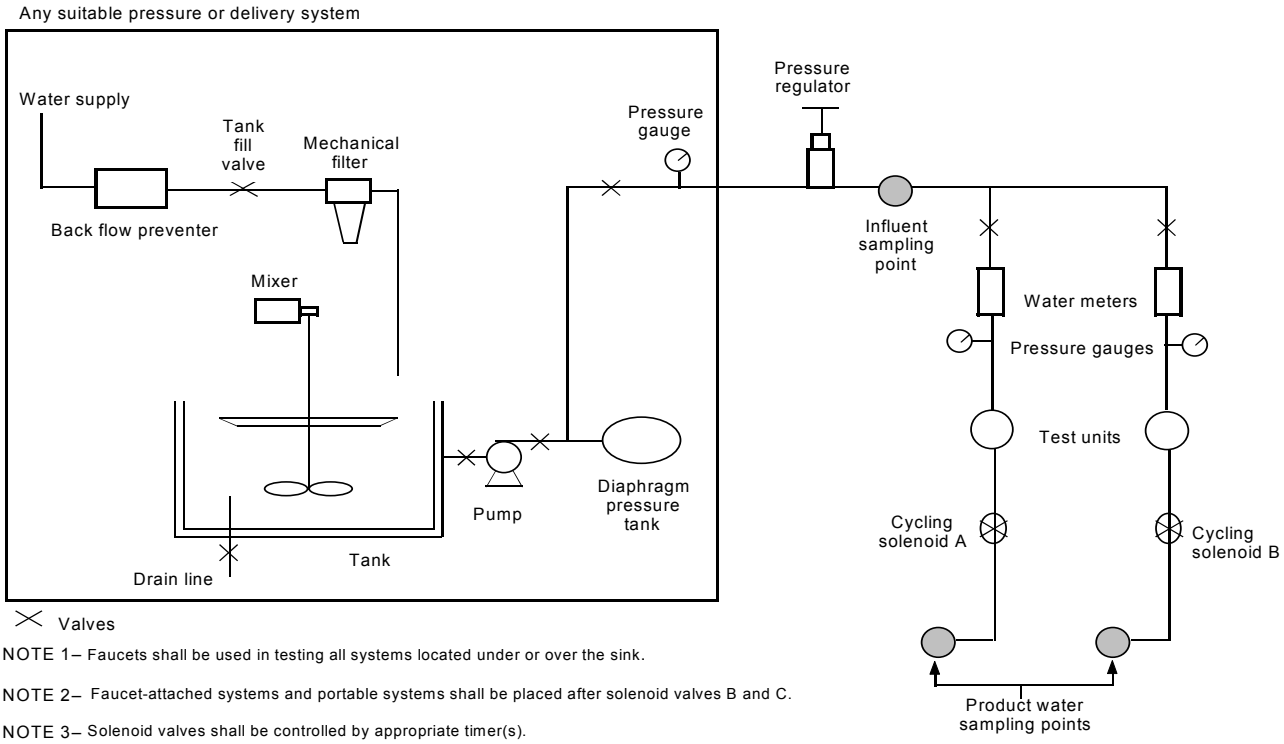
3.2.1 Test Rig

Each group of five test units was plumbed to a single test station. The test rig used a 500-gallon polyethylene tank to hold the influent challenge water. See Figure 3-1 for a schematic diagram. Please note that the units of each group of five were attached to the rig such that all were plumbed to the same influent feed line. Figure 3-2 shows one group of the test units installed on the test rig.

3.2.2 Test Rig Sanitization

The test apparatus was sanitized with a sanitization agent prior to the beginning of each test to keep the heterotrophic bacteria population to a minimum. After sanitization, the test apparatus was flushed until a less-than-detectable concentration of sanitizing agent was present.

Figure 3-1. Schematic Diagram of Test Rig



NOTE 1– Faucets shall be used in testing all systems located under or over the sink.

NOTE 2– Faucet-attached systems and portable systems shall be placed after solenoid valves B and C.

NOTE 3– Solenoid valves shall be controlled by appropriate timer(s).

NOTE 4– Pressure gauges shall be located directly ahead of test units.

NOTE 5– Diameter of plumbing and equipment after test units shall not be less than the diameter at the connection to the unit.

3.2.3 Test Water

3.2.3.1 Base Water

Ann Arbor, Michigan municipal drinking water was deionized to make the base water for the tests. The base water had the following constraints:

- Conductivity ≤ 2 μS/cm at 25 °C;
- Total organic carbon < 100 μg/L; and
- Heterotrophic bacteria plate count < 10,000 colony forming units (CFU)/100 ml.

The base water was then adjusted to meet the following characteristics:

- Total chlorine < 0.05 mg/L;
- Addition of sodium bicarbonate to achieve an alkalinity (expressed as calcium carbonate) of 100 ± 5 mg/L prior to pH adjustment;
- pH adjustment with hydrochloric acid or sodium hydroxide to reach a value of 6.0 ± 0.5, 7.5 ± 0.5, or 9.0 ± 0.5 as required by the challenge schedule*; and
- Temperature of 20 ± 2.5 °C.

*Note that the lab technicians experienced difficulty maintaining the pH below 6.5 or above 8.5. See section 4.2.3 and 5.7.5.1.2 for more discussion.

The test water for each challenge was made in 200-gallon volumes. In addition to the above characteristics, total hardness, TDS, and turbidity were measured daily.

Figure 3-2. Test Units Installed on the Test Rig

3.2.3.2 Bacteria and Virus Challenges

The viruses were purchased from Biological Consulting Services of North Florida, and the bacteria from ATCC. The viruses were purchased in adequate volumes so that the suspensions received were added directly to the test water. The bacteria were cultivated at NSF to obtain the challenge suspensions. Section 3.3.2.3 describes the method used to create the bacteria challenges.

The targeted influent challenge concentrations for the bacteria were $1x10^5$ CFU of bacteria per 100 milliliters, or greater. The targeted influent challenge concentration for the viruses was $1x10^4$ plaque forming units (PFU) of virus per milliliter, or greater. Phi X 174 is more difficult to cultivate, and so was supplied at lower concentrations than the other viruses. The suspensions

received for the conditioned units were too low to cost effectively obtain the target challenge level ($3.6x10^6$ PFU/ml, vs. $6.7x10^9$ PFU/ml for fr and $2.4x10^{11}$ PFU/ml for MS2), so the challenge levels were on the order of 10^3 PFU/ml. The suspensions received for unconditioned units were more concentrated, at $3.7x10^8$ PFU/ml, so the target challenge level was exceeded.

See Appendix A for the measured influent challenge levels.

The test units were challenged with each bacteria separately, but all three viruses were mixed together for each virus challenge. After addition of the challenge organism to the base test water, the resultant challenge water was mixed for a minimum of 30 minutes using a recirculation pump prior to beginning the test.

3.2.4 Test Unit Operation

3.2.4.1 Test Unit Installation

All test units were installed and conditioned in accordance with Watts Premier's instructions using the base test water described above at pH 7.5 ± 0.5. The conditioning instructions called for operating each unit continuously until its storage tank was full. The operation time to fill the tank varied from unit to unit, but was on average approximately six hours. After this conditioning period, an effluent sample was collected from each unit as a negative control and analyzed for the challenge organisms.

3.2.4.2 TDS Reduction System Check

After completion of Watts Premier's conditioning procedure, the test units underwent a one-day TDS reduction test using the test protocol in NSF/ANSI Standard 58. The Standard 58 test was modified so that the units were operated continuously for one tank-fill period. Product water samples were then collected from each storage tank and analyzed for TDS. This test ensured that the products undergoing verification testing were representative of the expected performance of the system, and that there were no membrane integrity or membrane seal problems.

The units receiving 25 days of conditioning were tested for TDS reduction prior to the initiation of the conditioning period. The unconditioned units were tested after completion of all of the bacteria and virus challenges due to an error in scheduling the testing sequence.

3.2.4.3 Long-Term Conditioning

The five units receiving long-term conditioning were tested first. They were operated using the test water without surrogate organisms for a period of 25 working days prior to challenge testing. On each day the units were operated continuously at a dynamic inlet pressure of 80 ± 3 psig for one tank-fill period. The units then sat idle overnight under pressure, and the tanks were emptied the next morning prior to resumption of unit operation.

3.2.4.4 Conditioned Units Challenge Testing

Following the conditioning period, the units were challenged according to the schedule in Table 3-1. Prior to the start of the challenge schedule, the test rig was sanitized again as described above in Section 3.2.2. The test units were taken off-line to prevent sanitizer from entering them, and the test rig was flushed free of sanitizer before they were reconnected to the rig.

At the end of the day before each challenge, the base test water was prepared as described in Section 3.2.3.1. The morning of the challenge, the pH was checked and adjusted, if necessary, and the bacteria or viruses were added as described in Section 3.2.3.2.

The dynamic inlet water pressure for operation was set at either 40 ± 3 or 80 ± 3 psig according to the challenge schedule.

An influent sample was collected each day at the time test unit operation started. Each test unit was then operated continuously for one tank-fill period (approximately six to eight hours). In a couple of cases during the 40 psig challenge periods, the lab technician manually shut-off the water supply to a unit because the shut-off device did not activate after approximately nine hours of operation due to the low inlet pressure.

At 40 psig, approximately two gallons of treated water was produced before shut-off, while at 80 psig, approximately three gallons were produced.

After each unit shut off, its storage tank was emptied into a sterile container, and a sub-sample was collected for challenge organism enumeration. The sub-sample volumes were one liter for the bacteria challenges, and 150 ml for virus challenges. A second influent sample was collected after all units ceased operation. All samples were collected in sterile polypropylene bottles, and were enumerated in triplicate.

Following each day's challenge period, the systems were operated for one tank-fill cycle using the test water without any test organisms present. This served to flush the systems in-between challenge periods. The units rested overnight under pressure, and the storage tanks were emptied the next morning prior to initiation of that day's challenge.

Table 3-1. Challenge Schedule for Conditioned Units

Day	Challenge Organism(s)	pH	Inlet Pressure (psig)
1	All Viruses	6.0 ± 0.5	40 ± 3
2	All Viruses	6.0 ± 0.5	80 ± 3
3	All Viruses	7.5 ± 0.5	40 ± 3
4	All Viruses	7.5 ± 0.5	80 ± 3
5	All Viruses	9.0 ± 0.5	40 ± 3
6	All Viruses	9.0 ± 0.5	80 ± 3
7	*H. pseudoflava*	7.5 ± 0.5	80 ± 3
8	*H. pseudoflava*	7.5 ± 0.5	40 ± 3
9	*B. diminuta*	7.5 ± 0.5	40 ± 3
10	*B. diminuta*	7.5 ± 0.5	80 ± 3

3.2.4.5 Unconditioned Units Testing

Challenge testing for the unconditioned units began immediately after completion of the manufacturer's conditioning instructions. The testing schedule is given below in Table 3-2. Only four units were tested for this group because one of the units did not operate properly. The automatic shutoff device was hooked-up incorrectly, causing the influent water to flow directly into the storage tank. This problem was not noticed until the first day of challenge testing, so the storage tank was contaminated before it could be corrected.

At the end of the day before each challenge, the base test water was prepared as described in 3.2.3.1. The morning of the challenge, the pH was checked and adjusted, if necessary, and the bacteria or viruses were added as described in Section 3.2.3.2.

The dynamic inlet water pressure for operation was set at either 40 ± 3 or 80 ± 3 psig according to the challenge schedule.

Many heterotrophic bacteria were observed on the effluent sample agar plates from the conditioned units bacteria challenge testing, which made counting the challenge organism colonies more difficult. The influent samples had very low levels of heterotrophic bacteria due to the sanitization of the test rigs, but the test units could not be sanitized in the same way. To evaluate whether the heterotrophic bacteria populations would be lower in the unconditioned units, since they were being tested only a couple days after being installed on the test rigs, the bacteria reduction tests were carried out first for this set of units. During testing of both the conditioned units and unconditioned units, heterotrophic bacteria counts up to 10^6 CFU/100ml were observed in the effluent samples, so the timing of the bacteria challenge tests did not appear to make a difference. See Section 5.4.4 for more discussion about heterotrophic bacteria.

An influent sample was collected each day at the time test unit operation started. Each test unit was then operated continuously for eight hours, or the time to fill the storage tank, whichever came first. An eight-hour maximum operation period was instituted for this group because of the observed operation times at 40 psig during the conditioned units challenge period. As each unit shut off, its storage tank was emptied into a sterile container, and a sub-sample was collected for challenge organism enumeration. The sub-sample volumes were one liter for the bacteria challenges, and 150 ml for virus challenges. A second influent sample was collected after all units ceased operation. All samples were collected in sterile polypropylene bottles, and enumerated in triplicate.

Following each challenge period, the systems were operated for one tank-fill period using the test water without any test organisms present. This served to flush the systems in between challenge periods. The units rested overnight under pressure, and the storage tanks were emptied the next morning prior to initiation of that days challenge period.

Table 3-2. Challenge Schedule for Unconditioned Units

Day	Challenge Organism(s)	PH	Inlet Pressure (psig)
1	*H. pseudoflava*	7.5 ± 0.5	40 ± 3
2	*H. pseudoflava*	7.5 ± 0.5	80 ± 3
3	*B. diminuta*	7.5 ± 0.5	40 ± 3
4	*B. diminuta*	7.5 ± 0.5	80 ± 3
5	All Viruses	6.0 ± 0.5	40 ± 3
6	All Viruses	6.0 ± 0.5	80 ± 3
7	All Viruses	7.5 ± 0.5	40 ± 3
8	All Viruses	7.5 ± 0.5	80 ± 3
9	All Viruses	9.0 ± 0.5	40 ± 3
10	All Viruses	9.0 ± 0.5	80 ± 3

3.3 Analytical Methods

3.3.1 Water Quality Analytical Methods

The following are the analytical methods used during verification testing. All analyses followed procedures detailed in NSF Standard Operating Procedures (SOP).

- pH – All pH measurements were made with an Orion Model SA 720 meter. The meter was operated according to the manufacturer's instructions, which are based on Standard Method 4500-H^+.
- Temperature – Water temperature was measured using an Omega model HH11 digital thermometer.
- TDS – TDS for the TDS reduction system check test was measured through conductivity according to Standard Method 2510. An Oakton pH/Conductivity 510 Series meter was used to analyze the samples from the conditioned units. The samples from the unconditioned units were measured using a Fisher Scientific Traceable™ Conductivity Meter. The Fisher meter was purchased between the two sets of challenges, replacing the Oakton meter.
- Total Chlorine – Total chlorine was measured according to Standard Method 4500-Cl G with a Hach Model DR/2010 spectrophotometer using AccuVac vials.

3.3.2 Microbiology Methods

3.3.2.1 Sample Processing, and Enumeration of Viruses

The viruses were enumerated using a double agar layer method published in NSF/ANSI Standard 55 – Ultraviolet microbiological water treatment systems, for enumerating MS2. This method is similar to the double agar layer method in EPA Method 1601.

Four to eighteen hours prior to sample processing, 100 µl of the appropriate host *E.coli* suspension was pipetted into a fresh 10 ml of Tryptic Soy Broth (TSB), and incubated at 35 °C. After incubation, 100 µl volumes of the resulting *E. coli* culture were transferred to sterile, capped test tubes.

All samples were enumerated in triplicate. All samples were serially diluted for enumeration, and the effluent samples were also enumerated directly. One ml volumes of the sample or dilution were pipetted into the *E. coli* suspension test tubes. The tubes were vortexed for a minimum of 30 seconds to "mate" the bacteria and virus, and then 4 ml of molten, tempered TSB plus 1% agar was added to each tube. These mixtures were then poured over Tryptic Soy Agar (TSA) plates, and allowed to solidify. The plates were incubated at 35°C for 18-24 hours. Viral plaques were counted using a Quebec Colony Counter.

3.3.2.2 Bacteria Cultivation

The bacteria were purchased from ATCC and rehydrated with nutrient broth. After 48 hours of incubation at 30 °C, tubes containing 10 mL of TSB were inoculated with 100 µL of the nutrient broth suspension. These tubes were incubated for 48 hours at 30 °C. After this incubation period, 100 µL of these suspensions were pipetted into new tubes containing 10 mL of fresh TSB. These tubes were then also incubated for 48 hours at 30 °C. This process was repeated at least three times, up to a maximum of 30 times.

3.3.2.3 Preparation of Bacteria Challenge Suspensions

To obtain the challenge suspensions, 1 mL of a 48-hour TSB culture was pipetted onto an appropriate number of TSA slants. The slants were inoculated at 30 °C for 48 hours. After inoculation, 5 mL of sterile phosphate buffered dilution water (PBDW) was pipetted onto each slant, and the agar surfaces were scraped to suspend the cells. The suspensions were then pipetted out of the slants into an appropriate volume of PBDW. The resulting challenge suspension was vortexed for approximately 30 seconds to disperse the cells. The challenge suspensions were refrigerated and added to the tank of test water within one hour. Samples of the challenge suspension were collected and enumerated according to the method in 3.3.2.4.

3.3.2.4 Bacteria Sample Processing and Enumeration

All samples were enumerated in triplicate using a membrane filtration method based on Standard Method 9215 D. All samples were serially diluted for enumeration with sterile PBDW, and the effluent samples were also enumerated directly. One milliliter volumes of the influent sample dilutions, and 100 ml volumes of either the effluent samples or dilution were pipetted into sterile vacuum filtration apparatuses, 25 ml of sterile PBDW added, and the suspension vacuum filtered through sterile 0.1 µm membrane filters. The funnels were then rinsed three times with approximately 5 ml of PBDW, and the rinse water also suctioned through the filters. The membrane filters were aseptically removed from the apparatuses and placed onto R2A agar plates. The plates were incubated at 30°C for 48 hours. Characteristic *B. diminuta* or *H. pseudoflava* colonies were enumerated with a Quebec Colony Counter.

Chapter 4
Results and Discussion

4.1 TDS Reduction

The performance data from the TDS reduction system check test described in 3.2.4.2 are presented below in Table 4-1. Watts Premier's reported TDS reduction performance for the Ultra 5 is 96.8%, so the units tested are representative of expected membrane performance.

Table 4-1. Short-Term TDS Reduction Test Results

Unconditioned Units	TDS (mg/L)	Percent Reduction
Influent	790	
Effluents:		
Unit 1	28	96%
Unit 2	32	96%
Unit 3	29	96%
Unit 4	23	97%

Conditioned units	TDS (mg/L)	Percent Reduction
Influent	750	
Effluents:		
Unit 1	39	95%
Unit 2	33	96%
Unit 3	37	95%
Unit 4	30	96%
Unit 5	35	95%

4.2 Virus Reduction

The virus $\log_{10}$ reduction data for each challenge scenario are presented below in Tables 4-2 and 4-3. The influent and effluent virus PFU count data for each individual test unit are given in Appendix A. The triplicate influent and effluent counts in Appendix A were averaged by calculating geometric means. The means were then $\log_{10}$ transformed and $\log_{10}$ reduction values calculated for each test unit.

Please note that the "non-detect" effluent counts of < 1 PFU/ml were treated as 1 PFU/ml for geometric mean calculations. Also, if the triplicate enumeration yielded two counts of < 1 PFU/ml and only one count above the detection limit, the geometric mean is footnoted to indicate this.

Table 4-2. Virus Log Reduction Data for Unconditioned Units

Challenge Conditions					Geometric Mean Log_{10} Reduction					
Target pH	Actual pH	Pressure (psig)	Challenge Organisms	Log_{10} Influent Challenge	Unit 1	Unit 2	Unit 3	Unit 4	Mean[1]	Log_{10} Mean Effluent Count
6.0 ± 0.5	6.5	40	fr	6.3	4.8	3.1	2.9	4.6	3.8	2.5
			MS2	6.1	5.6[2]	3.0	2.8	4.7	4.0	2.1
			Phi X 174	5.0	5.0	2.4	2.3	5.0[2]	3.7	1.3
6.0 ± 0.5	6.2	80	fr	5.9	4.5	3.2	3.3	5.9	4.2	1.7
			MS2	5.8	4.5	3.0	3.3	5.8	4.2	1.6
			Phi X 174	4.9	4.6[2]	2.8	2.4	4.9	3.7	1.2
7.5 ± 0.5	7.6	40	fr	5.9	4.0	2.9	4.9	4.4	4.1	1.8
			MS2	5.6	3.8	2.7	5.0	4.3	4.0	1.6
			Phi X 174	5.7	3.7	2.3	5.7[2]	4.3	4.0	1.7
7.5 ± 0.5	7.7	80	fr	5.8	4.6	2.5	4.3	5.5	4.2	1.6
			MS2	5.7	4.4	2.6	4.3	5.4[2]	4.2	1.5
			Phi X 174	5.9	4.3	2.6	3.7	5.1	3.9	2.0
9.0 ± 0.5	8.7	40	fr	5.8	4.4	2.9	4.2	4.8	4.1	1.7
			MS2	5.6	4.1	2.7	4.1	4.8	3.9	1.7
			Phi X 174	5.7	3.8	2.6	3.3	4.1	3.5	2.2
9.0 ± 0.5	9.0	80	fr	6.0	4.6	3.5	3.7	5.1	4.2	1.8
			MS2	5.7	4.7	3.4	3.8	5.1	4.3	1.4
			Phi X 174	5.6	4.1	3.5	3.5	4.5	3.9	1.7
				fr mean[3]	4.5	3.0	3.9	5.1	4.1	1.9
				MS2 mean[3]	4.5	2.9	3.9	5.0	4.1	1.7
				Phi X 174 mean[3]	4.3	2.7	3.5	4.7	3.6	1.7

[1] The arithmetic mean of all test units for each challenge.
[2] Triplicate count had two "non-detect" agar plates.
[3] The arithmetic mean for all challenges against each test unit.

Table 4-3. Virus Log Reduction Data for Conditioned Units

Challenge Conditions				Log_{10}	Geometric Mean Log_{10} Reduction						Log_{10} Mean
Target pH	Actual pH	Pressure (psig)	Challenge Organisms	Influent Challenge	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Mean[1]	Effluent Count
6.0 ± 0.5	6.5	40	fr	5.1	3.6	4.1	4.0	4.8	4.0	4.1	1.0
			MS2	4.8	3.2	3.7	3.8	4.1	3.2	3.6	1.2
			Phi X 174	3.4	3.4	3.4	3.4	3.4	3.4	3.4	0.0
6.0 ± 0.5	6.4	80	fr	6.1	4.6	4.2	4.3	4.7	4.6	4.5	1.6
			MS2	6.0	4.6	4.2	4.2	4.8	3.7	4.3	1.7
			Phi X 174	3.8	3.8	3.8	3.8	3.8	3.8	3.8	0.0
7.5 ± 0.5	7.5	40	fr	6.4	4.2	4.8	4.7	4.8	4.2	4.5	1.9
			MS2	6.2	4.2	4.5	4.8	4.7	4.3	4.5	1.7
			Phi X 174	4.0	3.7	4.0[2]	4.0[2]	4.0	3.7	3.9	0.1
7.5 ± 0.5	7.3	80	fr	6.3	4.8	5.6	5.6	5.3	4.8	5.2	1.1
			MS2	6.1	5.2	5.5	5.6	4.9	5.0	5.2	0.9
			Phi X 174	4.1	4.1	4.1[2]	4.1	4.1	4.1[2]	4.1	0.1
9.0 ± 0.5	8.9	40	fr	6.2	4.4	4.2	4.3	4.3	4.3	4.3	1.9
			MS2	5.8	4.2	4.0	4.2	4.1	4.2	4.1	1.7
			Phi X 174	4.1	4.1	4.1	4.1	4.1	4.1	4.1	0.0
9.0 ± 0.5	7.9[3]	80	fr	6.0	4.4	4.9	4.7	4.7	4.6	4.7	1.3
			MS2	5.9	4.3	5.9	4.8	4.9	4.6	4.9	1.0
			Phi X 174	4.0	4.0	4.0	4.0	4.0	4.0	4.0	0.0
				fr mean[4]	4.3	4.6	4.6	4.8	4.4	4.6	1.5
				MS2 mean[4]	4.3	4.6	4.6	4.6	4.2	4.4	1.4
				Phi X 174 mean[4]	3.9	3.9	3.9	3.9	3.9	3.9	0.0

[1] The arithmetic mean of all test units for each challenge.
[2] Triplicate count had two "non-detect" agar plates.
[3] See Section 5.8.3 for discussion of pH variance.
[4] The arithmetic mean for all challenges against each test unit.

As discussed in Section 3.2.3.2, the Phi X 174 influent challenges for the conditioned units did not consistently exceed the desired minimum challenge level of $1x10^4$ PFU/ml (4.0 logs). Furthermore, the effluent counts were almost all < 1 PFU/ml, so the log_{10} reductions were capped at 3.4 to 4.1. These data, then, represent a minimum level of performance for the Ultra 5 in regards to Phi X 174 reduction. The Phi X 174 influent levels for the unconditioned units did exceed the desired minimum challenge level, and effluent counts at 1 PFU/ml or greater were recorded in all but one case (unit 4 at pH 6 and 80 psig).

4.2.1 Unconditioned Scenario versus Conditioning Scenario

An evaluation of the virus reduction data shows that overall, the conditioned units performed better than the unconditioned units. The mean $\log_{10}$ reductions and mean $\log_{10}$ effluent counts are shown in the bottom right corners of Tables 4-2 and 4-3. A comparison of the mean $\log_{10}$ effluent counts for the unconditioned versus the conditioned units shows that the conditioned units performed approximately 0.3 to 1.7 $\log_{10}$ better than the unconditioned units. However, the unit-to-unit performance variation for the unconditioned units is wider than for the conditioned units. Units 1 and 4 consistently performed as well as the conditioned units, while units 2 and 3 did not.

These data indicate that for the Watts Premier Ultra 5, either the systems give better or more consistent performance with 25 days of conditioning, perhaps due to biofilm and/or scale buildup on the membranes that serves to partially plug the membrane pore structure, or that units 2 and 3 of the unconditioned group simply did not perform as well as the other seven.

4.2.2 Inlet Pressure Influence

As described in Section 1.2.2, the test units were evaluated at both 40 and 80 psig inlet pressure. For the conditioned units, there seemed to be a significant increase in performance at 80 psig for fr and MS2 reduction. Many of the $\log_{10}$ reduction numbers at 80 psig are more than 0.5 logs greater than for the corresponding 40 psig challenge. This trend was not as evident for the unconditioned units. Again, this could possibly be due to the more inconsistent performance of this group.

4.2.3 Performance Comparison at Different pH Settings

The test units were also evaluated at three different pH settings: 6.0 ± 0.5, 7.5 ± 0.5, and 9.0 ± 0.5. However, the pH of the challenge water was not measured at the end of each challenge period as required in the test/QA plan. As a result, the degree of pH drift could not be determined. Subsequent testing has shown significant pH drift does occur, because the water chemistry gives it low buffering capacity. Furthermore, the required pH value of 9.0 ± 0.5 was not obtained for the conditioned units virus challenge testing at pH 9 and 80 psig. The measured pH was only 7.9. Therefore, no confident comparisons could be made, nor conclusions drawn about the effect of pH on virus rejection. Inability to maintain the pH in the test water will be addressed in the next revision of the generic test/QA plan.

4.3 Bacteria Reduction

Presented in Tables 4-4 and 4-5 are the log reduction data for the bacteria challenge portion of the verification test. The influent and effluent bacteria count data for each individual test unit is given in Appendix A. As was done for the viruses, the triplicate influent and effluent counts were averaged by calculating geometric means. The means were then $\log_{10}$ transformed and $\log_{10}$ reduction values were calculated for each test unit.

Table 4-4. Bacteria Log Reduction Data for Unconditioned Units

pH	Pressure (psig)	Challenge Organisms	Log_{10} Influent Challenge (log/100 ml)	Geometric Mean Log_{10} Reduction (log/100 ml) Unit 1	Unit 2	Unit 3	Unit 4
7.5	40	*H. pseudoflava*	6.9	4.4	4.9	2.2	1.6
		B. diminuta	8.2	8.2	3.0	2.0	8.2
7.5	80	*H. pseudoflava*	6.9	4.6	6.6	1.9	3.0
		B. diminuta	8.1	3.5	2.2	3.3	8.1

Table 4-5. Bacteria Log Reduction Data for Conditioned Units

pH	Pressure (psig)	Challenge Organisms	Log_{10} Influent Challenge (log/100 ml)	Geometric Mean Log_{10} Reduction (log/100 ml) Unit 1	Unit 2	Unit 3	Unit 4	Unit 5
7.5	40	*H. pseudoflava*	6.7	6.7	6.7	6.7	6.7	6.7
		B. diminuta	8.3	8.3	8.3	8.3	7.2	8.3
7.5	80	*H. pseudoflava*	6.7	6.7	6.7	6.7	6.7	6.7
		B. diminuta	8.4	8.4	8.4	8.4	8.4	8.4

The bacteria data also indicates that conditioning stabilizes and/or improves performance. All effluent counts for the conditioned units were non-detect for both bacteria, except for unit 4 for *B. diminuta* reduction at pH 7.5 and 40 psig. In contrast, for the unconditioned units there were 13 cases out of 16 where the challenge bacteria were detected in the effluents. In addition, the performance varied from day to day as also observed for the virus challenges. For instance, unit 2 performed well during the *H. pseudoflava* challenges, with 4.9 and 6.6 log_{10} reductions, but this unit did not perform as well during the *B. diminuta* challenges, with reductions of only 2.0 and 3.3 log_{10}. In contrast, unit 4 performed much better at *B. diminuta* reduction (8.1 and 8.2 log_{10}) than at *H. pseudoflava* reduction (1.6 and 3.0 log_{10}). These results are puzzling, since the two challenge organisms are similar in size.

Because of the highly variable data from the unconditioned units, and the frequent cases of nondetectible effluent counts for the conditioned units, no influent pressure comparison is possible

4.4 Unit-To-Unit Variability

To assess performance between units, and for the same unit through the challenge period, the performance of the unconditioned units was ranked for each challenge organism. The TDS reduction results were also ranked to provide a comparison. The rankings are presented below in Table 4-6. The conditioned units were not ranked, since there was little performance variation from unit to unit, as can be seen in Table 4-3, and all but one bacteria reduction effluents were at undetectable levels.

Table 4-6. Performance Rankings for the Unconditioned Test Units

	H. pseudoflava Reduction	*B. diminuta* Reduction	fr Reduction	MS2 Reduction	Phi X 174 Reduction	TDS Reduction
Unit 1	2	2	2	2	2	2
Unit 2	1	3	4	4	4	4
Unit 3	4	4	3	3	3	3
Unit 4	3	1	1	1	1	1

The rankings are given left to right across the table in the order in which the challenges were performed. The rankings are very consistent, except for *H. pseudoflava* reduction. A possible explanation for this is that this organism was the first challenge, on days one and two before membrane performance stabilized. Ranking unit performance separately for the two *B. diminuta* challenge days (data not shown), shows that on day four the rankings are identical to those for the viruses and TDS. This indicates that perhaps it takes approximately four days of operation, or four tank fill cycles (including the manufacturer's recommended conditioning) for system performance to stabilize.

Chapter 5
QA/QC

5.1 QA/QC Responsibilities

NSF QA/QC staff reviewed the raw data records for compliance with QA/QC requirements and checked 100% of the data against the reported results in the official lab reports.

5.2 Test Procedure QA/QC

The test procedure followed an NSF SOP created specifically for this ETV test.

5.3 Water Chemistry Analytical Methods QA/QC

- pH – Three point calibration at pH 4, 7, and 10 was conducted daily using traceable buffers. The calibration is checked with a pH 8 buffer. During the challenge testing periods, the precision of the instrument was checked by collecting a sample of drinking water and splitting it into two samples for pH measurement. The relative percent deviation (RPD) was calculated using the equation in Section 5.7.3. The acceptable RPD limit was 10%. The daily pH 8 buffer readings and results of the duplicate analyses are given in Table B-1 of Appendix B.
- Temperature – The digital thermometer is calibrated every six months using a Hart Scientific Model 9105 Dry Well Calibrator.
- Total Chlorine – The instrument was calibrated daily according to the manufacturer's instructions. During the challenge testing periods, the precision of the instrument was checked daily by analyzing a sample of municipal drinking water in duplicate. The samples were diluted by approximately 50% with deionized water, and then split into subsamples for analysis. The RPD for the two samples was then calculated, with an acceptable RPD limit of 10%. Results of the duplicate analyses are given in Table B-3 of Appendix B.
- Total Dissolved Solids – The Oakton 510 Series pH/Conductivity meter was calibrated daily using a potassium chloride QC standard. The calibration was checked with a second potassium chloride QC standard. The Fisher Scientific Traceable™ Conductivity Meter was calibrated with two potassium chloride standards. A third QC standard was then used to check the calibration. Ten percent of samples were analyzed in duplicate, and RPDs were calculated. The acceptable RPD limit was 10%. The calibration check standard measurements and duplicate analyses are given in Table B-2 of Appendix B.

5.4 Microbiology Laboratory QA/QC

5.4.1 Growth Media

All media was checked for sterility and positive growth response when prepared and when used for microorganism enumeration. The media was discarded if growth occurred on the sterility check media, or if there is an absence of growth in the positive response check. All three *E. coli*

hosts for the viruses were plated on TSA and incubated with the virus enumeration plates during sample enumeration as a second positive growth control. *B. diminuta* and *H. pseudoflava* from the stock cultures were plated on R2A agar and incubated with the bacteria enumeration plates as positive controls.

5.4.2 Bacteria Cell Size

The theoretical minimum size for *B. diminuta* and *H. pseudoflava* cells is 0.2 to 0.3 μm in diameter, however, the NSF Microbiology Laboratory was not able to achieve that size. The stock culture was examined microscopically using a stage micrometer, and the observed diameters were approximately 0.5 μm. To achieve the smallest cell size, the bacteria need to be grown in a medium such as Saline Lactose Broth that keeps the cells small due to osmotic pressure constraints. However, this medium is low in nutrients, so the Microbiology Laboratory had difficulty cultivating the bacteria in high titers. The Microbiology Laboratory instead cultivated the bacteria in TSB. TSB is more nutrient rich, and as a result yielded larger cells.

The larger cell size may have enhanced the bacteria reduction performance of the test units, so the bacteria reduction data cannot be used to predict expected performance against bacterial agents smaller than 0.5 μm. However, the viruses used in this study are much smaller than any bacteria, so the virus challenges could be considered to be a more conservative challenge than the smallest size bacteria.

5.4.3 Sample Processing and Enumeration

All samples were enumerated in triplicate. For each sample batch processed, an unused membrane filter, and a blank with 100 ml of PBDW filtered through the membrane were also placed onto the appropriate media and incubated with the samples as negative controls. No growth was observed on any blanks.

5.4.4 Heterotrophic Bacteria Interference

As discussed in Section 3.2.4.5, heterotrophic bacteria also grew with the challenge organisms on the agar plates for the effluent samples, because the challenge organisms had to be grown on nonselective media. In many instances, the heterotrophic bacteria were present at levels that gave up to 250 colonies on the 10^{-4} dilution plates, and almost confluent lawns on the 10^{-2} dilution and undiluted sample plates. However, the microbiologists were able to observe and count the challenge organism colonies on these plates, due to their color and morphology. The *H. pseudoflava* and *B. diminuta* colonies were circular, entire, and convex, whereas the heterotrophic bacteria colonies were circular, but with slightly undulate edges, and they were flat or raised, instead of convex. The *H. pseudoflava* and *B. diminuta* colonies were also smaller than most of the heterotrophic colonies. The *H. pseudoflava* were bright yellow, and the *B. diminuta* colonies were an off-white, slightly grayish color. Most of the heterotrophic bacteria colonies were tan colored.

5.5 Sample Handling

All samples analyzed by the NSF Microbiology and Wet Chemistry Laboratories were labeled with unique ID numbers. These ID numbers appeared on the NSF lab report for the tests. All water chemistry samples were analyzed within allowable hold times. All samples for bacteria and virus analysis were processed within one hour of collection.

5.6 Documentation

All laboratory activities were documented using lab bench sheets and NSF laboratory reports. This documentation can be found in the appendices.

5.7 Data Quality Indicators

The quality of the data generated for this ETV test can be established through five indicators of data quality: representativeness, accuracy, precision, statistical uncertainty, and completeness.

5.7.1 Representativeness

Representativeness refers to the degree to which the data accurately and precisely represent the expected performance of the RO system under normal use conditions. Representativeness of the test units themselves was ensured by using the equipment selection criteria as described in Section 3.2.1.

The test protocol was designed to be a conservative evaluation of product performance. The test water was of very low turbidity to minimize the potential of microbial adhesion to suspended particles, which could enhance apparent log reduction. The surrogates were chosen because of their small size. The virus surrogate challenges were conducted at different pH values in an attempt to assess whether pH affects the performance of the RO membrane. RO membrane performance was also evaluated at both 40 and 80 psig inlet pressure.

5.7.2 Accuracy

Accuracy of the pH and total chlorine measurement instruments was evaluated with calibration check standards during the daily calibrations. Accuracy of the conductivity meter used for TDS analyses was measured through the use of QC samples. Accuracy measurements for these parameters are given in Appendix B.

5.7.3 Precision

Precision refers to the degree of mutual agreement among individual measurements and provides an estimate of random error. The bacteria and viruses were enumerated in triplicate, although no precision calculations were made. One sample per batch was analyzed in duplicate for the TDS measurements. Duplicate municipal drinking water samples were analyzed for pH and total chlorine as part of the daily calibration process. Precision of the water chemistry duplicate analyses was measured by use of the following equation to calculate RPD:

$$RPD = \left| \frac{S_1 - S_2}{S_1 + S_2} \right| \times 200$$

where:

S_1 = sample analysis result; and

S_2 = sample duplicate analysis result.

The RPD calculations for individual duplicate pairs are given in the tables in Appendix B. The duplicate measurements for the two TDS sample batches gave RPD values of 0% and 8.7%. The RPD values for the pH measurements ranged from 0% to 0.9%, with a mean of 0.3%. The RPD values for the total chlorine measurements ranged from 0% to 6.3%, with a mean of 1.3%.

5.7.4 Statistical Uncertainty

Statistical uncertainty can be expressed using confidence intervals. No data for this ETV test was suitable for confidence interval calculations.

5.7.5 Completeness

Completeness is the proportion of valid, acceptable data generated using each method as compared to the requirements of the test/QA plan. The completeness objective for data generated during verification testing is based on the number of samples collected and analyzed for each parameter and/or method.

Table 5-1. Completeness Requirements

Number of Samples per Parameter and/or Method	Percent Completeness
0-10	80%
11-50	90%
> 50	95%

Completeness is defined as follows for all measurements:

$$\%C = (V/T) \times 100$$

where:

%C = percent completeness;

V = number of measurements judged valid; and

T = total number of measurements.

5.7.5.1 Completeness Measurements

5.7.5.1.1. Number of Units Tested

The test/QA plan called for testing ten units. However, one of the units in the unconditioned group did not function properly, as discussed in Section 3.2.4.5, so only nine units were tested. This gives a completeness measure of 90%.

5.7.5.1.2. pH, Temperature, and Total Chlorine

As discussed in Section 4.2.3, the test/QA plan called for measuring pH and the other water chemistry parameters at the beginning and end of the daily challenge periods. However, pH, temperature, and total chlorine were only measured at the beginning of the challenge period. Sixty-five samples should have been measured for these parameters, but only 45 were, giving a completeness of 69%.

Of the missed analyses, the loss of the pH data was the most crucial. The loss of this data precluded analysis of the pH drift issue or the effect of pH on test unit performance, as discussed in Section 4.2.3. However, the lack of this data does not diminish the quality of the bacteria and virus data itself. The temperature likely did not rise or drop out of the allowable range if it wasn't already at the beginning of the challenge periods, since the water was kept at room temperature. The missed total chlorine measurements also are not crucial, since the amount of chlorine in the test water could not increase above the initial level.

5.7.5.1.3. Microbiological Analyses

One hundred and forty influent and effluent samples were to be collected for microbiological analysis. However, since only nine units were tested, only 120 samples were collected, for a completeness of 86%. Likewise, the 140 samples were to yield 924 plate counts for bacteria and virus enumeration, but the 120 samples collected instead gave 858 plate counts. There was one plate that gave an invalid result because of a lab accident, so the plate count completeness measure is 857 out of 924, which gives 93%.

5.7.5.1.4. TDS

Fourteen samples were to be collected for the two TDS challenge system check tests described in 3.2.4.2. However, since only nine units were tested, only thirteen samples were collected. This gives a completeness measure of 93%.

5.8 Measurements Outside of the Test/QA Plan Specifications

5.8.1 Total Chlorine

The test/QA plan called for the test water to have a total chlorine level below 0.05 mg/L. Of the 45 total chlorine measurements collected during testing, two were above the allowable level. One was 0.05 mg/L, and the other was 0.07 mg/L. Both of these measurements could be due to

the instrument's random error, and they both occurred during the 25-day conditioning period, so they are not significant deviations.

5.8.2 Temperature

The test/QA plan called for the water temperature to be 20 ± 2.5°C. On day 15 of the conditioning period, the water temperature was measured at 26°C. This is not a significant deviation. Temperature control was critical during the bacteria challenge periods because of its effect on organism viability. However, during the conditioning period, the water temperature only affected the treated water production rate of the test units.

5.8.3 pH

The test water pH for the conditioned units pH 9.0 ± 0.5, 80 psig challenge was only 7.9. As discussed in Section 4.2.3, the laboratory technicians had difficulty maintaining the pH within the allowable range due to the low buffering capacity of the test water. This is a significant deviation from the test/QA plan, but not one that invalidates the virus reduction data. It does, however, invalidate comparison of the data based on pH.

Chapter 6
References

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Chapter 7
Vendor Comments

Watts Premier submitted the following comments on the DRAFT report to the NSF. These comments were not included in the body of the text.

7.1 Section 2.3 Trade Names - Addition

Watts Premier has recently launched a new line of point of use reverse osmosis units. Watts Premier considers the results in this ETV report to also be valid for this new line of products. The new products use the same filtration components as the Ultra 5, and function at the same flux, therefore providing the same level of performance. An independent evaluation of the new products was conducted by NSF's certification program staff. NSF determined that the test results for the NSF certification of the Ultra 5 under NSF/ANSI Standard 58 can also apply to the NSF certification of the new devices. Based upon this, the results obtained within this ETV report are valid for the following additional models:

- WP-5
- KP-5
- RO-5M
- RO5M-50

Watts Premier has also recently launched a line of water purification reverse osmosis units. This device incorporates a patented microbiological interception filter in addition to the RO membrane. The test results contained with in this report do not reflect the reduction capabilities of the purifier reverse osmosis as all filters other than the RO membrane were removed for the testing in this report.

7.2 HPC Interference

When sampling from auxiliary outlets as observed with in this testing, the EPA recommends sanitization of the outlet with sodium hypochlorite in order to remove possible HPC sample contamination originating from the outlet faucet. This sanitization procedure was not conducted during this testing. Incidental contact with water outlets can significantly alter HPC counts with in any testing. Additionally, as concluded by the NSF International / World Health Organization Symposium on HPC Bacteria in Drinking Water, HPC by themselves, do not indicate increased risks to consumers unless they happen to correspond with sanitary contamination, which is detectable by other more specific methods.

7.3 Conclusion

The goal of the ETV program is to further environmental protection by accelerating the acceptance and use of improved and cost-effective technologies. As part of the national Homeland Security effort, NSF through its ETV program has developed a test/QA plan under the

EPA ETV program for evaluating POU drinking water treatment systems for removal of biological contamination agents. This test/QA plan uses surrogate bacteria and viruses in place of testing with the actual agents of concern.

The verifications serve to inform the public of the possible avenues they can pursue in order to provide personal protection against biological contamination agents afforded to them by the use of verified systems. This is accomplished by evaluating the reduction in risk of potential exposure to biological agents in drinking water treated by the tested system in comparison to drinking water directly from the public water supply system.

The Watts Premier Ultra 5 and affiliated reverse osmosis systems demonstrated through this ETV testing removal of 97.4% to 99.9999996% bacteria and 99.5% to 99.9999% viruses from the drinking water. Higher levels of reduction were obtained when the reverse osmosis systems were installed and running for 25 days prior to challenging the unit with water contaminants.

Based upon these results, the use of these devices would significantly reduce the risk of exposure to water borne bacteria and virus in the event there is a contamination incident within the municipal or private water distribution system.