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Evaluation of Improved Type I Marine Sanitation Devices

PERFORMANCE EVALUATION REPORT

Office of Research and Development
National Risk Management Research Laboratory - Water Supply and Water Resources Division

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PERFORMANCE EVALUATION OF TYPE I MARINE SANITATION DEVICES

by

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for:

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Notice

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Foreword

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The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Sally Gutierrez, Director
National Risk Management Research Laboratory

Executive Summary

Performance tests were conducted to evaluate the effectiveness of Type I Marine Sanitation Devices (MSDs) in reducing fecal coliform bacteria and visible floating solids (VFS). In addition, the performance evaluation described herein also included testing for enterococci and *Escherichia coli (E. coli*) indicators, biochemical oxygen demand (BOD_5), total suspended solids (TSS), and nutrients (ammonia, total Kjeldahl nitrogen (TKN), nitrate/nitrite, and total phosphorous) in both influent to and effluent from the devices. Note that this testing was not performed for Type I MSD certification as both devices were already certified by the U.S. Coast Guard (USCG) to meet EPA performance standards at the time of testing.

The Electro Scan™ Model EST 12, manufactured by Raritan Engineering Company, Inc., and the Thermopure-2 Model TP-210, by Gross Mechanical Laboratories, Inc., were selected for the performance tests because these manufacturers were willing to provide devices for testing, and the devices represented the range of technologies that were commercially available at the time of testing. Both devices use maceration to eliminate visible floating solids and disinfection to destroy pathogens. The Electro Scan™ device disinfects wastewater using chlorine generated from salt water, while the Thermopure-2 device disinfects wastewater using heat.

The Electro Scan™ system consists of a two-chamber treatment tank, system status panel, control unit, liquid-crystal display (LCD), and an optional salt feed tank system that can be added for operation in fresh or brackish water. The system creates disinfectant from salt water. Flushing moves waste to the maceration chamber for particle size reduction. Subsequent flushing moves the waste to the oxidation chamber where it is mixed and brought into direct contact with electrode plates. When these plates are submerged in salt water and supplied with electricity, hypochlorous acid is formed, which then breaks down organic waste products by oxidation, including bacteria. The cycle runs for about two minutes in the second chamber, and the waste is held in the oxidation chamber until the next flushing cycle, then it is discharged.

The Thermopure-2 system consists of three main components: the holding tank module, SweetTank™ aeration module, and the Thermopure treatment chamber. The unit is designed to be plumbed to either a toilet head or a preexisting remote holding tank, and all functions and operations in the unit are automatic. Treatment is accomplished by macerating the waste in the holding tank module, and then pumping it through the Thermopure treatment chamber where low level heat is introduced to eliminate bacteria. No chemicals or additives are required. In addition,

the Thermopure-2 system does not require salt water to operate; therefore, it is equally efficient in fresh, brackish, or salt water.

Performance Testing

Performance testing was conducted using procedures for the Sewage Processing Test contained in the USCG's MSD certification requirements at 33 CFR 159.121. One exception to the USCG's Sewage Processing Test requirements is that, for reasons of practicality, testing was conducted using a feed of fresh domestic human sewage rather than human sewage in a ratio of four urinations to one defecation, as specified at 33 CFR 159.121(c). Furthermore, for this evaluation, testing was not limited to fecal coliform bacteria and visible floating solids measured in the treated effluent, but rather included a variety of analyses of both influent and effluent samples to measure the effectiveness of each treatment device and to characterize influent and effluent quality.

The 10-day tests were performed at the Waco Metropolitan Area Regional Sewerage System test facility, beginning on April 9, 2007. The site provided a ready source of fresh wastewater and primary sludge as challenge wastewater for testing. An influent sample of the challenge wastewater was collected immediately prior to dosing the devices each day and analyzed for all parameters to characterize influent quality.

MSDs were set-up, started, and operated, as closely as possible, to installation onboard a vessel and according to the devices' operation manuals. Operational considerations included a tilting schedule, a salt-feed, and a cool-down time. The devices were tested for an 8-hour period over 10 days. Sampling personnel dosed each MSD with challenge wastewater at average loading levels throughout each day, with peak capacity wastewater doses three times each day. Sampling personnel collected effluent samples from the test devices at the beginning, middle, and end of each eight-hour period, with one additional sample taken following a peak dosing period each day, for a total of 4 samples per device per day. Effluent samples were analyzed to characterize effluent quality and performance efficiency.

April 2007 Test Results

The effluent produced by the Electro Scan device ranged from nondetect to >1,600 fecal coliform bacteria most probable number (MPN) per 100 mL with a mean concentration of 82 MPN/100 mL. The effluent from the Thermopure-2 device ranged from nondetect to 30,000,000 fecal coliform bacteria MPN/100 mL with a mean concentration of 4,500,000 MPN/100 mL. For

the Electro Scan device, 33 of the 40 samples had VFS less than or equal to 10% of TSS. The Thermopure-2 device had VFS less than or equal to 10% of TSS in 36 of the 38 samples.

The Electro Scan device removed almost all pathogen indicators (99.99% or greater). In contrast, the Thermopure-2 device removed only half of the fecal coliform. The Thermopure-2 device did not reach the designated threshold temperature sufficient enough to kill bacteria, which may have occurred due to the thermal sensor being misplaced, possibly during manufacturing or shipping.

November/December 2007 Thermopure-2 Retest Results

Because of problems encountered with the provided Thermopure-2 unit, a retest was conducted using a replacement Thermopure-2 unit. The scope of the retesting was reduced due to a limitation of funding. The duration of the performance testing was reduced from 10 days to 9 days. Retesting dates were October 15 and 16, 2007, November 29 and 30, 2007, and December 3 through 7, 2007. (This resulted in another exception to USCG's Sewage Processing Test requirements at 33 CFR 159.121(c) as testing was not at least 10 days within a 20-day period. Furthermore, USCG certification for the Thermopure-2 unit expired on November 6, 2007.) The retesting was reduced to TSS testing of the challenge wastewater batch prepared each day, and testing of effluent samples for fecal coliform, VFS, BOD_5, and TSS.

There were 28 effluent samples collected during the November/December retesting period. The effluent produced by the Thermopure-2 device ranged from nondetect to 3,000,000 fecal coliform bacteria MPN/100 mL with a mean concentration of 380,000 fecal coliform bacteria MPN/100 mL. Of the 28 samples, 26 had VFS less than or equal to 10 % of the effluent TSS. While these results show some improvement compared to the April testing, device performance remained poor. Although the cause of the poor performance is unknown, the device pump-out volume may have exceeded the capacity of the heating chamber, which would have mixed unheated (untreated) wastewater with treated wastewater during discharge.

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1.0 INTRODUCTION

1.1 Evaluation Objective

This performance test was designed to evaluate the effectiveness of two Type I Marine Sanitation Devices (MSDs): the Electro Scan Model EST 12, manufactured by Raritan Engineering Company, Inc., and the Thermopure-2, manufactured by Gross Mechanical Laboratories, Inc. Performance tests were conducted to evaluate the effectiveness of Type I MSDs in reducing fecal coliform bacteria and visible floating solids (VFS). In addition, the performance evaluation described herein also included testing for enterococci and *Escherichia coli (E. coli*) indicators, biochemical oxygen demand (BOD_5), total suspended solids (TSS), and nutrients (ammonia, total Kjeldahl nitrogen (TKN), nitrate/nitrite, and total phosphorous) in both influent to and effluent from the devices.

The performance evaluation tests were conducted under the direction of EPA through the support of Eastern Research Group, Inc. (ERG) and ERG's subcontractor, NSF International (NSF). The purpose of this report is to provide objective performance data on these technologies so that consumers, developers, and regulators can make informed decisions about purchasing and applying the technology in these products.

1.2 Evaluation Description

A Type I MSD is a flow-through system designed for vessels of 65 feet or less in length, with capability for maceration and disinfection of waste prior to discharge. The Type I MSDs underwent performance evaluation testing using procedures for the Sewage Processing Test contained in the USCG's MSD certification requirements at 33 CFR 159.121 (see Appendix A). One exception is that, for reasons of practicality, testing was conducted using a feed of fresh domestic human sewage rather than human sewage in a ratio of four urinations to one defecation, as specified at 33 CFR 159.121(c). Furthermore, for this evaluation, testing was not limited to fecal coliform bacteria and visible floating solids measured in the treated effluent, but rather included a variety of analyses of both influent and effluent samples to measure the effectiveness of each treatment device and to characterize influent and effluent quality. Note that this testing was not performed for Type I MSD certification as both devices were already certified by the USCG to meet EPA performance standards at the time of testing.

Because of problems encountered with the provided Thermopure-2 unit, a retest was conducted using a replacement Thermopure-2 unit. The scope of the retesting was reduced due to

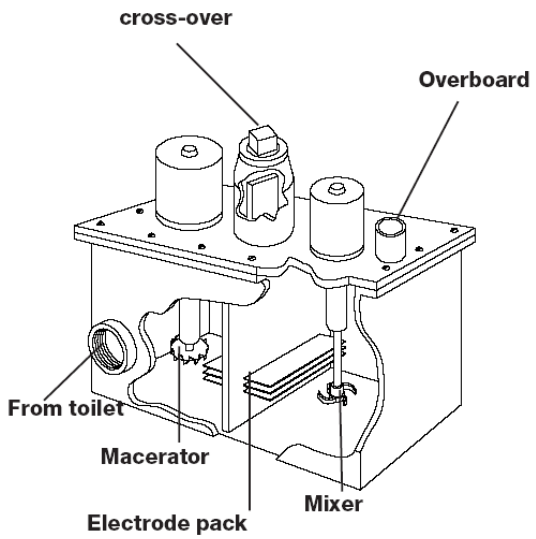
a limitation of funding. The duration of the performance testing was reduced from 10 days to 9 days. Retesting dates were October 15 and 16, 2007, November 29 and 30, 2007, and December 3 through 7, 2007. (This resulted in another exception to USCG's Sewage Processing Test requirements at 33 CFR 159.121(c) as testing was not at least 10 days within a 20-day period. Furthermore, USCG certification for the Thermopure-2 unit expired on November 6, 2007.) The retesting was reduced to TSS testing of the challenge wastewater batch prepared each day, and testing of effluent samples for fecal coliform, VFS, BOD_5, and TSS.

2.0 TECHNOLOGY DESCRIPTIONS AND SPECIFICATIONS

2.1 Electro Scan

2.1.1 Description

Electro Scan (Figure 2-1) is a USCG-approved Type I MSD manufactured by Raritan Engineering Company, Inc. The system consists of a two-chamber treatment tank, system status panel, control unit, LCD, and an optional salt feed tank system that can be added for operation in fresh or brackish water. The device is designed for use on vessels 65 feet or less in length and accommodates most existing marine toilets. The device creates disinfectant from salt water.



Source: Raritan Engineering Company, Inc

Figure 2-1. Internal Components of the Electro Scan Treatment Tank

Flushing moves waste to the maceration chamber for particle size reduction. Subsequent flushing moves the waste to the oxidation chamber where it is mixed and brought into direct contact with electrode plates. When these plates are submerged in salt water and supplied with electricity, hypochlorous acid is formed, which then breaks down organic waste products, including bacteria, by oxidation. The cycle runs for approximately two minutes in the second chamber, and the waste is held in the oxidation chamber until the next flushing cycle, then it is discharged.

2.2 Specifications

The Electro Scan has three models, EST12, EST24, and EST32, each with different volts of direct current as represented by the numbers in each model name. The EST 12 model was selected for performance testing. The main component of the system is the 3-gallon, or 11.4-L, treatment tank with dimensions of 13.5 x 9.25 x 16 inches (in.). The treatment tank is divided into two 1.5 gallon chambers. The dividing partition contains an electrode pack with electrodes protruding into each chamber. The first chamber, containing the macerator, reduces the sewage into tiny particles. Salt water used in the flush activates the electrode in the first chamber, which produces the disinfectant that treats the sewage. During subsequent flushes, the macerated sewage flows up and over the partition into the second chamber via a cross-over pipe. Because of this design, any settled solids remain in the first chamber for continued maceration and treatment. The second chamber continuously mixes the waste as the second set of electrodes continues waste disinfection. According to Raritan, the treatment tank holds about four flushes, averaging 0.75 gallons per flush. Therefore, the waste undergoes approximately four treatment cycles before being discharged. A complete treatment cycle lasts about 3.75 minutes.

The following are the chemical reactions that occur in the treatment chambers:

1. The process starts with salt water in the treatment tank. Sodium chloride (NaCl) is a strong electrolyte that exists in salt water as sodium (Na+) and chloride (Cl-) ions.

$$NaCl \text{ --> } Na^{+} + Cl^{-}$$

2. Through hydrolysis, water (H_2O) breaks into hydrogen (H^{+}) ions and hydroxyl (OH^{-}) ions.

$$H_2O \text{ --> } H^{+} + OH^{-}$$

3. The electrode pack is energized at the anode during the treatment cycle, and electricity passes through the conductive salt water. Hydrochloric acid (HCL), and hypochlorous acid (HOCL), a powerful bactericide and oxidizing agent, and are produced on the surface of the plates, liberating two electrons (e^-).

$$2Cl^- + OH^- + H^+ \text{ --> } HCl + HOCl + 2e^-$$

4. At the cathode, the two electrons, hydrogen ions, sodium ions and hydroxyl ions combine to produce sodium hydroxide (NaOH) and some hydrogen.

$$2e^- + 2H^+ + 2Na^+ + 2OH^- \text{ --> } 2\ NaOH + H_2\uparrow$$

5. The net reaction is:

$$2Cl^- + 3OH^- + 3H^+ + 2Na^+ \text{ --> } HCl + HOCl + 2NaOH + H_2\uparrow$$

6. Hypochlorous acid is formed when sodium hypochlorite (NaOCl) reacts with water.

$$NaOCl + H_2O \text{ --> } NaOH + HOCl$$

7. Hypochlorous acid reacts with contaminants (e.g., soil, dirt, and bacteria) giving up its oxygen; leaving hydrochloric acid.

$$HOCl + \text{contaminants --> } HCl + \text{contaminants } O_x$$

8. The hydrochloric acid reacts with the sodium hydroxide to form sodium chloride and water.

$$HCl + NaOH \text{ --> } H_2O + NaCl$$

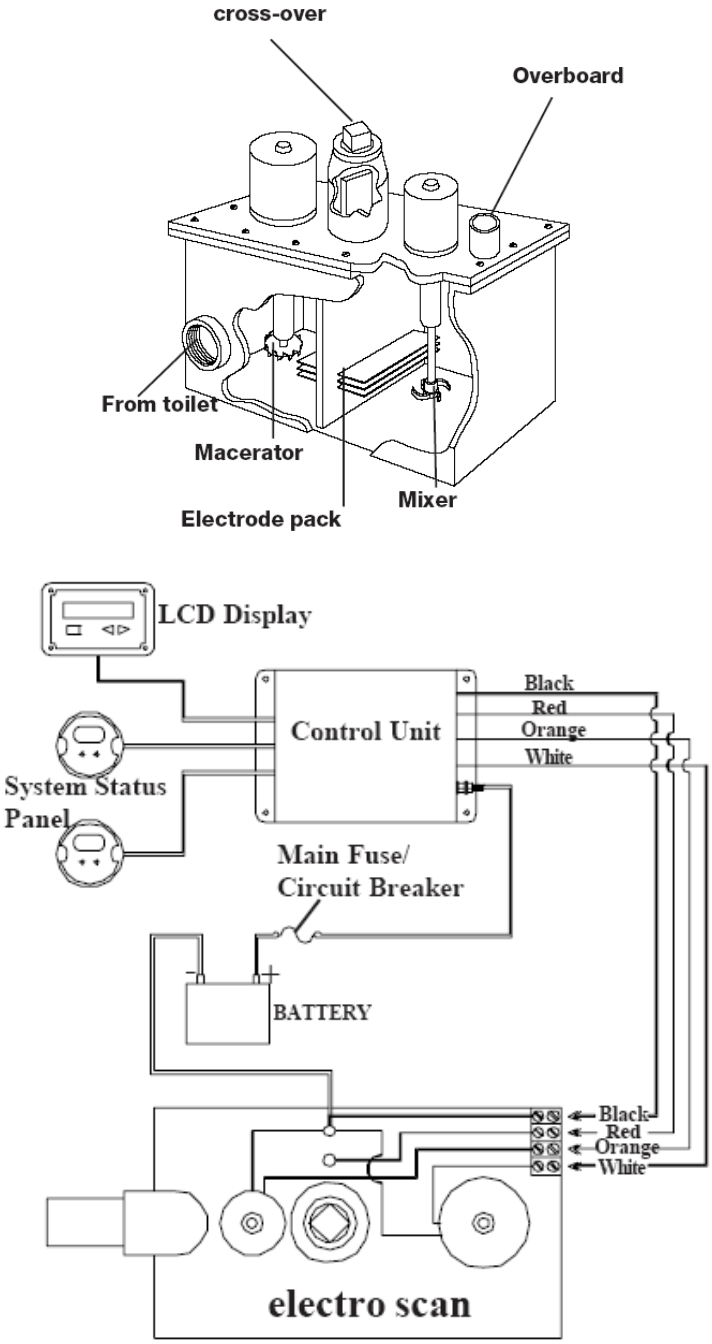
Another component of this device is a credit-card-sized system status panel (Figure 2-2), which contains a touch pad button for starting the treatment cycle and labeled light-emitting diode (LED) indicators to show proper operation or the nature of a possible fault. When installed with an electric toilet, flushing the toilet initiates waste treatment as a one-touch operation. When installed with a manually operated toilet (hand pump type), an optional pump sensor kit can be

installed at the toilet, which is wired to, and automatically activates, the Electro Scan treatment process.

The control module (Figure 2-2), containing two boards, serves as the system's central control. The main microprocessor/memory board contains system programming, logic circuitry, treatment monitoring, and operational data storage. The second board is an input/output component that allows the user to make connections to accessories. Power switching solenoids, fuse protection, and a leaf shunt to measure the current flowing through the electrodes are built-in.

The LCD display unit (Figure 2-2) is the new feature of the system, which distinguishes the EST 12 model from the older generation Lectra/San device. The display provides the user with information regarding the treatment cycle, such as voltage status, and historical data regarding the use of the system. It also contains a reset button if a system error occurs.

Finally, there is an optional salt feed tank, which is used when the boat is operating in freshwater or brackish waters. The feed tank is available in three models: 2 gallon (7.6 L) tank, 4 gallon (15.2 L) tank, and a 4 gallon (15.2 L) tank with automatic water refill and salt water injection. Standard table salt is used to make the salt solution, and this salt water is metered to the suction line of the toilet or injected directly into the treatment tank. The standard formula for making salt water is 4.6 ounces (oz) of non-iodized salt per gallon of water.



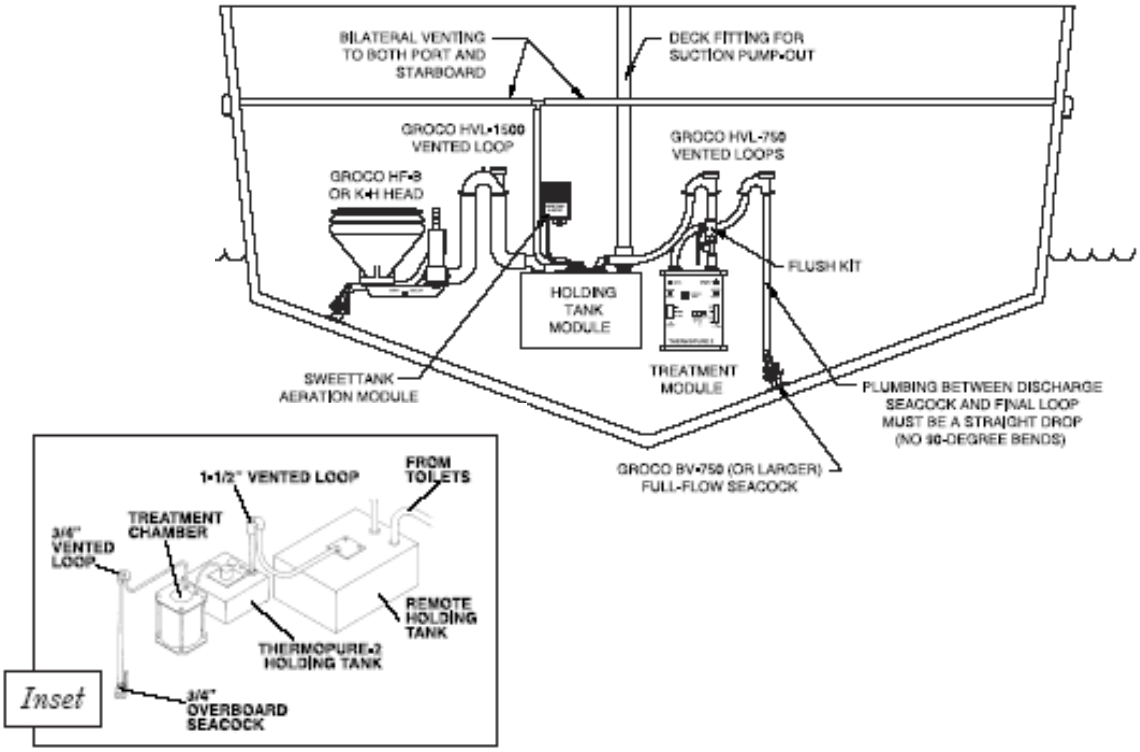
Source: Raritan Engineering Company, Inc

Figure 2-2. Electrical Hookup of Electro Scan Components

2.3 Thermopure-2

2.3.1 Description

At the time of the April 2007 performance test, the Thermopure-2 (Figure 2-3) was a USCG-approved Type I MSD manufactured by Gross Mechanical Laboratories, Inc. At the time of the November/December retesting, the Thermopure-2 was not longer USCG-approved as the USCG certification expired on November 6, 2007. The system consists of three main components: The holding tank module, SweetTank™ aeration module, and the Thermopure-2 treatment chamber. The device is designed to be plumbed to either a toilet head or a preexisting remote holding tank, and all functions and operations in the device are automatic.



Source: Gross Mechanical Laboratories, Inc

Figure 2-3. Example Installation for Thermopure-2

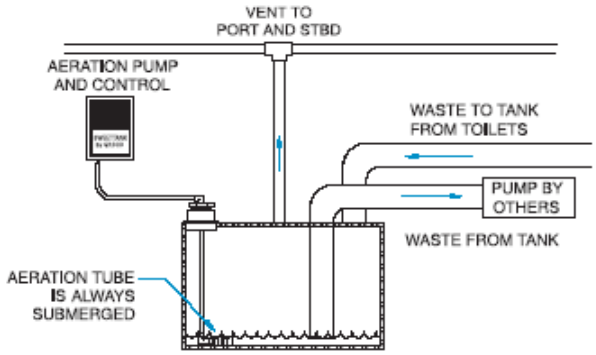
Treatment is accomplished by macerating the waste in the holding tank module and then pumping it thought the Thermopure-2 treatment chamber where low-level heat is introduced to

eliminate bacteria. No chemicals or additives are required. In addition, the Thermopure-2 device does not require salt water to operate, so it is equally efficient in fresh or brackish water.

2.3.2 Specifications

The Thermopure-2 device is available in four models: TP-210, TP-215, TP-220, and TP-230. The last two digits of the model name represent the different sizes of holding tank capacity in gallons. The TP-210 model was selected for performance testing.

For the Thermopure-2 device, wastewater enters a holding tank module as the toilet is flushed, where it is macerated. (For installations with a remote holding tank, waste is pulled into the Thermopure-2 holding tank module and treated in a series of batches). When wastewater enters the holding tank module, the SweetTank Odor Neutralization System™ also begins working. The SweetTank™ (Figure 2-4) is a unit that was developed to eliminate odors in holding tanks without the use of chemicals or filters. Instead, SweetTank™ induces a constant flow of air into the holding tank module through a submerged aeration tube, producing an oxygen-rich environment in which anaerobic bacteria cannot thrive, thus eliminating odors. The air is released though a lateral ventilation system on either side of the boat.



Source: Gross Mechanical Laboratories, Inc

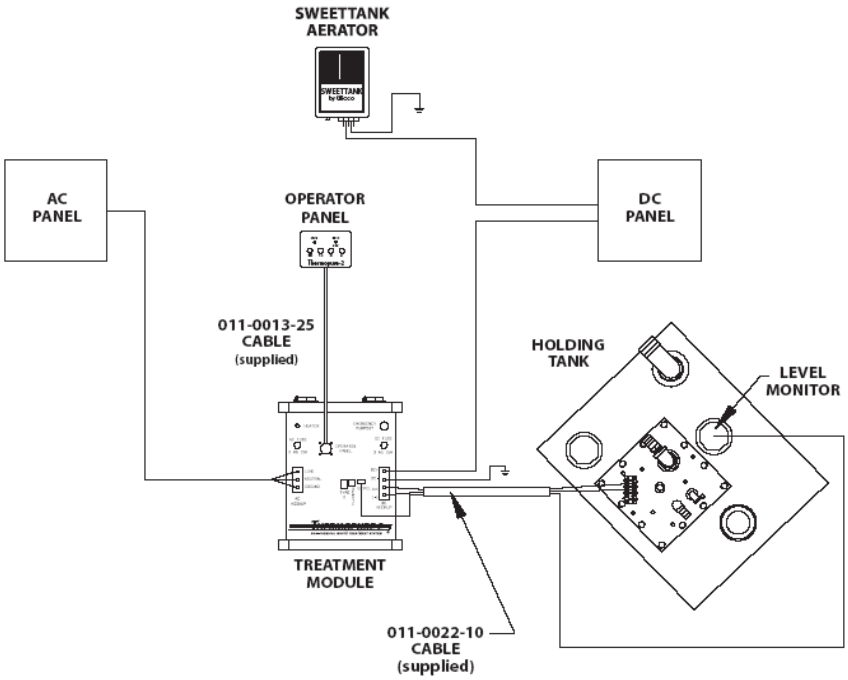
Figure 2-4. SweetTank™ Setup

Whenever macerated wastewater is detected in the holding tank module and the macerator has operated for a set amount of time, the treatment system pumps the batch of wastewater from the treatment chamber into the Thermopure-2 chamber where heat is applied to the wastewater to eliminate bacteria. (Gross Mechanical Laboratories, Inc. representatives did not provide the length of maceration time or operating temperature of the device.) If the two

modules are not at the same height, the device will not pump properly and will require the installation of a HVL-750 3/4 in. Vented Loop, which is sold separately. After a treatment cycle, the treated waste is then pumped overboard.

When no wastewater is detected in the holding tank module, the device automatically enters stand-by mode. However, when the holding tank module is close to full, use of the toilets must stop as additional flushing will overflow the device.

The treatment unit also has an operation panel (Figure 2-5), which gives the user information about the system. At 10% capacity, a yellow light on the panel indicates the initiation of treatment and discharge, assuming the system is already at adequate temperatures. At 75% capacity, a flashing yellow light and audible alarm goes off to warn users the system is close to maximum capacity. Other functions of the panel includes alternating current (AC) and direct current (DC) power "on" indicators, a system failure alarm, a hold switch that disables the system temporarily, and a mute button. Lastly, a flush kit is installed after the treatment unit which facilitates winterization and maintenance, and provides an access port to clear blockages, should one occur.



Source: Gross Mechanical Laboratories, Inc

Figure 2-5. Electrical Hookup for Thermopure-2

Warm-up time for the device (measured from the time AC power is first applied to when the device is ready to treat and discharge) is approximately six minutes at 15 amperes (A) of AC power. The use of the pumps in the system is an additional 16 A of DC power. During periods of time when the system is on stand-by, 150 milliamperes (mA) of DC circuit power is used.

3.0 PERFORMANCE EVALUATION TESTING PROCEDURES

3.1 Test Facility

NSF conducted the performance tests at its Waco, Texas test facility, located at the Waco Metropolitan Area Regional Sewerage System (WMARSS) treatment facility.[1] The site provided a ready source of fresh wastewater and primary sludge to provide a challenge wastewater for testing.

3.2 Device Installation

NSF test-site personnel reviewed the documentation for the two devices to determine the best approach for setup and testing of the systems. The size of the two devices allowed them to be installed in a manner convenient for dosing and sampling. As shown in Figure 3-1, the devices were installed on plywood platforms, taking into account the configuration indicated in the manufacturers' literature.

Electro Scan device is in the foreground and Thermopure-2 device is in the background. Dosing system shown in upper left and effluent receiving tanks in lower right.

Figure 3-1. Thermopure-2 and Electro Scan Installation

[1] NSF's facility located in Ann Arbor, Michigan is currently accepted by the USCG as a Recognized Facility for the evaluation, inspected, and testing of marine sanitation devices under 33 CFR 159.15. However, NSF's Waco, Texas and Aqua-Tech Laboratories, Inc. subfacility currently is not accepted as a Recognized Facility by the USCG.

The devices were anchored to the platform to accommodate tilting during testing to an angle of 30º from the horizontal along one side of the devices (specified by both manufacturers as maximum roll/pitch angle). Hinges were installed in the middle of the platform in both the length and width directions to permit pivoting of the equipment to the required angle. With this platform, tilting of the equipment could be performed along the edges of each device over the course of the testing. The tilt angles were pre-set, but were also verified during each tilt event using an inclinometer. Figure 3-2 shows the devices during testing in the tilted position.

Figure 3-2. Tilting Mechanism for MSDs

Dosing was accomplished through use of infrastructure dedicated to each test device. Each test device had a separate dosing pump, dosing manifold, programmable electronic timer, dosing bucket, motorized ball valve, return flow line and dose counter in place to allow dosing on separate test schedule intervals and dosing volumes as determined by the overall test schedule. In each dosing sequence event, the timer closed the drain valve, activated the dosing pump, and ran the pump for a set run time to allow complete volume dosing for each dosing

bucket and then turned off the pump. Each bucket was calibrated before implementing the test (including the volume of pipe and valve) to ensure an exact volume for each dosing event. The excess dose water overflow pumped to each device for dosing was allowed to flow as gravity return flow to the batch tank. After a set period to allow the water level to equilibrate, the timer activated the drain valve allowing the dose to gravity flow to the respective test device. The Electro Scan device required a separate input signal from the timer used to control dosing through a 12 VDC converter, since the dosing would not be from an actual toilet input. The Thermopure-2 device, operating off the liquid level in the holding tank, required no special interface with the control panel.

Each device also had a separate 10-gallon polyethylene effluent receiving container. Treated effluent accumulated in the receiving containers to ensure a sufficient effluent volume for sampling analysis. The effluent receiving containers were emptied, decontaminated, and returned to service following collection of each effluent sample.

3.3 Start-Up Testing

A trial run of the devices was completed prior to the start of sewage processing to ensure everything was operating properly. The testing included preparing the challenge wastewater and following the start-up instructions provided by the manufacturers.

Electro Scan Device

The Electro Scan device was filled with salt water per the manufacturer's instructions and placed into operation. No leaks were found, measures for voltage and amperage to the device were found appropriate, and the device was placed into operation. The control panel fuse burned out after two cycles of operation and the wire size was changed to address the matter. The change did not remedy the problem, as the control panel indicated "low amp error," which prompted site personnel to talk with the manufacturer. It was intended to use a 110 VAC/12 VDC converter (manufacturer's manual indicated that an unfiltered power supply was needed), but discussion with the manufacturer indicted that the batteries were needed to provide a pure power supply. Four 850 cranking amp automobile batteries were used for the power supply, which prevented the error message over each eight-hour test period. The device was then deemed to be in proper operation for sewage processing.

Thermopure-2 Device

The Thermopure-2 device was filled to 10% of the holding tank volume with fresh water. The start-up procedures provided in the manufacturer's literature were followed, and the device was found to be ready for testing. However, when the trial run with wastewater was completed, two leaks were found in the tank top. The first was a leak at the interface of the holding tank and the plate holding the macerator pump. The cap nuts used to secure the plate to the tank were tightened to compress the rubber gasket between the tank and plate, but the leak was not stopped, possibly from an uneven mold or bad seam. The second leak was from a thermally-welded adapter for the pump-out fitting. A replacement tank, which was found to be free of leaks, was provided by the manufacturer and placed into operation.

3.4 Sewage Processing Test

The sewage processing test was performed in accordance with 33 CFR 159.121, except testing was conducted using a feed of fresh domestic human sewage rather than human sewage in a ratio of four urinations to one defecation, as specified at 33 CFR 159.121(c), for reasons of practicality. Testing was performed over an eight-hour period for 10 days (five week days per week for two consecutive weeks). During this period, the MSDs were challenged with wastewater at the average loading flow, with three periods of each day of the MSDs processing waste at the peak capacity. The testing dates were April 9 through 13, 2007, and April 16 through 20, 2007. The MSDs were tilted to an angle of 30° for a one-hour period each day.

3.4.1 Wastewater Dosing Schedules

Electro Scan Device

The peak flow process designated by Raritan is 1 gallon flush of wastewater every six minutes and a 30-minute cool-down period after every four to five flushes. This averages to a peak flow of 40 gallons in an eight-hour day. Flushing wastewater through the device at a faster rate than the suggested peak flow would result in the discharge of untreated or partially treated wastewater, as the device has no failsafe to prevent such discharge. The off-peak (average) process flow was based on the assumption of four passengers each using the toilet five times in an eight-hour day. This resulted in the off-peak flow of 20 gallons in an eight-hour day, which was the average loading flow that was used during certification of the device. The dosing schedule allowed six minutes for processing each flush, with five cycles before a 30-minute

cool-down period, as mentioned above. The total daily volume processed was approximately 28 gallons. The wastewater dosing schedule for the Electro Scan is included in Appendix B. The Electro Scan device was dosed daily with 28, 1-gallon doses over the entire 10-day test period.

Thermopure-2 Device

As indicated in the technology description, the Thermopure-2 device dosing pattern was designed based on an assumed challenge wastewater temperature of 68° Fahrenheit (20° Celsius). At this temperature, the peak flow rate was 50 gallons per eight-hour day or about 1 gallon every 10 minutes. The off peak (average) process flow was based on an assumption of four passengers each using the toilet five times in an eight-hour day. This resulted in the off-peak flow of 20 gallons in an eight-hour day or 1 gallon of wastewater every 24 minutes. The total daily volume of wastewater processed was approximately 32 gallons. The wastewater dosing schedule for the Thermopure-2 device is also included in Appendix B. The Thermopure-2 device was dosed daily with 32, 1-gallon doses for nine of the 10-day test period. On days two (4/10) and seven (4/17), the device received 28 and 14 doses, respectively, because of operational problems with the device (see Section 3.5).

3.4.2 Challenge Wastewater

A single batch of challenge water was mixed each morning in a 300 gallon batch tank, approximately 30 minutes ahead of initial dosing. A 1/3 horsepower circulating pump, used to minimize solids settling in the batch tank, was turned on and allowed to run during the 30-minute setup period before initial dosing, and continued operating throughout the day until dosing was discontinued. In order to achieve the target 500 mg/L TSS minimum influent, trial runs bracketing the ratio of primary sludge solids to raw influent ahead of testing indicated an approximate ratio of 1/3 primary sludge to 2/3 raw wastewater. Raw influent was pumped directly into the batch tank from a drawoff point just after the raw water inlet screen to the Waco plant. The primary sludge solids were added to the batch tank using a hose attached to a pressure fitting in the primary sludge line from the primary clarifiers to the plant digester. The batch tank contained a predetermined volume level that was marked on the tank to which the tank was filled with return solids flow from the raw water pump to achieve the target volume for TSS concentration.

Variations in the primary sludge solids concentrations accounted for variations in the challenge water TSS concentration encountered during the testing. The batch was made daily based on the best estimate of the site personnel to meet the targeted 500 mg/L concentration; however, the actual concentration each day was determined after the dosing was completed. As shown in Table 3-1, the influent TSS concentrations during the testing ranged from 420 mg/L to more than 12,000 mg/L. The average influent TSS concentration over the course of the test was 2,500 mg/L with a standard deviation of ±3,600 mg/L.

Table 3-1. Influent TSS Results

Date	Influent TSS (mg/L)
4/9/07	4,000
4/10/07	12,000
4/11/07	1,100
4/12/07	720
4/13/07	420
4/16/07	1,100
4/17/07	740
4/18/07	500
4/19/07	450
4/20/07	3,300

3.5 MSD Operation and Maintenance

Electro Scan Device

There was no routine maintenance required during the testing, as treatment/electrode cleaning is recommended every six months. The device was flushed with two doses of fresh water prior to the weekend following the first five days of testing. The power and salt feed device were turned off for the weekend and restarted on the following Monday. The same process was followed at the end of testing.

The four-gallon salt feed tank was used for the testing. The manual instructions for the salt tank indicated that the tank be filled with up to 10 pounds of solar salt, which would mix with a fresh water supply to provide about a 3% salt solution for injection into the device. While it was not possible to record the amount of salt water actually injected into the device, the amount of solar salt added to the tank was recorded over the 10 days of the test. Over the course

of the testing, including the trial run prior to the start of the test, a total of 39 pounds of solar salt was added to the salt tank.

Operationally, maintenance was provided several days during the test:

- Day eight – An error message on the control panel (MAC MOTOR OVERLD) occurred. NSF site personnel removed the macerator motor screws to access the macerator shaft and turned the shaft by hand to free it up. The motor was returned to service with no further messages. An error message (ELECTROD OVERLD) on the control panel was investigated, including wiring checks. The power was turned off then back on, and the panel returned to the normal status of "Ready to Flush." The problem may have been related to the salt concentration in the device.

- Day nine – An error message (LOW ELECTRODE AMPS) appeared on the control panel, indicating that the salt in the salt tank should be checked. A visual check of the tank found the salt dosing pump running continuously. The device was reset by shutting off the water and power to the pump, then restarting. The warning was repeated during the day, with about 10 pounds of salt being added to the tank over the course of the day. For the latter part of the day, the power to the pump had to be disconnected between doses to keep it from running continuously and getting control panel operational errors. At the end of the day, power was reset to the control panel and the salt tank was cleaned, flushed, and restocked with salt for the next day. The device operated as it had prior to the problems on day nine.

Thermopure-2 Device

The only routine maintenance required during the testing was weekly flushing of the device, which was completed on Friday of each week. This maintenance involved filling the holding tank to 75% capacity with fresh water and allowing the device to process normally.

Operationally, maintenance was provided several days during the test:

- Day two – The device was not pumping out effluent, with the tank filling the holding tank, and the 10% and 75% alarm lights and audible alarm activating. All electrical connections were checked; however, the fuse blew three times. The emergency discharge button was actuated and the pump could be heard running, but still with no discharge.

The device was shut down, missing four doses, and the pump assembly was replaced, which corrected the problem. Disassembly of the failed pump revealed that the retaining bolt securing the impeller to the pump shaft had come out, allowing the pump shaft to turn without turning the impeller.

- Day four – When the device was tilted (to 30º) the audible alarm sounded and the 10% and 75% warning lights blinked. No cause was found for this condition, and the alarms stopped after about 20 minutes following the device being returned to the upright position. The heater light also did not light during this time.

- Day six – The air compressor provided with the Sweet Tank component began making a rattling noise, which was resolved by removing the retainer clip and allowing the compressor to hang by the plastic air line and wiring. The compressor operated without noise for the remainder of the test.

- Day seven – The same condition of warning alarm and alarm lights occurred and no discharge was occurring from the device. All electrical was checked and floats cleaned, per manual. The manual pump-out worked, but when dosing was resumed, the tank once again filled with no discharge. Dosing was discontinued and the manufacturer contacted. Site personnel, working with the manufacturer, determined that the thermal switch in the device was open, not allowing for discharge from the device. The final solution was to jumper across contacts for the switch to keep the testing going. This was successful, although eighteen doses and two effluent samples were lost because of the problem.

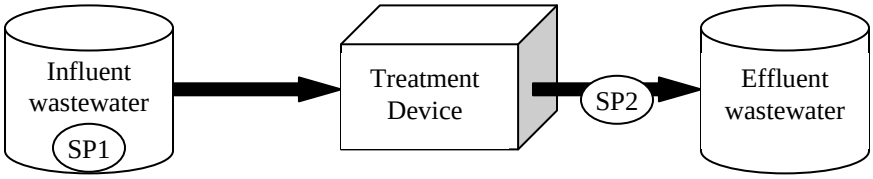
- Day eight – It was observed that the device did not heat when tilted to one of the four directions (three o’clock position). Also on that day, effluent was observed spraying out of the vacuum breaker on the inlet side of the device when it was pumping out. NSF site personnel dismantled the breaker and found no apparent reason for the malfunction. A modification of the breaker, which the manufacturer representative acknowledged did not impact device operation, was made to accommodate the remainder of the test.

- Day nine – During the tilt cycle (to the three o’clock position), steam and a small amount of solids were emitting from the effluent hose, which indicated that the discharge pump

may have been out of the water. The device was righted for 30 seconds and the emergency pump-out switch was activated to prevent damage to the heating element. The device was returned to the tilt position and subsequent doses filled the tank enough to allow the pump to operate properly.

3.6 Sample Collection

Samples of the influent feed (challenge wastewater) and of the effluent discharged from each device (Figure 3-3) were collected according to the schedule provided in Appendix B. Note that the automated dosing schedule was started at the same time each day and the sample schedule was followed precisely to accommodate the processing times needed for each of the MSDs and the number of wastewater doses required to obtain sufficient effluent volume for testing.



Note: SP1 is the influent sampling point; SP2 is the effluent sampling point.

Figure 3-3. Schematic Diagram of Sampling Points

A grab sample of the challenge wastewater (mixed contents of the batch tank) was collected from the outlet of the recirculation pump immediately prior to dosing to the devices each day, for a total of 10 samples. Grab samples were collected using a clean 1.5-gallon glycol-modified polyethylene terephthalate (PETG) carboy, collecting approximately six liters each day. The collected wastewater was thoroughly mixed and poured off into appropriate sample bottles for the analyses (See Table 3-2). The sampling device was dedicated to challenge wastewater sample collection and was thoroughly decontaminated using Alconox cleaning solution and deionized/distilled water rinse after each use.

Table 3-2. Methods, Sample Volume, Preservatives, and Holding Time

Reference/Method	Name	Sample Volume (mL)	Preservative[a]	Holding Time
160.2	Total Suspended Solids	250	4C	7 days
405.1	Biochemical Oxygen Demand, 5-day	1000	4C	48 hours
350.1	Ammonia	500	H_2SO_4, 4C	28 days
353.2	Nitrate/ Nitrite	100	H_2SO_4, 4C	28 days
351.2	Kjeldahl nitrogen	500	H_2SO_4, 4C	28 days
365.2	Total phosphorus	50	H_2SO_4, 4C	28 days
Hach #58700-00	Residual chlorine	50	None	None
9221 C	Fecal coliform	100	$Na_2S_2O_3$[b], 4C	6 hour
Enterolert®	Enterococcus	100	$Na_2S_2O_3$[b], 4C	6 hour
Colilert®	*E. coli*	100	$Na_2S_2O_3$[b], 4C	6 hour
33 CFR 159.125	Visible Floating Solids	1000	None	None

[a] Sample containers were pre-preserved with chemical preservatives as appropriate, and proper sample preservation was verified upon sample receipt at the laboratory.
[b] $Na_2S_2O_3$ addition performed only for samples from the Electro Scan device due to presence of total residual chlorine.

Effluent samples from the test devices were collected at the beginning, middle, and end of each eight hour period during dosing, with one additional sample taken following a peak dosing period each day. A total of 40 effluent samples were collected for the Electro Scan device (four samples per day for 10 days), and a total of 38 effluent samples were collected for the Thermopure-2 unit (two effluent sampled were missed due to unit operating problems on day 7 as discussed in Section 3.5). Grab samples from each device were taken by draining the effluent from each of the 10-gallon effluent receiving containers into separate clean 1.5-gallon PETG carboys, collecting approximately six liters each sample time. The carboys were thoroughly mixed and poured off into appropriate sample bottles for the analyses to be completed (Table 3-2). The sampling devices (effluent receiving containers and carboys) were dedicated to effluent sample collection from each device and were thoroughly decontaminated using Alconox cleaning solution and deionized/distilled water rinse after each use.

NSF site personnel measured residual chlorine and visible floating solids onsite due to the relatively short holding times. Aqua-Tech Laboratories, Inc.[2] completed the chemical and biological analyses.

[2] NSF's facility located in Ann Arbor, Michigan is currently accepted by the USCG as a Recognized Facility for the evaluation, inspected, and testing of marine sanitation devices under 33 CFR 159.15. However, NSF's Waco, Texas and Aqua-Tech Laboratories, Inc. subfacility currently is not accepted as a Recognized Facility by the USCG.

3.7 Process Monitoring

Process monitoring of influent and effluent streams was performed to verify that test conditions remained relatively constant over the course of the evaluation. Monitoring parameters were measured at regular intervals over the course of testing.

Each grab sample of challenge water and effluent was tested for pH and temperature to monitor the operating conditions of the test system. Conductivity testing was also completed on the influent and effluent wastewater for the Electro Scan device.

- **pH:** Analyses for pH were performed according to SM 4500-H. A three-point calibration was performed each day that the meter was used for testing.
- **Temperature:** Temperature was measured according to SM 2550.
- **Conductivity:** Salt content of challenge water and treated effluent were monitored using a conductivity meter, similar to method EPA 120.1. This testing was performed for testing of the Electro Scan device only.

Wastewater flow rates (peak and off peak) were also monitored and recorded over the course of testing.

3.8 Field Quality Control (QC) Measures

Field quality control samples for this project included equipment blanks and field duplicate samples. Note that not all QC measures listed are required for all methods.

The purpose of equipment blanks is to document adequate decontamination of sampling equipment before use and to evaluate possible contamination caused by sampling equipment or by sampling equipment decontamination procedures. Sampling equipment included the effluent receiving containers for each device and the plastic carboys used to collect, mix, and pour the influent and effluent samples. The sampling crew collected these blanks by rinsing decontaminated sampling equipment with deionized/distilled water. Equipment blanks were analyzed for the same parameters as those analyzed on the samples collected using the sampling equipment.

Field duplicate samples were collected to evaluate total measurement precision and covered all the sources of data variability in sample collection, handling, preparation, and

analysis. Test personnel collected field duplicate samples simultaneously as split samples from the selected composite sample at a rate of one per batch of 10 to 20 samples for microbiologicals and one per batch of 10 samples for all other analytes.

3.9 Deviations from the Work Plan

Performance testing proceeded as specified in the work plan with the deviations below:

- Malfunction of effluent pump on the Thermopure-2 device on day two resulted in four missed doses of challenge wastewater. No samples were missed.
- Malfunction of the thermal switch on the Thermopure-2 device on day seven resulted in eighteen missed doses of challenge wastewater and two missed effluent samples.

4.0 TEST RESULTS AND DISCUSSION

This section presents the data collected during the performance tests. Section 4.1 presents the analytical results and discussion for fecal coliform and visible floating solids. Section 4.2 presents the analytical results and discussion for analytes other than coliform and visible floating solids. Section 4.3 discusses the performance of the two MSDs tested. Analytical data for the Electro Scan device are presented in Tables 4-1 through 4-14, and analytical data for the Thermopure-2 device are presented in Tables 4-15 through 4-26. Tables are presented at the end of this section.

4.1 Fecal Coliform and Visible Floating Solids

4.1.1 Fecal Coliform

Table 4-1 presents the fecal coliform data for the Electro Scan device, and Table 4-15 presents the fecal coliform data for the Thermopure-2 device. Note that two effluent samples were not collected for the Thermopure-2 device as discussed in Section 3.9, resulting in a total of 38 effluent samples for this device rather than the planned 40 samples. The effluent produced by the Electro Scan device ranged from nondetect to >1,600 fecal coliform bacteria MPN/100 mL with a mean concentration of 82 MPN/100 mL (see Table 4-1). The effluent from the Thermopure-2 device ranged from nondetect to 30,000,000 fecal coliform bacteria MPN/100 mL with a mean concentration of 4,500,000 MPN/100 mL (see Table 4-15).[3]

Upon receipt of the analytical data, ERG contacted representatives of Gross Mechanical Laboratories, Inc., the manufacturer of the Thermopure-2 device, to inform them of the performance of their device. The manufacturer's representative visited the test facility to investigate. The representative verified proper device installation and test infrastructure. After drilling a 1-in. hole in the schedule 80 housing on the Thermopure-2 device, the representative found that a small internal thermal sensor that controls the heating and pumping cycle for the device, which is supposed to be inserted in a drilled recess in the heating block, was not in the recess or was not completely in the recess. The representative stated that misplacement of the thermal sensor would result in the device not reaching the designated threshold temperature sufficient to kill bacteria. It would also account for the shorting that occurred in the thermal

[3] Performance testing was not conducted in accordance with the test conditions described in 33 CFR 159.53 (Appendix A). For reasons of practicality, testing was conducted using a feed of fresh domestic human sewage rather than human sewage in a ratio of four urinations to one defecation, as specified in 33 CFR 159.121(c).

switch on day seven (see discussion in Section 3.5). The manufacturer's representative placed the sensor all the way into the recess and ran water through the device, measuring the temperature through several cycles. Effluent temperatures ranging between 61ºC and 85ºC were observed, which the representative stated was perfect working order. This compares to effluent temperatures ranging between 38ºC and 49ºC during the performance test (see Table 4-26). Per a request by Gross Mechanical Laboratories, Inc., a retest of a replacement Thermopure-2 device was conducted (see Section 5.0).

It is not clear whether the sensor had come out in shipping or had simply not been installed properly during assembly. Given that the sensor is approximately 1-1/2 in. in length, and the distance between the outer schedule-80 housing and the surface of the heating block, into which the recess hole was drilled is only approximately 3/8-in., it does not appear likely that the sensor could have slipped out during shipping.

4.1.2 Visible Floating Solids

Table 4-2 presents the VFS data for the Electro Scan device, and Table 4-16 presents the VFS data for the Thermopure-2 device. Note that two effluent samples were missed for the Thermopure-2 device as discussed in Section 3.9, resulting in a total of 38 effluent samples for this device rather than the planned 40 samples. VFS is determined by passing approximately 1L of sample expeditiously through a U.S. Sieve No. 12 (openings of 0.0661 in. or 1.68 mm). The material retained on the sieve is dried to a constant weight at 103 °C and reported in mg/L. VFS is also reported as a percentage of the sample TSS.

VFS concentrations in the effluent produced by the Electro Scan device ranged from zero to 5,500 mg/L with a mean concentration of 190 mg/L (see Table 4-2). VFS concentrations in the effluent from the Thermopure-2 device ranged from zero to 1,600 mg/L with a mean concentration of 66 mg/L (see Table 4-16). For the Electro Scan device, 33 of the 40 effluent samples had VFS less than or equal to 10% of the effluent TSS (see Table 4-2). For the Thermopure-2 device, 36 of the 38 effluent samples had VFS less than or equal to 10% of the effluent TSS (see Table 4-16).[4]

The effluent TSS concentration does not appear to indicate the effluent VFS concentration. For the Electro Scan device, 10 samples had TSS concentrations that exceeded

[4] Performance testing was not conducted in accordance with the test conditions described in 33 CFR 159.53 (Appendix A). For reasons of practicality, testing was conducted using a feed of fresh domestic human sewage rather than human sewage in a ratio of four urinations to one defecation, as specified in 33 CFR 159.121(c).

1,000 mg/L. Of these, eight samples had corresponding VFS concentrations that were 10% or less than the TSS concentration and two samples did not. While the Electro Scan effluent sample with the highest TSS concentration had a corresponding VFS concentration significantly greater than 10% of the TSS concentration, the sample with the second highest TSS concentration had a corresponding VFS concentration significantly less than 10% of the TSS concentration. For the Thermopure-2 device, eight samples had effluent TSS concentrations that exceeded 1,000 mg/L. Of these, seven samples had corresponding VFS concentrations that were 10% or less than the TSS concentration (including the sample with the highest TSS concentration), and only one sample did not.

4.2 Other Analyses

4.2.1 Pathogen Indicators *E. Coli* and Enterococci

Tables 4-3 and 4-4 present *E. coli*, and enterococci data for the Electro Scan device, respectively, and Tables 4-17, and 4-18 present *E. coli*, and enterococci data for the Thermopure-2 device, respectively. *E. coli* is a subgroup of fecal coliform that indicates possible presence of enteric pathogens. Enterococcus is a subgroup of fecal streptococcus and is the most efficient bacterial indicator of water quality. (Fecal streptococcus is a subgroup of fecal coliform used to differentiate human versus animal sources of these microbiologicals.) Epidemiological studies suggest a positive relationship between high concentrations of *E. coli* and enterococci in ambient waters and incidents of gastrointestinal illnesses associated with swimming. The studies support the use of *E. coli* and enterococci (instead of fecal coliform) as indicators of microbiological pollution.[5] There are currently no *E. coli* or enterococci federal performance standards for Type I MSDs.

Pathogen indicators generally were not detected in the effluent from the Electro Scan device. For those samples where pathogen indicators were detected, they were generally found at concentrations within 10 times the analytical detection limit. Four pathogen indicator results were uncharacteristically high: two detected *E. coli* concentrations of >24,000 MPN/100 mL, and two detected enterococci concentrations of 5,900 MPN/100 mL and >24,000 MPN/100 mL.

[5] U.S. Environmental Protection Agency. Health Effects Criteria for Fresh Recreational Waters, EPA-600/1-84-004, Research Triangle Park, NC, August 1984.
U.S. Environmental Protection Agency. Health Effects Criteria for Marine Recreational Waters, EPA-600/1-80-031, Research Triangle Park, NC, August 1983.

Both pathogen indicators were detected at elevated concentrations in the effluent from the Thermopure-2 device. *E. coli* concentrations were generally in the millions of MPN/100 mL, while enterococci were generally in the hundreds of thousands of MPN/100 mL. As discussed in Section 4.1.1, misplacement of the thermal sensor in the Thermopure-2 device is believed to have resulted in the device not reaching the designated threshold temperature sufficient to kill bacteria.

4.2.2 Biochemical Oxygen Demand and Total Suspended Solids

Tables 4-5 and 4-6 present BOD_5 and TSS data, respectively, for the Electro Scan device, and Tables 4-19 and 4-20 present BOD_5 and TSS data, respectively, for the Thermopure-2 device. BOD_5 and TSS were detected in all effluent samples for both devices. There are currently no BOD_5 or TSS federal performance standards for Type I MSDs.

The following table, for the purpose of comparison, shows the effluent quality from the Type I MSDs (which are not required to remove BOD_5 or TSS) and EPA's standards for secondary treatment for land-based publicly owned treatment works (POTWs). Note that the technology and capacity of Type I MSDs and POTWs are very different and must be considered in any comparison.

BOD_5 Comparison of Effluent from Type I MSDs to Secondary Treatment Standards

Analyte	Average Effluent Concentration From Type I MSDs		EPA Secondary Treatment Standards [a]
	Electro Scan	Thermopure-2	
BOD_5 (mg/L)	780	920	45
TSS (mg/L)	1,000	1,000	45

[a] 40 CFR 133.102 Secondary Treatment Regulations, 7-day average.

4.2.3 Nutrients

Tables 4-7 through 4-10 present nutrient data for the Electro Scan device, and Tables 4-21 through 4-24 present nutrient data for the Thermopure-2 device. Ammonia, TKN, and total phosphorus were detected in all effluent samples for both devices. Detection of nitrate/nitrite was generally not consistent in effluent samples for both devices. There are currently no nutrient federal performance standards for Type I MSDs.

Ammonia is an inorganic form of nitrogen in water and wastewater, as is nitrate/nitrite. Ammonia is produced within humans when proteins are digested and used by the body, and excess ammonia is excreted in urine. TKN measures both ammonia and organic nitrogen. Examples of organic nitrogen include proteins, peptides, nucleic acids, and urea. A comparison of the ammonia and TKN results in both the influent and effluent samples show that approximately 20% of TKN is the ammonia form. Total nitrogen is the combination of inorganic and organic forms of nitrogen in water and wastewater.

4.2.4 Process Monitoring

Review of pH results for the Electro Scan and Thermopure-2 devices in Tables 4-11 and 4-25, respectively, showed there were no uncharacteristic pH excursions in the challenge wastewater or the treated effluent.

Temperature variations for the Electro Scan device (see Table 4-12) reflect variations in ambient temperatures at the test site. On average, influent and effluent temperatures were similar, which is expected as the Electro Scan device does not affect wastewater temperature. In contrast, effluent temperatures for the Thermopure-2 device were greater than the influent temperatures (see Table 4-26) due to the Thermopure-2 heating mechanism. However, as discussed in Section 4.1.1, the Thermopure-2 device failed to reach the designated temperature sufficient to kill bacteria.

Elevated effluent conductivity as compared to influent conductivity for the Electro Scan device (see Table 4-13) results from the salt addition required for the electrodes to generate chlorine residual. Successful generation of residual chlorine is demonstrated by the free and total chlorine residual results provided in Table 4-14. Conductivity and chlorine residual testing were performed for the Electro Scan device only.

4.3 Type I MSD Performance

Table 4-27 compares the average influent and effluent concentrations for each device as determined from the individual results presented in Tables 4-1 through 4-26.[6] Review of these results reveals significant variability in analyte concentrations in both the influent and effluent

[6] Performance testing for fecal coliform and VFS was not conducted in accordance with the test conditions described in 33 CFR 159.53 (Appendix A). For reasons of practicality, testing was conducted using a feed of fresh domestic human sewage rather than human sewage in a ratio of four urinations to one defecation, as specified in 33 CFR 159.121(c). There are currently no federal performance standards for Type I MSDs for parameters other than fecal coliform and VFS.

for most analyses as illustrated by high standard deviations. Challenge wastewater and treated effluent are not homogeneous, and sample concentrations are highly dependent on the amount solids in the individual grab samples. Such variability is expected with raw, complex wastewater with high amounts of solids. With the exception of the fecal coliform, *E. coli*, and enterococci sample results, extreme variability in influent and effluent sample results preclude any meaningful assessment of MSD performance efficiency.

The Electro Scan device removed almost all fecal coliform, *E. coli*, and enterococci (99.99% or greater). In contrast, the performance of the Thermopure-2 device in removing these analytes was generally low and highly erratic. In general, only half of fecal coliform, *E. coli*, and enterococci were removed. As discussed in Section 4.1.1, misplacement of the thermal sensor in the Thermopure-2 device is believed to have resulted in the device not reaching the designated threshold temperature sufficient to kill bacteria.

Table 4-1. Fecal Coliform - Electro Scan

Date	Influent Concentration (MPN/100mL)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (MPN/100mL)
4/9/2007	4,000,000	8:12 AM	Peak	2
		8:24 AM	Peak	4
		12:15 PM	Off Peak	2
		3:48 PM	Off Peak	ND(2)
4/10/2007	6,000,000	8:12 AM	Peak	ND(1.1)
		10:36 AM	Peak	ND(1.1)
		12:15 PM	Off Peak	>23
		3:48 PM	Off Peak	ND(1.1)
4/11/2007	5,000,000	8:12 AM	Peak	ND(1.1)
		12:15 PM	Off Peak	ND(1.1)
		1:36 PM	Peak	ND(1.1)
		3:48 PM	Off Peak	ND(1.1)
4/12/2007	4,700,000	8:12 AM	Peak	1.1
		8:24 AM	Peak	ND(1.1)
		12:15 PM	Off Peak	ND(1.1)
		3:48 PM	Off Peak	12
4/13/2007	30,000,000	8:12 AM	Peak	2
		12:15 PM	Off Peak	ND(1.1)
		1:36 PM	Peak	<2.2
		3:48 PM	Off Peak	ND(1.1)
4/16/2007	6,000,000	8:12 AM	Peak	1.1
		8:24 AM	Peak	ND(1.1)
		12:15 PM	Off Peak	ND(1.1)
		3:48 PM	Off Peak	ND(1.1)
4/17/2007	22,000,000	8:12 AM	Peak	<1.1
		10:36 AM	Peak	2.2
		12:15 PM	Off Peak	ND(1.1)
		3:48 PM	Off Peak	ND(1.1)
4/18/2007	3,000,000	8:12 AM	Peak	2
		12:15 PM	Off Peak	ND(1.1)
		1:36 PM	Peak	9.2
		3:48 PM	Off Peak	ND(1.1)
4/19/2007	5,000,000	8:12 AM	Peak	ND(1.1)
		8:24 AM	Peak	ND(1.1)
		12:15 PM	Off Peak	>1,600
		3:45 PM	Off Peak	>1,600
4/20/2007	9,000,000	8:12 AM	Peak	ND(1.1)
		12:15 PM	Off Peak	ND(1.1)
		1:36 PM	Peak	ND(1.1)
		3:48 PM	Off Peak	ND(1.1)
Average ± Standard Deviation	**9,500,000 ± 9,100,000**			**<82 ± 350**

ND – Not detected (number in parentheses is detection limit).

> - The sample was not diluted sufficiently; actual concentration is greater than the reported upper limit.

< - Average result includes at least one non-detect value (calculation uses detection limits for non-detected results).

Table 4-2. Visible Floating Solids - Electro Scan

Date	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent TSS Concentration (mg/L)	Effluent VFS Concentration (mg/L)	VFS as % TSS (%)
4/9/2007	8:12 AM	Peak	560	0	0
	8:24 AM	Peak	460	0	0
	12:15 PM	Off Peak	4,800	5,500	110
	3:48 PM	Off Peak	1,700	100	5.9
4/10/2007	8:12 AM	Peak	3,300	100	3.2
	10:36 AM	Peak	1,500	0	0
	12:15 PM	Off Peak	650	100	15
	3:48 PM	Off Peak	500	100	20
4/11/2007	8:12 AM	Peak	580	0	0
	12:15 PM	Off Peak	460	0	0
	1:36 PM	Peak	450	0.6	0.13
	3:48 PM	Off Peak	430	0.7	0.16
4/12/2007	8:12 AM	Peak	1,800	370	21
	8:24 AM	Peak	2,500	86	3.4
	12:15 PM	Off Peak	1,700	32	1.9
	3:48 PM	Off Peak	1,300	110	8.5
4/13/2007	8:12 AM	Peak	1,300	130	10
	12:15 PM	Off Peak	760	9.4	1.2
	1:36 PM	Peak	960	180	15
	3:48 PM	Off Peak	630	4.7	0.8
4/16/2007	8:12 AM	Peak	680	16	2.4
	8:24 AM	Peak	910	6	0.7
	12:15 PM	Off Peak	670	0	0
	3:48 PM	Off Peak	1,000	130	13
4/17/2007	8:12 AM	Peak	1,000	46	5.8
	10:36 AM	Peak	1,400	110	7.9
	12:15 PM	Off Peak	710	7	1
	3:48 PM	Off Peak	840	50	6
4/18/2007	8:12 AM	Peak	590	10	1.7
	12:15 PM	Off Peak	490	8	1.6
	1:36 PM	Peak	910	110	12
	3:48 PM	Off Peak	600	7	1.2
4/19/2007	8:12 AM	Peak	450	5	1.1
	8:24 AM	Peak	920	27	2.9
	12:15 PM	Off Peak	320	1	0.31
	3:45 PM	Off Peak	270	2	0.74
4/20/2007	8:12 AM	Peak	590	30	5.1
	12:15 PM	Off Peak	600	5	0.83
	1:36 PM	Peak	1,000	70	7.4
	3:48 PM	Off Peak	780	14	1.8
Average ± Standard Deviation			**1,000 ± 860**	**190 ± 860**	

Table 4-3. *Escherichia coli* - Electro Scan

Date	Influent Concentration (MPN/100mL)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (MPN/100mL)
4/9/2007	6,400,000	8:12 AM	Peak	ND(500)
		8:24 AM	Peak	ND(500)
		12:15 PM	Off Peak	ND(500)
		3:48 PM	Off Peak	ND(500)
4/10/2007	7,700,000	8:12 AM	Peak	ND(100)
		10:36 AM	Peak	ND(100)
		12:15 PM	Off Peak	980
		3:48 PM	Off Peak	ND(100)
4/11/2007	6,800,000	8:12 AM	Peak	ND(1.1)
		12:15 PM	Off Peak	ND(11)
		1:36 PM	Peak	ND(10)
		3:48 PM	Off Peak	ND(10)
4/12/2007	20,000,000	8:12 AM	Peak	ND(11)
		8:24 AM	Peak	ND(11)
		12:15 PM	Off Peak	Excluded
		3:48 PM	Off Peak	Excluded
4/13/2007	8,000,000	8:12 AM	Peak	ND(10)
		12:15 PM	Off Peak	ND(10)
		1:36 PM	Peak	ND(5.6)
		3:48 PM	Off Peak	ND(1.1)
4/16/2007	6,100,000	8:12 AM	Peak	ND(11)
		8:24 AM	Peak	ND(11)
		12:15 PM	Off Peak	ND(11)
		3:48 PM	Off Peak	ND(10)
4/17/2007	19,000,000	8:12 AM	Peak	<11
		10:36 AM	Peak	ND(11)
		12:15 PM	Off Peak	ND(11)
		3:48 PM	Off Peak	ND(10)
4/18/2007	6,300,000	8:12 AM	Peak	79
		12:15 PM	Off Peak	41
		1:36 PM	Peak	ND(10)
		3:48 PM	Off Peak	ND(10)
4/19/2007	3,700,000	8:12 AM	Peak	Excluded
		8:24 AM	Peak	ND(10)
		12:15 PM	Off Peak	>24,000
		3:45 PM	Off Peak	>24,000
4/20/2007	7,400,000	8:12 AM	Peak	ND(10)
		12:15 PM	Off Peak	ND(10)
		1:36 PM	Peak	ND(10)
		3:48 PM	Off Peak	ND(10)
Average ± Standard Deviation	**9,100,000 ± 5,600,000**			**<1,400 ± 5,500**

ND – Not detected (number in parentheses is detection limit).
Excluded – Sample result was determined by the laboratory to be inconclusive (see Section 6.1).
> - The sample was not diluted sufficiently; actual concentration is greater than the reported upper limit.
< - Average result includes at least one non-detect value (calculation uses detection limits for non-detected results).

Table 4-4. Enterococci - Electro Scan

Date	Influent Concentration (MPN/100mL)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (MPN/100mL)
4/9/2007	1,300,000	8:12 AM	Peak	38.1
		8:24 AM	Peak	29.4
		12:15 PM	Off Peak	ND(1,000)
		3:48 PM	Off Peak	1.0
4/10/2007	3,300,000	8:12 AM	Peak	ND(100)
		10:36 AM	Peak	3.0
		12:15 PM	Off Peak	6.2
		3:48 PM	Off Peak	1.0
4/11/2007	350,000	8:12 AM	Peak	3.3
		12:15 PM	Off Peak	ND(1.1)
		1:36 PM	Peak	ND(1.1)
		3:48 PM	Off Peak	ND(1.1)
4/12/2007	9,200,000	8:12 AM	Peak	ND(10)
		8:24 AM	Peak	10
		12:15 PM	Off Peak	1.1
		3:48 PM	Off Peak	257
4/13/2007	570,000	8:12 AM	Peak	1.1
		12:15 PM	Off Peak	ND(1.1)
		1:36 PM	Peak	ND(1.1)
		3:48 PM	Off Peak	ND(1.1)
4/16/2007	960,000	8:12 AM	Peak	ND(1.1)
		8:24 AM	Peak	ND(1.1)
		12:15 PM	Off Peak	ND(1.1)
		3:48 PM	Off Peak	ND(1.1)
4/17/2007	370,000	8:12 AM	Peak	ND(1.1)
		10:36 AM	Peak	1.0
		12:15 PM	Off Peak	ND(1.1)
		3:48 PM	Off Peak	ND(1.1)
4/18/2007	840,000	8:12 AM	Peak	ND(1.1)
		12:15 PM	Off Peak	15
		1:36 PM	Peak	ND(10)
		3:48 PM	Off Peak	ND(10)
4/19/2007	1,900,000	8:12 AM	Peak	17
		8:24 AM	Peak	6.9
		12:15 PM	Off Peak	>24,000
		3:45 PM	Off Peak	5,900
4/20/2007	720,000	8:12 AM	Peak	ND(10)
		12:15 PM	Off Peak	ND(10)
		1:36 PM	Peak	ND(10)
		3:48 PM	Off Peak	ND(10)
Average ± Standard Deviation	**2,000,000 ± 2,700,000**			**<790 ± 3,900**

ND – Not detected (number in parentheses is detection limit).

> - The sample was not diluted sufficiently; actual concentration is greater than the reported upper limit.

< - Average result includes at least one non-detect value (calculation uses detection limits for non-detected results).

Table 4-5. Biochemical Oxygen Demand (5 day) - Electro Scan

Date	Influent Concentration (mg/L)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (mg/L)
4/9/2007	1,900	8:12 AM	Peak	310
		8:24 AM	Peak	240
		12:15 PM	Off Peak	1,500
		3:48 PM	Off Peak	600
4/10/2007	NA	8:12 AM	Peak	1,200
		10:36 AM	Peak	690
		12:15 PM	Off Peak	410
		3:48 PM	Off Peak	320
4/11/2007	530	8:12 AM	Peak	290
		12:15 PM	Off Peak	200
		1:36 PM	Peak	170
		3:48 PM	Off Peak	180
4/12/2007	810	8:12 AM	Peak	920
		8:24 AM	Peak	1,400
		12:15 PM	Off Peak	1,300
		3:48 PM	Off Peak	1,100
4/13/2007	500	8:12 AM	Peak	1,700
		12:15 PM	Off Peak	1,800
		1:36 PM	Peak	2,600
		3:48 PM	Off Peak	2,600
4/16/2007	990	8:12 AM	Peak	340
		8:24 AM	Peak	610
		12:15 PM	Off Peak	500
		3:48 PM	Off Peak	670
4/17/2007	820	8:12 AM	Peak	760
		10:36 AM	Peak	970
		12:15 PM	Off Peak	770
		3:48 PM	Off Peak	1,100
4/18/2007	450	8:12 AM	Peak	690
		12:15 PM	Off Peak	270
		1:36 PM	Peak	540
		3:48 PM	Off Peak	450
4/19/2007	400	8:12 AM	Peak	650
		8:24 AM	Peak	350
		12:15 PM	Off Peak	280
		3:45 PM	Off Peak	350
4/20/2007	2,100	8:12 AM	Peak	380
		12:15 PM	Off Peak	710
		1:36 PM	Peak	1,100
		3:48 PM	Off Peak	490
Average ± Standard Deviation	**950 ± 630**			**780 ± 600**

NA – Sample not analyzed due to laboratory error (see Section 6.1).

Table 4-6. Total Suspended Solids - Electro Scan

Date	Influent Concentration (mg/L)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (mg/L)
4/9/2007	4,000	8:12 AM	Peak	560
		8:24 AM	Peak	460
		12:15 PM	Off Peak	4,800
		3:48 PM	Off Peak	1,700
4/10/2007	12,000	8:12 AM	Peak	3,300
		10:36 AM	Peak	1,500
		12:15 PM	Off Peak	650
		3:48 PM	Off Peak	500
4/11/2007	1,100	8:12 AM	Peak	580
		12:15 PM	Off Peak	460
		1:36 PM	Peak	450
		3:48 PM	Off Peak	430
4/12/2007	720	8:12 AM	Peak	1,800
		8:24 AM	Peak	2,500
		12:15 PM	Off Peak	1,700
		3:48 PM	Off Peak	1,300
4/13/2007	420	8:12 AM	Peak	1,300
		12:15 PM	Off Peak	760
		1:36 PM	Peak	960
		3:48 PM	Off Peak	630
4/16/2007	1,100	8:12 AM	Peak	680
		8:24 AM	Peak	910
		12:15 PM	Off Peak	670
		3:48 PM	Off Peak	1,000
4/17/2007	740	8:12 AM	Peak	1,000
		10:36 AM	Peak	1,400
		12:15 PM	Off Peak	710
		3:48 PM	Off Peak	840
4/18/2007	500	8:12 AM	Peak	590
		12:15 PM	Off Peak	490
		1:36 PM	Peak	910
		3:48 PM	Off Peak	600
4/19/2007	450	8:12 AM	Peak	450
		8:24 AM	Peak	920
		12:15 PM	Off Peak	320
		3:45 PM	Off Peak	270
4/20/2007	3,300	8:12 AM	Peak	590
		12:15 PM	Off Peak	600
		1:36 PM	Peak	1,000
		3:48 PM	Off Peak	780
Average ± Standard Deviation	**2,500 ± 3,600**			**1,000 ± 860**

Table 4-7. Ammonia as Nitrogen - Electro Scan

Date	Influent Concentration (mg/L)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (mg/L)
4/9/2007	13	8:12 AM	Peak	4.2
		8:24 AM	Peak	3.3
		12:15 PM	Off Peak	9.8
		3:48 PM	Off Peak	11
4/10/2007	12	8:12 AM	Peak	7.7
		10:36 AM	Peak	3.4
		12:15 PM	Off Peak	2.2
		3:48 PM	Off Peak	3.9
4/11/2007	14	8:12 AM	Peak	3.2
		12:15 PM	Off Peak	6.8
		1:36 PM	Peak	8.9
		3:48 PM	Off Peak	6.9
4/12/2007	15	8:12 AM	Peak	6.2
		8:24 AM	Peak	5.6
		12:15 PM	Off Peak	7.2
		3:48 PM	Off Peak	10
4/13/2007	15	8:12 AM	Peak	16
		12:15 PM	Off Peak	8.7
		1:36 PM	Peak	8.0
		3:48 PM	Off Peak	8.1
4/16/2007	13	8:12 AM	Peak	1.5
		8:24 AM	Peak	10
		12:15 PM	Off Peak	5.9
		3:48 PM	Off Peak	5.7
4/17/2007	14	8:12 AM	Peak	5.7
		10:36 AM	Peak	9.3
		12:15 PM	Off Peak	3.2
		3:48 PM	Off Peak	7.0
4/18/2007	18	8:12 AM	Peak	10
		12:15 PM	Off Peak	5.5
		1:36 PM	Peak	7.7
		3:48 PM	Off Peak	12
4/19/2007	19	8:12 AM	Peak	2.2
		8:24 AM	Peak	6.5
		12:15 PM	Off Peak	21
		3:45 PM	Off Peak	19
4/20/2007	21	8:12 AM	Peak	8.8
		12:15 PM	Off Peak	16
		1:36 PM	Peak	12
		3:48 PM	Off Peak	18
Average ± Standard Deviation	**15 ± 3.0**			**8.2 ± 4.7**

Table 4-8. Total Kjeldahl Nitrogen - Electro Scan

Date	Influent Concentration (mg/L)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (mg/L)
4/9/2007	170	8:12 AM	Peak	17
		8:24 AM	Peak	28
		12:15 PM	Off Peak	130
		3:48 PM	Off Peak	82
4/10/2007	290	8:12 AM	Peak	37
		10:36 AM	Peak	27
		12:15 PM	Off Peak	28
		3:48 PM	Off Peak	30
4/11/2007	62	8:12 AM	Peak	15
		12:15 PM	Off Peak	27
		1:36 PM	Peak	22
		3:48 PM	Off Peak	21
4/12/2007	230	8:12 AM	Peak	31
		8:24 AM	Peak	38
		12:15 PM	Off Peak	66
		3:48 PM	Off Peak	76
4/13/2007	41	8:12 AM	Peak	37
		12:15 PM	Off Peak	43
		1:36 PM	Peak	49
		3:48 PM	Off Peak	38
4/16/2007	73	8:12 AM	Peak	22
		8:24 AM	Peak	31
		12:15 PM	Off Peak	43
		3:48 PM	Off Peak	46
4/17/2007	37	8:12 AM	Peak	43
		10:36 AM	Peak	56
		12:15 PM	Off Peak	47
		3:48 PM	Off Peak	54
4/18/2007	75	8:12 AM	Peak	47
		12:15 PM	Off Peak	15
		1:36 PM	Peak	66
		3:48 PM	Off Peak	44
4/19/2007	46	8:12 AM	Peak	5
		8:24 AM	Peak	15
		12:15 PM	Off Peak	45
		3:45 PM	Off Peak	34
4/20/2007	74	8:12 AM	Peak	66
		12:15 PM	Off Peak	47
		1:36 PM	Peak	69
		3:48 PM	Off Peak	61
Average ± Standard Deviation	**110 ± 89**			**42 ± 23**

Table 4-9. Nitrate/Nitrite as Nitrogen - Electro Scan

Date	Influent Concentration (mg/L)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (mg/L)
4/9/2007	0.11	8:12 AM	Peak	3.0
		8:24 AM	Peak	3.6
		12:15 PM	Off Peak	2.3
		3:48 PM	Off Peak	1.3
4/10/2007	0.3	8:12 AM	Peak	1.2
		10:36 AM	Peak	1.1
		12:15 PM	Off Peak	1.1
		3:48 PM	Off Peak	1.8
4/11/2007	ND(0.05)	8:12 AM	Peak	2.2
		12:15 PM	Off Peak	0.95
		1:36 PM	Peak	0.97
		3:48 PM	Off Peak	1.0
4/12/2007	0.08	8:12 AM	Peak	2.3
		8:24 AM	Peak	1.8
		12:15 PM	Off Peak	1.9
		3:48 PM	Off Peak	0.8
4/13/2007	ND(0.05)	8:12 AM	Peak	1.1
		12:15 PM	Off Peak	1.1
		1:36 PM	Peak	1.4
		3:48 PM	Off Peak	1.4
4/16/2007	ND(0.05)	8:12 AM	Peak	4.7
		8:24 AM	Peak	2.7
		12:15 PM	Off Peak	0.94
		3:48 PM	Off Peak	1.1
4/17/2007	ND(0.05)	8:12 AM	Peak	1.4
		10:36 AM	Peak	1.1
		12:15 PM	Off Peak	1.5
		3:48 PM	Off Peak	1.4
4/18/2007	ND(0.05)	8:12 AM	Peak	2.0
		12:15 PM	Off Peak	5.5
		1:36 PM	Peak	4.3
		3:48 PM	Off Peak	2.3
4/19/2007	0.07	8:12 AM	Peak	10
		8:24 AM	Peak	6.8
		12:15 PM	Off Peak	ND(0.05)
		3:45 PM	Off Peak	0.2
4/20/2007	ND(0.05)	8:12 AM	Peak	1.7
		12:15 PM	Off Peak	1.2
		1:36 PM	Peak	1.2
		3:48 PM	Off Peak	0.77
Average ± Standard Deviation	**<0.09 ± 0.078**			**<2.1 ± 1.9**

ND – Not detected (number in parentheses is detection limit).
< - Average result includes at least one non-detect value (calculation uses detection limits for non-detected results).

Table 4-10. Total Phosphorus - Electro Scan

Date	Influent Concentration (mg/L)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (mg/L)
4/9/2007	59	8:12 AM	Peak	9
		8:24 AM	Peak	12
		12:15 PM	Off Peak	53
		3:48 PM	Off Peak	31
4/10/2007	79	8:12 AM	Peak	33
		10:36 AM	Peak	16
		12:15 PM	Off Peak	13
		3:48 PM	Off Peak	11
4/11/2007	15	8:12 AM	Peak	15
		12:15 PM	Off Peak	12
		1:36 PM	Peak	12
		3:48 PM	Off Peak	12
4/12/2007	72	8:12 AM	Peak	15
		8:24 AM	Peak	17
		12:15 PM	Off Peak	19
		3:48 PM	Off Peak	21
4/13/2007	9.6	8:12 AM	Peak	16
		12:15 PM	Off Peak	11
		1:36 PM	Peak	13
		3:48 PM	Off Peak	10
4/16/2007	11	8:12 AM	Peak	16
		8:24 AM	Peak	12
		12:15 PM	Off Peak	9
		3:48 PM	Off Peak	9
4/17/2007	9	8:12 AM	Peak	11
		10:36 AM	Peak	15
		12:15 PM	Off Peak	12
		3:48 PM	Off Peak	14
4/18/2007	19	8:12 AM	Peak	10
		12:15 PM	Off Peak	6
		1:36 PM	Peak	18
		3:48 PM	Off Peak	12
4/19/2007	14	8:12 AM	Peak	3
		8:24 AM	Peak	7
		12:15 PM	Off Peak	11
		3:45 PM	Off Peak	9
4/20/2007	13	8:12 AM	Peak	14
		12:15 PM	Off Peak	14
		1:36 PM	Peak	20
		3:48 PM	Off Peak	15
Average ± Standard Deviation	**30 ± 28**			**15 ± 8.4**

Table 4-11. pH - Electro Scan

Date	Influent pH	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent pH
4/9/2007	6.2	8:12 AM	Peak	5.8
		8:24 AM	Peak	6.2
		12:15 PM	Off Peak	6.1
		3:48 PM	Off Peak	6.1
4/10/2007	6.1	8:12 AM	Peak	6.3
		10:36 AM	Peak	6.3
		12:15 PM	Off Peak	6.5
		3:48 PM	Off Peak	6.4
4/11/2007	6.4	8:12 AM	Peak	6.2
		12:15 PM	Off Peak	5.8
		1:36 PM	Peak	6.1
		3:48 PM	Off Peak	6.2
4/12/2007	5.8	8:12 AM	Peak	6.4
		8:24 AM	Peak	6.4
		12:15 PM	Off Peak	6.1
		3:48 PM	Off Peak	6.1
4/13/2007	6.2	8:12 AM	Peak	6.2
		12:15 PM	Off Peak	6.2
		1:36 PM	Peak	6.4
		3:48 PM	Off Peak	6.3
4/16/2007	7.0	8:12 AM	Peak	6.6
		8:24 AM	Peak	6.4
		12:15 PM	Off Peak	6.3
		3:48 PM	Off Peak	6.3
4/17/2007	5.9	8:12 AM	Peak	6.3
		10:36 AM	Peak	6.2
		12:15 PM	Off Peak	6.4
		3:48 PM	Off Peak	6.3
4/18/2007	7.0	8:12 AM	Peak	6.5
		12:15 PM	Off Peak	6.3
		1:36 PM	Peak	6.2
		3:48 PM	Off Peak	6.4
4/19/2007	6.1	8:12 AM	Peak	6.0
		8:24 AM	Peak	6.2
		12:15 PM	Off Peak	6.8
		3:45 PM	Off Peak	6.0
4/20/2007	6.7	8:12 AM	Peak	6.5
		12:15 PM	Off Peak	6.4
		1:36 PM	Peak	6.4
		3:48 PM	Off Peak	6.4

Table 4-12. Temperature - Electro Scan

Date	Influent Temperature (°C)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Temperature (°C)
4/9/2007	14	8:12 AM	Peak	14
		8:24 AM	Peak	13
		12:15 PM	Off Peak	16
		3:48 PM	Off Peak	18
4/10/2007	21	8:12 AM	Peak	15
		10:36 AM	Peak	18
		12:15 PM	Off Peak	20
		3:48 PM	Off Peak	23
4/11/2007	21	8:12 AM	Peak	17
		12:15 PM	Off Peak	25
		1:36 PM	Peak	26
		3:48 PM	Off Peak	27
4/12/2007	22	8:12 AM	Peak	18
		8:24 AM	Peak	19
		12:15 PM	Off Peak	23
		3:48 PM	Off Peak	26
4/13/2007	22	8:12 AM	Peak	20
		12:15 PM	Off Peak	23
		1:36 PM	Peak	25
		3:48 PM	Off Peak	26
4/16/2007	20	8:12 AM	Peak	12
		8:24 AM	Peak	16
		12:15 PM	Off Peak	22
		3:48 PM	Off Peak	23
4/17/2007	21	8:12 AM	Peak	15
		10:36 AM	Peak	21
		12:15 PM	Off Peak	21
		3:48 PM	Off Peak	24
4/18/2007	21	8:12 AM	Peak	17
		12:15 PM	Off Peak	18
		1:36 PM	Peak	22
		3:48 PM	Off Peak	25
4/19/2007	21	8:12 AM	Peak	19
		8:24 AM	Peak	25
		12:15 PM	Off Peak	26
		3:45 PM	Off Peak	27
4/20/2007	22	8:12 AM	Peak	19
		12:15 PM	Off Peak	25
		1:36 PM	Peak	26
		3:48 PM	Off Peak	27
Average ± Standard Deviation	**20 ± 2.4**			**21 ± 4.3**

Table 4-13. Conductivity - Electro Scan

Date	Influent Conductivity (mS/cm)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Conductivity (mS/cm)
4/9/2007	0	8:12 AM	Peak	0
		8:24 AM	Peak	20
		12:15 PM	Off Peak	0.08
		3:48 PM	Off Peak	0.06
4/10/2007	0.01	8:12 AM	Peak	0.11
		10:36 AM	Peak	0.17
		12:15 PM	Off Peak	0.55
		3:48 PM	Off Peak	18
4/11/2007	0	8:12 AM	Peak	0.04
		12:15 PM	Off Peak	0.43
		1:36 PM	Peak	0.25
		3:48 PM	Off Peak	15
4/12/2007	0.04	8:12 AM	Peak	18
		8:24 AM	Peak	0.42
		12:15 PM	Off Peak	15
		3:48 PM	Off Peak	17
4/13/2007	0.05	8:12 AM	Peak	32
		12:15 PM	Off Peak	0.38
		1:36 PM	Peak	25
		3:48 PM	Off Peak	17
4/16/2007	0	8:12 AM	Peak	35
		8:24 AM	Peak	37
		12:15 PM	Off Peak	18
		3:48 PM	Off Peak	34
4/17/2007	0.48	8:12 AM	Peak	17
		10:36 AM	Peak	33
		12:15 PM	Off Peak	19
		3:48 PM	Off Peak	18
4/18/2007	0.51	8:12 AM	Peak	27
		12:15 PM	Off Peak	41
		1:36 PM	Peak	39
		3:48 PM	Off Peak	31
4/19/2007	0.51	8:12 AM	Peak	110
		8:24 AM	Peak	75
		12:15 PM	Off Peak	3
		3:45 PM	Off Peak	27
4/20/2007	1.1	8:12 AM	Peak	35
		12:15 PM	Off Peak	31
		1:36 PM	Peak	36
		3:48 PM	Off Peak	36
Average ± Standard Deviation	**0.27 ± 0.37**			**22 ± 22**

Table 4-14. Chlorine Residual - Electro Scan

Date	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Free Chlorine (mg/L)	Effluent Total Chlorine (mg/L)
4/9/2007	8:12 AM	Peak	1.0	2.2
	8:24 AM	Peak	0.80	2.2
	12:15 PM	Off Peak	1.2	1.7
	3:48 PM	Off Peak	0.34	2.2
4/10/2007	8:12 AM	Peak	0.45	0.90
	10:36 AM	Peak	0.66	2.2
	12:15 PM	Off Peak	0.74	2.2
	3:48 PM	Off Peak	0.59	2.2
4/11/2007	8:12 AM	Peak	0.55	2.2
	12:15 PM	Off Peak	0.81	2.2
	1:36 PM	Peak	1.1	2.2
	3:48 PM	Off Peak	0.73	2.2
4/12/2007	8:12 AM	Peak	0.10	2.2
	8:24 AM	Peak	0.54	2.2
	12:15 PM	Off Peak	0.30	2.2
	3:48 PM	Off Peak	0.50	2.2
4/13/2007	8:12 AM	Peak	6.8	6.8
	12:15 PM	Off Peak	0.76	6.9
	1:36 PM	Peak	0.61	8.8
	3:48 PM	Off Peak	0.89	8.8
4/16/2007	8:12 AM	Peak	0.25	2.2
	8:24 AM	Peak	0.86	2.2
	12:15 PM	Off Peak	0.98	2.2
	3:48 PM	Off Peak	0.69	2.2
4/17/2007	8:12 AM	Peak	0.40	2.2
	10:36 AM	Peak	1.2	2.2
	12:15 PM	Off Peak	1.2	2.2
	3:48 PM	Off Peak	1.6	2.2
4/18/2007	8:12 AM	Peak	1.0	2.2
	12:15 PM	Off Peak	1.4	2.2
	1:36 PM	Peak	1.5	2.2
	3:48 PM	Off Peak	1.4	2.2
4/19/2007	8:12 AM	Peak	0.96	2.2
	8:24 AM	Peak	0.90	2.2
	12:15 PM	Off Peak	0.99	2.2
	3:45 PM	Off Peak	1.3	2.2
4/20/2007	8:12 AM	Peak	0.82	2.2
	12:15 PM	Off Peak	1.2	2.2
	1:36 PM	Peak	1.3	2.2
	3:48 PM	Off Peak	1.4	2.2
Average ± Standard Deviation			**1.0 ± 1.0**	**2.7 ± 1.8**

Table 4-15. Fecal Coliform - Thermopure-2

Date	Influent Concentration (MPN/100mL)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (MPN/100mL)
4/9/2007	4,000,000	8:30 AM	Peak	13,000,000
		8:50 AM	Peak	220
		12:15 PM	Off Peak	8,000,000
		3:52 PM	Off Peak	5,000,000
4/10/2007	6,000,000	8:30 AM	Peak	9,000,000
		11:46 AM	Peak	5,000,000
		12:15 PM	Off Peak	5,000,000
		3:52 PM	Off Peak	3,000,000
4/11/2007	5,000,000	8:30 AM	Peak	1,300,000
		12:15 PM	Off Peak	2,700,000
		2:52 PM	Peak	2,400,000
		3:52 PM	Off Peak	3,500,000
4/12/2007	4,700,000	8:30 AM	Peak	1,700,000
		8:50 AM	Peak	140,000
		12:15 PM	Off Peak	500,000
		3:52 PM	Off Peak	6,000,000
4/13/2007	30,000,000	8:30 AM	Peak	30,000,000
		12:15 PM	Off Peak	1,300,000
		2:58 PM	Peak	3,000,000
		3:52 PM	Off Peak	7,000,000
4/16/2007	6,000,000	8:30 AM	Peak	5,000,000
		8:50 AM	Peak	7,000,000
		12:15 PM	Off Peak	11,000,000
		3:52 PM	Off Peak	5,000,000
4/17/2007	22,000,000	8:30 AM	Peak	17,000,000
		11:46 AM	Peak	NC
		12:15 PM	Off Peak	NC
		3:52 PM	Off Peak	13,000,000
4/18/2007	3,000,000	8:30 AM	Peak	5,000,000
		12:15 PM	Off Peak	ND(2,000)
		2:52 PM	Peak	170,000
		3:52 PM	Off Peak	ND(2,000)
4/19/2007	5,000,000	8:30 AM	Peak	13,000
		8:50 AM	Peak	11,000
		12:15 PM	Off Peak	ND(2,000)
		3:52 PM	Off Peak	<3,000
4/20/2007	9,000,000	8:30 AM	Peak	500,000
		12:15 PM	Off Peak	23,000
		2:52 PM	Peak	90,000
		3:52 PM	Off Peak	ND(2000)
Average ± Standard Deviation	**9,500,000 ± 9,100,000**			**<4,500,000 ± 6,100,000**

NC – Sample not collected due to unit operating problems (see Section 3.9).
ND – Not detected (number in parentheses is detection limit).
< - Average result includes at least one non-detect value (calculation uses detection limits for non-detected results).

Table 4-16. Visible Floating Solids - Thermopure-2

Date	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent TSS Concentration (mg/L)	Effluent VFS Concentration (mg/L)	VFS as % TSS (%)
4/9/2007	8:30 AM	Peak	2,400	78	3.2
	8:50 AM	Peak	2,000	0	0
	12:15 PM	Off Peak	400	0	0
	3:52 PM	Off Peak	620	0	0
4/10/2007	8:30 AM	Peak	2,700	100	3.7
	11:46 AM	Peak	880	0	0
	12:15 PM	Off Peak	600	100	17
	3:52 PM	Off Peak	320	0	0
4/11/2007	8:30 AM	Peak	380	0	0
	12:15 PM	Off Peak	260	0	0
	2:52 PM	Peak	260	1.9	0.7
	3:52 PM	Off Peak	310	0.9	0.29
4/12/2007	8:30 AM	Peak	4,900	1,600	33
	8:50 AM	Peak	6,000	240	4.0
	12:15 PM	Off Peak	580	2.8	0.48
	3:52 PM	Off Peak	2,400	36	1.6
4/13/2007	8:30 AM	Peak	2,200	49	2.2
	12:15 PM	Off Peak	370	3.1	0.84
	2:58 PM	Peak	660	5	0.76
	3:52 PM	Off Peak	400	0	0
4/16/2007	8:30 AM	Peak	960	79	8.2
	8:50 AM	Peak	1,200	35	2.9
	12:15 PM	Off Peak	290	0	0
	3:52 PM	Off Peak	400	10	2.5
4/17/2007	8:30 AM	Peak	420	1	0.24
	11:46 AM	Peak	NC	NC	NC
	12:15 PM	Off Peak	NC	NC	NC
	3:52 PM	Off Peak	360	7.5	2.1
4/18/2007	8:30 AM	Peak	260	1	0.38
	12:15 PM	Off Peak	360	3	0.83
	2:52 PM	Peak	800	28	3.5
	3:52 PM	Off Peak	410	12	2.9
4/19/2007	8:30 AM	Peak	970	49	5.0
	8:50 AM	Peak	310	18	5.8
	12:15 PM	Off Peak	360	4.5	1.2
	3:52 PM	Off Peak	310	1	0.36
4/20/2007	8:30 AM	Peak	560	9	1.6
	12:15 PM	Off Peak	530	26	4.9
	2:52 PM	Peak	640	51	8.0
	3:52 PM	Off Peak	310	0	0
Average ± Standard Deviation			**1,000 ± 1,300**	**66 ± 260**	

NC – Sample not collected due to unit operating problems (see Section 3.9).

Table 4-17. *Escherichia coli* - Thermopure-2

Date	Influent Concentration (MPN/100mL)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (MPN/100mL)
4/9/2007	6,400,000	8:30 AM	Peak	4,900,000
		8:50 AM	Peak	1,000
		12:15 PM	Off Peak	1,500,000
		3:52 PM	Off Peak	2,300,000
4/10/2007	7,700,000	8:30 AM	Peak	3,200,000
		11:46 AM	Peak	8,600,000
		12:15 PM	Off Peak	3,600,000
		3:52 PM	Off Peak	3,300,000
4/11/2007	6,800,000	8:30 AM	Peak	9,700,000
		12:15 PM	Off Peak	3,900,000
		2:52 PM	Peak	2,600,000
		3:52 PM	Off Peak	1,500,000
4/12/2007	20,000,000	8:30 AM	Peak	4,300,000
		8:50 AM	Peak	4,400,000
		12:15 PM	Off Peak	1,800,000
		3:52 PM	Off Peak	ND(20,000)
4/13/2007	8,000,000	8:30 AM	Peak	7,400,000
		12:15 PM	Off Peak	2,000,000
		2:58 PM	Peak	3,900,000
		3:52 PM	Off Peak	2,500,000
4/16/2007	6,100,000	8:30 AM	Peak	7,600,000
		8:50 AM	Peak	13,000,000
		12:15 PM	Off Peak	2,400,000
		3:52 PM	Off Peak	1,200,000
4/17/2007	19,000,000	8:30 AM	Peak	21,000,000
		11:46 AM	Peak	NC
		12:15 PM	Off Peak	NC
		3:52 PM	Off Peak	18,000,000
4/18/2007	6,300,000	8:30 AM	Peak	2,800,000
		12:15 PM	Off Peak	<20,000
		2:52 PM	Peak	260,000
		3:52 PM	Off Peak	15,000,000
4/19/2007	3,700,000	8:30 AM	Peak	20,000
		8:50 AM	Peak	20,000
		12:15 PM	Off Peak	ND(20,000)
		3:52 PM	Off Peak	<30,000
4/20/2007	7,400,000	8:30 AM	Peak	630,000
		12:15 PM	Off Peak	20,000
		2:52 PM	Peak	82,000
		3:52 PM	Off Peak	20,000
Average ± Standard Deviation	**9,100,000 ± 5,600,000**			**<4,000,000 ± 5,200,000**

NC – Sample not collected due to unit operating problems (see Section 3.9).
ND – Not detected (number in parentheses is detection limit).
< - Average result includes at least one non-detect value (calculation uses detection limits for non-detected results).

Table 4-18. Enterococci - Thermopure-2

Date	Influent Concentration (MPN/100mL)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (MPN/100mL)
4/9/2007	1,300,000	8:30 AM	Peak	ND(1,000,000)
		8:50 AM	Peak	32,000
		12:15 PM	Off Peak	440,000
		3:52 PM	Off Peak	730,000
4/10/2007	3,300,000	8:30 AM	Peak	2,000,000
		11:46 AM	Peak	800,000
		12:15 PM	Off Peak	530,000
		3:52 PM	Off Peak	450,000
4/11/2007	350,000	8:30 AM	Peak	480,000
		12:15 PM	Off Peak	160,000
		2:52 PM	Peak	31,000
		3:52 PM	Off Peak	68,000
4/12/2007	9,200,000	8:30 AM	Peak	990,000
		8:50 AM	Peak	180,000
		12:15 PM	Off Peak	10,000
		3:52 PM	Off Peak	110,000
4/13/2007	570,000	8:30 AM	Peak	440,000
		12:15 PM	Off Peak	190,000
		2:58 PM	Peak	440,000
		3:52 PM	Off Peak	310,000
4/16/2007	960,000	8:30 AM	Peak	370,000
		8:50 AM	Peak	750,000
		12:15 PM	Off Peak	200,000
		3:52 PM	Off Peak	43,000
4/17/2007	370,000	8:30 AM	Peak	870,000
		11:46 AM	Peak	NC
		12:15 PM	Off Peak	NC
		3:52 PM	Off Peak	200,000
4/18/2007	840,000	8:30 AM	Peak	110,000
		12:15 PM	Off Peak	<1,000
		2:52 PM	Peak	4,100
		3:52 PM	Off Peak	1,000
4/19/2007	1,900,000	8:30 AM	Peak	39,000
		8:50 AM	Peak	3,100
		12:15 PM	Off Peak	ND(1,000)
		3:52 PM	Off Peak	<1,000
4/20/2007	720,000	8:30 AM	Peak	170,000
		12:15 PM	Off Peak	2,000
		2:52 PM	Peak	2,000
		3:52 PM	Off Peak	ND(1,000)
Average ± Standard Deviation	**2,000,000 ± 2,700,000**			**<320,000 ± 410,000**

NC – Sample not collected due to unit operating problems (see Section 3.9).
ND – Not detected (number in parentheses is detection limit).
< - Average result includes at least one non-detect value (calculation uses detection limits for non-detected results).

Table 4-19. Biochemical Oxygen Demand (5 day) - Thermopure-2

Date	Influent Concentration (mg/L)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (mg/L)
4/9/2007	1,900	8:30 AM	Peak	1,200
		8:50 AM	Peak	1,100
		12:15 PM	Off Peak	460
		3:52 PM	Off Peak	470
4/10/2007	NA	8:30 AM	Peak	1,200
		11:46 AM	Peak	540
		12:15 PM	Off Peak	570
		3:52 PM	Off Peak	370
4/11/2007	530	8:30 AM	Peak	280
		12:15 PM	Off Peak	270
		2:52 PM	Peak	200
		3:52 PM	Off Peak	250
4/12/2007	810	8:30 AM	Peak	3,700
		8:50 AM	Peak	3,700
		12:15 PM	Off Peak	910
		3:52 PM	Off Peak	2,600
4/13/2007	500	8:30 AM	Peak	1,700
		12:15 PM	Off Peak	1,200
		2:58 PM	Peak	1,300
		3:52 PM	Off Peak	1,900
4/16/2007	990	8:30 AM	Peak	660
		8:50 AM	Peak	1,100
		12:15 PM	Off Peak	460
		3:52 PM	Off Peak	610
4/17/2007	820	8:30 AM	Peak	460
		11:46 AM	Peak	NC
		12:15 PM	Off Peak	NC
		3:52 PM	Off Peak	630
4/18/2007	450	8:30 AM	Peak	260
		12:15 PM	Off Peak	400
		2:52 PM	Peak	1,300
		3:52 PM	Off Peak	600
4/19/2007	400	8:30 AM	Peak	380
		8:50 AM	Peak	410
		12:15 PM	Off Peak	640
		3:52 PM	Off Peak	350
4/20/2007	2,100	8:30 AM	Peak	470
		12:15 PM	Off Peak	440
		2:52 PM	Peak	1,600
		3:52 PM	Off Peak	480
Average ± Standard Deviation	**950 ± 630**			**920 ± 850**

NA – Sample not analyzed due to laboratory error (see Section 6.1).
NC – Sample not collected due to unit operating problems (see Section 3.9).

Table 4-20. Total Suspended Solids - Thermopure-2

Date	Influent Concentration (mg/L)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (mg/L)
4/9/2007	4,000	8:30 AM	Peak	2,400
		8:50 AM	Peak	2,000
		12:15 PM	Off Peak	400
		3:52 PM	Off Peak	620
4/10/2007	12,000	8:30 AM	Peak	2,700
		11:46 AM	Peak	880
		12:15 PM	Off Peak	600
		3:52 PM	Off Peak	320
4/11/2007	1,100	8:30 AM	Peak	380
		12:15 PM	Off Peak	260
		2:52 PM	Peak	260
		3:52 PM	Off Peak	310
4/12/2007	720	8:30 AM	Peak	4,900
		8:50 AM	Peak	6,000
		12:15 PM	Off Peak	580
		3:52 PM	Off Peak	2,400
4/13/2007	420	8:30 AM	Peak	2,200
		12:15 PM	Off Peak	370
		2:58 PM	Peak	660
		3:52 PM	Off Peak	400
4/16/2007	1,100	8:30 AM	Peak	960
		8:50 AM	Peak	1,200
		12:15 PM	Off Peak	290
		3:52 PM	Off Peak	400
4/17/2007	740	8:30 AM	Peak	420
		11:46 AM	Peak	NC
		12:15 PM	Off Peak	NC
		3:52 PM	Off Peak	360
4/18/2007	500	8:30 AM	Peak	260
		12:15 PM	Off Peak	360
		2:52 PM	Peak	800
		3:52 PM	Off Peak	410
4/19/2007	450	8:30 AM	Peak	970
		8:50 AM	Peak	310
		12:15 PM	Off Peak	360
		3:52 PM	Off Peak	310
4/20/2007	3,300	8:30 AM	Peak	560
		12:15 PM	Off Peak	530
		2:52 PM	Peak	640
		3:52 PM	Off Peak	310
Average ± Standard Deviation	**2,500 ± 3,600**			**1,000 ± 1,300**

NC – Sample not collected due to unit operating problems (see Section 3.9).

Table 4-21. Ammonia as Nitrogen - Thermopure-2

Date	Influent Concentration (mg/L)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (mg/L)
4/9/2007	13	8:30 AM	Peak	11
		8:50 AM	Peak	13
		12:15 PM	Off Peak	17
		3:52 PM	Off Peak	21
4/10/2007	12	8:30 AM	Peak	12
		11:46 AM	Peak	12
		12:15 PM	Off Peak	12
		3:52 PM	Off Peak	16
4/11/2007	14	8:30 AM	Peak	12
		12:15 PM	Off Peak	15
		2:52 PM	Peak	15
		3:52 PM	Off Peak	14
4/12/2007	15	8:30 AM	Peak	15
		8:50 AM	Peak	15
		12:15 PM	Off Peak	17
		3:52 PM	Off Peak	20
4/13/2007	15	8:30 AM	Peak	18
		12:15 PM	Off Peak	16
		2:58 PM	Peak	17
		3:52 PM	Off Peak	18
4/16/2007	13	8:30 AM	Peak	9
		8:50 AM	Peak	12
		12:15 PM	Off Peak	14
		3:52 PM	Off Peak	15
4/17/2007	14	8:30 AM	Peak	14
		11:46 AM	Peak	NC
		12:15 PM	Off Peak	NC
		3:52 PM	Off Peak	16
4/18/2007	18	8:30 AM	Peak	3
		12:15 PM	Off Peak	21
		2:52 PM	Peak	21
		3:52 PM	Off Peak	22
4/19/2007	19	8:30 AM	Peak	16
		8:50 AM	Peak	18
		12:15 PM	Off Peak	23
		3:52 PM	Off Peak	22
4/20/2007	21	8:30 AM	Peak	15
		12:15 PM	Off Peak	23
		2:52 PM	Peak	25
		3:52 PM	Off Peak	23
Average ± Standard Deviation	**15 ± 3.0**			**16 ± 4.5**

NC – Sample not collected due to unit operating problems (see Section 3.9).

Table 4-22. Total Kjeldahl Nitrogen - Thermopure-2

Date	Influent Concentration (mg/L)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (mg/L)
4/9/2007	170	8:30 AM	Peak	89
		8:50 AM	Peak	130
		12:15 PM	Off Peak	62
		3:52 PM	Off Peak	69
4/10/2007	290	8:30 AM	Peak	110
		11:46 AM	Peak	48
		12:15 PM	Off Peak	55
		3:52 PM	Off Peak	37
4/11/2007	62	8:30 AM	Peak	42
		12:15 PM	Off Peak	39
		2:52 PM	Peak	37
		3:52 PM	Off Peak	34
4/12/2007	230	8:30 AM	Peak	100
		8:50 AM	Peak	92
		12:15 PM	Off Peak	73
		3:52 PM	Off Peak	110
4/13/2007	41	8:30 AM	Peak	59
		12:15 PM	Off Peak	49
		2:58 PM	Peak	50
		3:52 PM	Off Peak	50
4/16/2007	73	8:30 AM	Peak	35
		8:50 AM	Peak	45
		12:15 PM	Off Peak	49
		3:52 PM	Off Peak	51
4/17/2007	37	8:30 AM	Peak	51
		11:46 AM	Peak	NC
		12:15 PM	Off Peak	NC
		3:52 PM	Off Peak	48
4/18/2007	75	8:30 AM	Peak	21
		12:15 PM	Off Peak	62
		2:52 PM	Peak	76
		3:52 PM	Off Peak	58
4/19/2007	46	8:30 AM	Peak	44
		8:50 AM	Peak	42
		12:15 PM	Off Peak	48
		3:52 PM	Off Peak	60
4/20/2007	74	8:30 AM	Peak	48
		12:15 PM	Off Peak	68
		2:52 PM	Peak	58
		3:52 PM	Off Peak	54
Average ± Standard Deviation	**110 ± 89**			**59 ± 24**

NC – Sample not collected due to unit operating problems (see Section 3.9).

Table 4-23. Nitrate/Nitrite as Nitrogen - Thermopure-2

Date	Influent Concentration (mg/L)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (mg/L)
4/9/2007	0.11	8:30 AM	Peak	0.28
		8:50 AM	Peak	0.36
		12:15 PM	Off Peak	0.22
		3:52 PM	Off Peak	0.24
4/10/2007	0.3	8:30 AM	Peak	ND(0.05)
		11:46 AM	Peak	ND(0.05)
		12:15 PM	Off Peak	ND(0.05)
		3:52 PM	Off Peak	ND(0.05)
4/11/2007	ND(0.05)	8:30 AM	Peak	0.08
		12:15 PM	Off Peak	0.15
		2:52 PM	Peak	0.17
		3:52 PM	Off Peak	0.14
4/12/2007	0.08	8:30 AM	Peak	0.23
		8:50 AM	Peak	0.19
		12:15 PM	Off Peak	0.20
		3:52 PM	Off Peak	0.24
4/13/2007	ND(0.05)	8:30 AM	Peak	0.13
		12:15 PM	Off Peak	0.12
		2:58 PM	Peak	0.13
		3:52 PM	Off Peak	0.12
4/16/2007	ND(0.05)	8:30 AM	Peak	ND(0.05)
		8:50 AM	Peak	ND(0.05)
		12:15 PM	Off Peak	ND(0.05)
		3:52 PM	Off Peak	ND(0.05)
4/17/2007	ND(0.05)	8:30 AM	Peak	ND(0.05)
		11:46 AM	Peak	NC
		12:15 PM	Off Peak	NC
		3:52 PM	Off Peak	ND(0.05)
4/18/2007	ND(0.05)	8:30 AM	Peak	0.44
		12:15 PM	Off Peak	0.22
		2:52 PM	Peak	0.13
		3:52 PM	Off Peak	0.08
4/19/2007	0.07	8:30 AM	Peak	0.25
		8:50 AM	Peak	0.23
		12:15 PM	Off Peak	0.27
		3:52 PM	Off Peak	0.14
4/20/2007	ND(0.05)	8:30 AM	Peak	0.11
		12:15 PM	Off Peak	0.21
		2:52 PM	Peak	0.39
		3:52 PM	Off Peak	0.34
Average ± Standard Deviation	**<0.09 ± 0.078**			**<0.17 ± 0.11**

NC – Sample not collected due to unit operating problems (see Section 3.9).
ND – Not detected (number in parentheses is detection limit).
< - Average result includes at least one non-detect value (calculation uses detection limits for non-detected results).

Table 4-24. Total Phosphorus - Thermopure-2

Date	Influent Concentration (mg/L)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (mg/L)
4/9/2007	59	8:30 AM	Peak	33
		8:50 AM	Peak	47
		12:15 PM	Off Peak	18
		3:52 PM	Off Peak	21
4/10/2007	79	8:30 AM	Peak	36
		11:46 AM	Peak	13
		12:15 PM	Off Peak	12
		3:52 PM	Off Peak	11
4/11/2007	15	8:30 AM	Peak	11
		12:15 PM	Off Peak	9.8
		2:52 PM	Peak	10
		3:52 PM	Off Peak	9.4
4/12/2007	72	8:30 AM	Peak	26
		8:50 AM	Peak	48
		12:15 PM	Off Peak	17
		3:52 PM	Off Peak	32
4/13/2007	9.6	8:30 AM	Peak	13
		12:15 PM	Off Peak	8.4
		2:58 PM	Peak	9.8
		3:52 PM	Off Peak	9.5
4/16/2007	11	8:30 AM	Peak	7.1
		8:50 AM	Peak	9.2
		12:15 PM	Off Peak	7.3
		3:52 PM	Off Peak	7.2
4/17/2007	9	8:30 AM	Peak	9.5
		11:46 AM	Peak	NC
		12:15 PM	Off Peak	NC
		3:52 PM	Off Peak	8.5
4/18/2007	19	8:30 AM	Peak	5.2
		12:15 PM	Off Peak	12
		2:52 PM	Peak	19
		3:52 PM	Off Peak	12
4/19/2007	14	8:30 AM	Peak	9.9
		8:50 AM	Peak	11
		12:15 PM	Off Peak	9.1
		3:52 PM	Off Peak	9.4
4/20/2007	13	8:30 AM	Peak	9.4
		12:15 PM	Off Peak	13
		2:52 PM	Peak	19
		3:52 PM	Off Peak	14
Average ± Standard Deviation	**30 ± 28**			**15 ± 11**

NC – Sample not collected due to unit operating problems (see Section 3.9).

Table 4-25. pH - Thermopure-2

Date	Influent pH	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent pH
4/9/2007	6.2	8:30 AM	Peak	6.3
		8:50 AM	Peak	6.4
		12:15 PM	Off Peak	6.7
		3:52 PM	Off Peak	7.1
4/10/2007	6.1	8:30 AM	Peak	6.4
		11:46 AM	Peak	6.4
		12:15 PM	Off Peak	6.6
		3:52 PM	Off Peak	7.1
4/11/2007	6.4	8:30 AM	Peak	6.4
		12:15 PM	Off Peak	6.4
		2:52 PM	Peak	6.3
		3:52 PM	Off Peak	6.6
4/12/2007	5.8	8:30 AM	Peak	6.5
		8:50 AM	Peak	6.4
		12:15 PM	Off Peak	6.5
		3:52 PM	Off Peak	6.4
4/13/2007	6.2	8:30 AM	Peak	6.7
		12:15 PM	Off Peak	6.5
		2:58 PM	Peak	6.6
		3:52 PM	Off Peak	7.0
4/16/2007	7.0	8:30 AM	Peak	5.4
		8:50 AM	Peak	7.1
		12:15 PM	Off Peak	7.1
		3:52 PM	Off Peak	7.4
4/17/2007	5.9	8:30 AM	Peak	6.9
		11:46 AM	Peak	NC
		12:15 PM	Off Peak	NC
		3:52 PM	Off Peak	6.7
4/18/2007	7.0	8:30 AM	Peak	7.0
		12:15 PM	Off Peak	7.2
		2:52 PM	Peak	6.9
		3:52 PM	Off Peak	6.9
4/19/2007	6.1	8:30 AM	Peak	7.0
		8:50 AM	Peak	6.7
		12:15 PM	Off Peak	6.5
		3:52 PM	Off Peak	7.0
4/20/2007	6.7	8:30 AM	Peak	6.9
		12:15 PM	Off Peak	7.2
		2:52 PM	Peak	7.0
		3:52 PM	Off Peak	7.3

NC – Sample not collected due to unit operating problems (see Section 3.9).

Table 4-26. Temperature – Thermopure-2

Date	Influent Temperature (°C)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Temperature (°C)
4/9/2007	14	8:30 AM	Peak	39
		8:50 AM	Peak	46
		12:15 PM	Off Peak	39
		3:52 PM	Off Peak	38
4/10/2007	21	8:30 AM	Peak	42
		11:46 AM	Peak	40
		12:15 PM	Off Peak	39
		3:52 PM	Off Peak	40
4/11/2007	21	8:30 AM	Peak	42
		12:15 PM	Off Peak	43
		2:52 PM	Peak	43
		3:52 PM	Off Peak	43
4/12/2007	22	8:30 AM	Peak	45
		8:50 AM	Peak	47
		12:15 PM	Off Peak	43
		3:52 PM	Off Peak	43
4/13/2007	22	8:30 AM	Peak	43
		12:15 PM	Off Peak	39
		2:58 PM	Peak	41
		3:52 PM	Off Peak	41
4/16/2007	20	8:30 AM	Peak	38
		8:50 AM	Peak	41
		12:15 PM	Off Peak	43
		3:52 PM	Off Peak	41
4/17/2007	21	8:30 AM	Peak	37
		11:46 AM	Peak	NC
		12:15 PM	Off Peak	NC
		3:52 PM	Off Peak	40
4/18/2007	21	8:30 AM	Peak	43
		12:15 PM	Off Peak	49
		2:52 PM	Peak	47
		3:52 PM	Off Peak	45
4/19/2007	21	8:30 AM	Peak	49
		8:50 AM	Peak	42
		12:15 PM	Off Peak	48
		3:52 PM	Off Peak	49
4/20/2007	22	8:30 AM	Peak	46
		12:15 PM	Off Peak	49
		2:52 PM	Peak	49
		3:52 PM	Off Peak	45
Average ± Standard Deviation	**20 ± 2.4**			**43 ± 3.5**

NC – Sample not collected due to unit operating problems (see Section 3.9).

Table 4-27. Summary of Type I MSD Performance

Analysis	Average Influent Concentration ± Standard Deviation	Average Effluent Concentration ± Standard Deviation		Unit
		Electro Scan	Thermopure-2	
Fecal Coliform	9,500,000 ± 9,100,000	<82 ± 350	<4,500,000 ± 6,100,000	MPN/100 mL
Visible Floating Solids	--	190 ± 860	66 ± 260	mg/L
Escherichia coli	9,100,000 ± 5,600,000	<1,400 ± 5,500	<4,000,000 ± 5,200,000	MPN/100 mL
Enterococci	2,000,000 ± 2,700,000	<790 ± 3,900	<320,000 ± 410,000	MPN/100 mL
Biochemical Oxygen Demand (5 day)	950 ± 630	780 ± 600	920 ± 850	mg/L
Total Suspended Solids	2,500 ± 3,600	1,000 ± 860	1,000 ± 1,300	mg/L
Ammonia as Nitrogen	15 ± 3.0	8.2 ± 4.7	16 ± 4.5	mg/L
Total Kjeldahl Nitrogen	110 ± 89	42 ± 23	59 ± 24	mg/L
Nitrate/Nitrite as Nitrogen	<0.09 ± 0.078	<2.1 ± 1.9	<0.17 ± 0.11	mg/L
Total Phosphorus	30 ± 28	15 ± 8.4	15 ± 11	mg/L
pH	5.8 to 7.0	5.8 to 6.8	5.4 to 7.4	--
Temperature	20 ± 2.4	21 ± 4.3	43 ± 3.5	°C
Conductivity	0.27 ± 0.37	22 ± 22	--	mS/cm
Chlorine Residual (Free)	--	1.0 ± 1.0	--	mg/L
Chlorine Residual (Total)	--	2.7 ± 1.8	--	mg/L

< - Average result includes at least one non-detect value (calculation uses detection limits for non-detected results).

5.0 THERMOPURE-2 RETEST

The Thermopure-2 unit is believed to have not reached the designated threshold temperature sufficient to kill bacteria due to the misalignment of a thermal sensor. Per a request by Gross Mechanical Laboratories, Inc., a retest of a replacement Thermopure-2 device was conducted. The scope of the retesting was reduced from that of the original test due to a limitation in funding. Accordingly, challenge wastewater sampling and analysis was reduced to a single sample of the challenge wastewater batch prepared each day to verify the target TSS concentration of 500 mg/L. Effluent sampling remained at four samples per day; however, sample analyses were reduced to fecal coliform, visible floating solids, BOD_5, and TSS. The duration of the performance testing was also reduced from 10 to nine days. Retesting dates were October 15 and 16, 2007, November 29 and 30, 2007, and December 3 through 7, 2007.

5.1 Performance Evaluation Retesting Procedures

Installation and Start-up

A replacement device, shipped by the manufacturer, was received at the test site on October 12 and was installed on the testing platform in the same manner as the April testing. The same means of tilting the device during testing was used. A trial run of the system was completed on October 13, using fresh water following the start-up procedures provided by the manufacturer. The device was found to be ready for testing.

Retesting with challenge wastewater began on October 15, using the same dosing schedule as the April testing. While sample effluent temperatures were higher than those measured during the April testing, they were not as high as the manufacturer indicated they should be. Test-site personnel conferred with the manufacturer, who expressed confidence in proper operation of the device. However, preliminary fecal coliform results from the first day of retesting on October 16 indicated that the unit was not performing as expected. After consulting with the manufacturer, retesting was halted on the morning of October 17.

On October 18, test facility personnel assisted the manufacturer in troubleshooting the device. Specifically, they accessed the processor chip that controls unit operation and took voltage readings as the device processed 10 cycles of clean water over three hours. The manufacturer confirmed that the voltage readings indicated that the chip was functioning as

designed. Based on this information, the manufacturer began evaluating whether the programming of the chip was causing the temperature to not reach manufacturer indicated levels.

The test facility received a new processor chip on November 27, installed it, and verified proper operation by testing with fresh water. Retesting with challenge wastewater commenced on November 29, and continued through December 7, using the same dosing schedule as the April testing.

Effluent sample temperatures were still not as high as expected. Following discussions with the manufacturer, test-site personnel investigated whether the temperature discrepancy resulted from temperature measurements taken at the sampling location rather than at the heating block during the treatment cycle. On November 29, test-site personnel installed a thermometer close to the outlet of the heating block to develop a temperature profile over several four- to five-minute treatment cycles. Over the first 60 to 90 seconds, the temperature rose to a high point of 85°C to 91°C. The heating element then turned off, and the temperature steadily declined over the next 120 to 180 seconds until it reached 75°C to 80°C at the start of pump-out. Effluent temperature at the end of pump-out was approximately 58°C. Based on these results, the manufacturer expressed confidence in proper operation of the device.

Sewage Processing Test

The sewage processing test was performed in the same manner as the April test. As shown in Table 5-1, the influent TSS concentrations during testing ranged from 230 mg/L to 3,100 mg/L. There were three days during the testing when the influent TSS concentration was less than 500 mg/L; however, the average TSS concentration over the course of the test was 1,280 mg/L with a standard deviation of ±3,600 mg/L (1,300 mg/L ± 1,100 mg/L excluding the October testing).

Table 5-1. Influent TSS Results – Theromopure-2 Retest

Date	Influent TSS (mg/L)
October Retesting	
10/15/2007	600
10/16/2007	1,700
November/December Retesting	
11/29/2007	1,000
11/30/2007	330
12/3/2007	230
12/4/2007	460
12/5/2007	1,700
12/6/2007	3,100
12/7/2007	2,400

MSD Operation and Maintenance

The device required no maintenance during the testing.

Sample Collection

Sample collection was performed identically with the April testing, with one exception. Because of the reduced number of analyses, the volume needed for each sample was reduced, allowing for collection of samples directly into sample bottles. This differs from the April testing where samples were collected into carboys, mixed, and poured off into appropriate sample bottles.

Process Monitoring

Process monitoring was the same as during the April testing.

Field QC Measures

Field QC samples for the Thermopure-2 retesting included duplicate samples. Equipment blanks were not required as the intermediate sample collection carboys were not used.

Deviation from the Work Plan

Performance retesting proceeded as specified in the work plan with the following deviations:

- The scope of the retesting was reduced from that of the original test due to a limitation in funding. Accordingly, challenge wastewater evaluation was reduced to a single sample of the challenge wastewater batch prepared each day to verify the minimum target TSS concentration of 500 mg/L. Effluent sampling remained at four samples per day; however, sample analyses were reduced to fecal coliform, visible floating solids, BOD_5, and TSS. The duration of the performance testing was also reduced from 10 days to nine days.

- The device overflowed during the morning of November 29, which resulted in six missed doses and only 26 gallons of wastewater processed for that day. No samples were missed. The holding tank filled and overflowed because of the longer heating cycles resulting from the reprogrammed processor chip, coupled with the warm-up time required for start-up each morning.

- The reprogramming of the chip affected the peak flow rate capacity of the Thermopure-2 device. After the overflow on November 29, the influent was allowed to back up into the dosing line, and the unit processed the wastewater during off-peak dosing periods. The full dosing volume of 32 gallons was processed in the days following November 29.

5.2 Retest Results and Discussion

5.2.1 Fecal Coliform

Table 5-2 presents the fecal coliform data for the Thermopure-2 retesting. The effluent produced by the Thermopure-2 device during the November/December retesting ranged from nondetect to 3,000,000 fecal coliform bacteria MPN/100 mL with a mean concentration of 380,000 MPN/100 mL (see Table 5-2).[7] While these results show some improvement compared to the April testing (range from nondetect to 30,000,000 fecal coliform bacteria MPN/100 mL with a mean concentration of 4,500,000 MPN/100 mL), device performance remained poor. Although the cause of the poor performance is unknown, the device pump-out volume may have

[7] Performance testing was not conducted in accordance with the test conditions described in 33 CFR 159.53 (Appendix A). For reasons of practicality, testing was conducted using a feed of fresh domestic human sewage rather than human sewage in a ratio of four urinations to one defecation, as specified in 33 CFR 159.121(c).

exceeded the capacity of the heating chamber, which would have mixed unheated (untreated) wastewater with treated wastewater during discharge (see discussion in Section 7.2).

5.2.2 Visible Floating Solids

Table 5-3 presents the VFS data for the Thermopure-2 retesting. VFS concentrations in the effluent from the Thermopure-2 device during the November/December retesting ranged from zero to 1,000 mg/L with a mean concentration of 100 mg/L. Of the 28 collected samples, 26 had VFS less than 10% of the effluent TSS.[8] The November/December VFS results are similar to those from the April testing.

5.2.3 Biochemical Oxygen Demand and Total Suspended Solids

Tables 5-4 and 5-5 present BOD_5 and TSS data, respectively, for the Thermopure-2 retesting. Both analytes were detected in all 28 samples. There are currently no BOD_5 or TSS federal performance standards for Type I MSDs.

The following table, for the purpose of comparison, shows the effluent quality from the Thermopure-2 device (which is not required to remove BOD_5 or TSS) and EPA's standards for secondary treatment for land-based publicly owned treatment works (POTWs). Note that the technology and capacity of Type I MSDs and POTWs are very different and must be considered in any comparison.

BOD_5 Comparison of Effluent from Type I MSDs to Secondary Treatment Standards

Analyte	Average Effluent Concentration From Thermopure-2		EPA Secondary Treatment Standards [a]
	November/December Retesting	April Testing	
BOD_5 (mg/L)	710	920	45
TSS (mg/L)	1,100	1,000	45

[a] 40 CFR 133.102 Secondary Treatment Regulations, 7-day average.

5.2.4 Process Monitoring

Review of the pH results for the Thermopure-2 retesting in Table 5-6 showed there were no uncharacteristic pH excursions in the challenge wastewater or the treated effluent.

[8] Performance testing was not conducted in accordance with the test conditions described in 33 CFR 159.53 (Appendix A). For reasons of practicality, testing was conducted using a feed of fresh domestic human sewage rather than human sewage in a ratio of four urinations to one defecation, as specified in 33 CFR 159.121(c).

As expected, the reprogrammed processor chip produced significantly greater effluent sample temperatures during the November/December retesting as compared to the original chip for the April testing: an average of 62°C (see Table 5-7) as compared to an average of 43°C. This increase in temperature is likely responsible for the somewhat improved device performance in removing fecal coliform (see Section 5.2.1).

Table 5-2. Fecal Coliform - Thermopure-2 Retest

Date	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (MPN/100mL)
October Retesting			
10/15/2007	8:40 AM	Peak	700,000
	9:05 AM	Peak	240,000
	12:20 PM	Off Peak	1,300,000
	4:00 PM	Off Peak	110,000
10/16/2007	8:35 AM	Peak	9,000,000
	11:50 AM	Peak	24,000,000
	12:20 PM	Off Peak	3,000,000
	3:56 PM	Off Peak	280,000,000
November/December Retesting			
11/29/2007	8:30 AM	Peak	2,200,000
	8:50 PM	Peak	3,000,000
	12:15 PM	Off Peak	300
	3:55 PM	Off Peak	2,200
11/30/2007	8:30 AM	Peak	1,700,000
	12:15 AM	Off Peak	3,000,000
	2:52 PM	Peak	50
	3:52 PM	Off Peak	1,700
12/3/2007	8:30 AM	Peak	5,000
	8:55 AM	Peak	4,000
	12:15 PM	Off Peak	1,600
	3:52 PM	Off Peak	ND(2.0)
12/4/2007	8:30 AM	Peak	14,000
	11:46 AM	Peak	28,000
	12:15 PM	Off Peak	3,000
	1:52 PM	Off Peak	3,000
12/5/2007	8:30 AM	Peak	5,000
	12:15 PM	Off Peak	1,300
	2:52 PM	Peak	2.0
	3:52 PM	Off Peak	2.0
12/6/2007	8:30 AM	Peak	300,000
	8:50 AM	Peak	500
	12:15 PM	Off Peak	900
	3:52 PM	Off Peak	22,000
12/7/2007	8:30 AM	Peak	130,000
	12:15 PM	Off Peak	170,000
	2:52 PM	Peak	800
	3:52 PM	Off Peak	350
Average ± Standard Deviation			**<9,100,000 ± 47,000,000 (<380,000 ± 900,000 [a])**

[a] Average of November/December samples.
ND – Not detected (number in parentheses is detection limit).
< - Average result includes at least one non-detect value (calculation uses detection limits for non-detected results).

Table 5-3. Visible Floating Solids - Thermopure-2 Retest

Date	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent TSS Concentration (mg/L)	Effluent VFS Concentration (mg/L)	VFS as % TSS
October Retesting					
10/15/2007	8:40 AM	Peak	330	NA	NA
	9:05 AM	Peak	320	NA	NA
	12:2 PM	Off Peak	820	NA	NA
	4:00 PM	Off Peak	790	NA	NA
10/16/2007	8:35 AM	Peak	870	NA	NA
	11:50 AM	Peak	1,500	NA	NA
	12:20 PM	Off Peak	1,100	NA	NA
	3:56 PM	Off Peak	1,400	NA	NA
November/December Retesting					
11/29/2007	8:30 AM	Peak	700	0	0
	8:50 AM	Peak	660	10	1.5
	12:15 PM	Off Peak	680	5	0.74
	3:55 PM	Off Peak	840	4	0.48
11/30/2007	8:30 AM	Peak	430	1	0.23
	12:15 PM	Off Peak	230	7	3.0
	2:52 PM	Peak	140	2	0.71
	3:52 PM	Off Peak	100	1	2.0
12/3/2007	8:30 AM	Peak	480	38	7.9
	8:50 AM	Peak	320	8	2.5
	12:15 PM	Off Peak	190	0	0
	3:52 PM	Off Peak	130	1	0.77
12/4/2007	8:30 AM	Peak	290	1	0.34
	11:46 AM	Peak	280	0	0
	12:15 PM	Off Peak	180	0	0
	1:52 PM	Off Peak	150	0	0
12/5/2007	8:30 AM	Peak	3,100	20	0.65
	12:15 PM	Off Peak	2,000	160	8.0
	2:52 PM	Peak	1,700	120	7.1
	3:52 PM	Off Peak	1,200	80	6.7
12/6/2007	8:30 AM	Peak	2,500	220	8.8
	8:50 AM	Peak	2,500	41	1.6
	12:15 PM	Off Peak	1,300	1,000	77
	3:52 PM	Off Peak	1,100	38	3.5
12/7/2007	8:30 AM	Peak	3,700	330	8.9
	12:15 PM	Off Peak	2,600	670	26
	14:52 PM	Peak	1,300	67	5.1
	3:52 PM	Off Peak	1,500	20	1.3
Average ± Standard Deviation			**1,000 ± 920 (1,100 ± 1,000 [a])**	**100 ± 230 [a]**	

[a] Average of November/December samples.
NA – Samples not analyzed due to termination of October retesting.

Table 5-4. Biochemical Oxygen Demand (5 day) - Thermopure-2 Retest

Date	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (mg/L)
October Retesting			
10/15/2007	8:40 AM	Peak	160
	9:05 AM	Peak	250
	12:20 PM	Off Peak	970
	4:00 PM	Off Peak	470
10/16/2007	8:30 AM	Peak	1,100
	11:50 AM	Peak	1,400
	12:20 PM	Off Peak	1,500
	3:56 PM	Off Peak	1,600
November/December Retesting			
11/29/2007	8:30 AM	Peak	320
	8:50 AM	Peak	320
	12:15 PM	Off Peak	420
	3:55 PM	Off Peak	480
11/30/2007	8:30 AM	Peak	370
	12:15 PM	Off Peak	230
	2:52 PM	Peak	350
	3:52 PM	Off Peak	220
12/3/2007	8:30 AM	Peak	440
	8:50 AM	Peak	300
	12:15 PM	Off Peak	270
	3:52 PM	Off Peak	230
12/4/2007	8:30 AM	Peak	250
	11:46 AM	Peak	200
	12:15 PM	Off Peak	190
	3:52 PM	Off Peak	240
12/5/2007	8:30 AM	Peak	1,200
	12:15 PM	Off Peak	1,500
	2:52 PM	Peak	1,300
	3:52 PM	Off Peak	980
12/6/2007	8:30 AM	Peak	920
	8:50 AM	Peak	1,400
	12:15 PM	Off Peak	940
	3:52 PM	Off Peak	970
12/7/2007	8:30 AM	Peak	>1,900
	12:15 PM	Off Peak	1,800
	2:52 PM	Peak	1,100
	3:52 PM	Off Peak	1,100
Average ± Standard Deviation			**760 ± 540 (710 ± 540 [a])**

[a] Average of November/December samples.

> - The sample was not diluted sufficiently; actual concentration is greater than the reported upper limit.

Table 5-5. Total Suspended Solids - Thermopure-2 Retest

Date	Influent Concentration (mg/L)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Concentration (mg/L)
10/15/2007	600	8:40 AM	Peak	330
		9:05 AM	Peak	320
		12:2 PM	Off Peak	820
		4:00 PM	Off Peak	790
10/16/2007	1,700	8:35 AM	Peak	870
		11:50 AM	Peak	1,500
		12:20 PM	Off Peak	1,100
		3:56 PM	Off Peak	1,400
11/29/2007	1,100	8:30 AM	Peak	700
		8:50 AM	Peak	660
		12:15 PM	Off Peak	680
		3:55 PM	Off Peak	840
11/30/2007	330	8:30 AM	Peak	430
		12:15 PM	Off Peak	230
		2:52 PM	Peak	140
		3:52 PM	Off Peak	100
12/3/2007	230	8:30 AM	Peak	480
		8:50 AM	Peak	320
		12:15 PM	Off Peak	190
		3:52 PM	Off Peak	130
12/4/2007	460	8:30 AM	Peak	290
		11:46 AM	Peak	280
		12:15 PM	Off Peak	180
		1:52 PM	Off Peak	150
12/5/2007	1,700	8:30 AM	Peak	3,100
		12:15 PM	Off Peak	2,000
		2:52 PM	Peak	1,700
		3:52 PM	Off Peak	1,200
12/6/2007	3,100	8:30 AM	Peak	2,500
		8:50 AM	Peak	2,500
		12:15 PM	Off Peak	1,300
		3:52 PM	Off Peak	1,100
12/7/2007	2,400	8:30 AM	Peak	3,700
		12:15 PM	Off Peak	2,600
		14:52 PM	Peak	1,300
		3:52 PM	Off Peak	1,500
Average ± Standard Deviation	**1,300 ± 1,000 (1,300 ± 1,100 [a])**			**1,000 ± 920 (1,100 ± 1,000 [a])**

[a] Average of November/December samples.

Table 5-6. pH - Thermopure-2 Retest

Date	Influent pH	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent pH
October Retesting				
10/15/2007	6.4	8:40 AM	Peak	6.9
		9:05 AM	Peak	6.9
		12:2 PM	Off Peak	7.1
		4:00 PM	Off Peak	7.0
10/16/2007	6.7	8:35 AM	Peak	6.7
		11:50 AM	Peak	6.5
		12:20 PM	Off Peak	6.7
		3:56 PM	Off Peak	6.6
November/December Retesting				
11/29/2007	6.7	8:30 AM	Peak	6.1
		8:50 AM	Peak	6.2
		12:15 PM	Off Peak	6.1
		3:55 PM	Off Peak	6.2
11/30/2007	6.4	8:30 AM	Peak	5.9
		12:15 PM	Off Peak	5.8
		2:52 PM	Peak	6.5
		3:52 PM	Off Peak	6.1
12/3/2007	6.8	8:30 AM	Peak	7.0
		8:50 AM	Peak	7.0
		12:15 PM	Off Peak	7.0
		3:52 PM	Off Peak	6.6
12/4/2007	6.6	8:30 AM	Peak	6.8
		11:46 AM	Peak	7.4
		12:15 PM	Off Peak	7.1
		1:52 PM	Off Peak	6.7
12/5/2007	6.9	8:30 AM	Peak	7.3
		12:15 PM	Off Peak	7.3
		2:52 PM	Peak	7.3
		3:52 PM	Off Peak	7.2
12/6/2007	6.9	8:30 AM	Peak	6.8
		8:50 AM	Peak	7.5
		12:15 PM	Off Peak	7.1
		3:52 PM	Off Peak	7.2
12/7/2007	7.0	8:30 AM	Peak	6.9
		12:15 PM	Off Peak	6.9
		14:52 PM	Peak	7.1
		3:52 PM	Off Peak	7.4

Table 5-7. Temperature – Thermopure-2 Retest

Date	Influent Temperature (°C)	Effluent Sample Collection Time	Peak/Off Peak Flow	Effluent Temperature (°C)
October Retesting				
10/15/2007	28	8:40 AM	Peak	56
		9:05 AM	Peak	57
		12:2 PM	Off Peak	66
		4:00 PM	Off Peak	58
10/16/2007	27	8:35 AM	Peak	63
		11:50 AM	Peak	61
		12:20 PM	Off Peak	57
		3:56 PM	Off Peak	53
November/December Retesting				
11/29/2007	22	8:30 AM	Peak	46
		8:50 AM	Peak	60
		12:15 PM	Off Peak	65
		3:55 PM	Off Peak	64
11/30/2007	22	8:30 AM	Peak	53
		12:15 PM	Off Peak	63
		2:52 PM	Peak	66
		3:52 PM	Off Peak	67
12/3/2007	21	8:30 AM	Peak	68
		8:50 AM	Peak	65
		12:15 PM	Off Peak	67
		3:52 PM	Off Peak	63
12/4/2007	22	8:30 AM	Peak	60
		11:46 AM	Peak	62
		12:15 PM	Off Peak	59
		1:52 PM	Off Peak	61
12/5/2007	22	8:30 AM	Peak	51
		12:15 PM	Off Peak	58
		2:52 PM	Peak	61
		3:52 PM	Off Peak	61
12/6/2007	22	8:30 AM	Peak	64
		8:50 AM	Peak	67
		12:15 PM	Off Peak	65
		3:52 PM	Off Peak	66
12/7/2007	23	8:30 AM	Peak	59
		12:15 PM	Off Peak	64
		14:52 PM	Peak	55
		3:52 PM	Off Peak	65
Average ± Standard Deviation	**23 ± 2.5 (22 ± 0.58 [a])**			**61 ± 5.1 (62 ± 5.2 [a])**

[a] Average of November/December samples.

6.0 DATA QUALITY

Quality assurance/quality control (QA/QC) procedures applicable to this Type I MSD performance evaluation are outlined in the *Evaluation of Type I Marine Sanitation Devices (MSDs) Quality Assurance Project Plan (QAPP)* dated March 20, 2007. This section describes the QC practices used to assess the precision and accuracy of the analytical data presented in Section 4.0. QC practices used for this performance evaluation include the analysis of matrix spikes, duplicate samples, and QC standard checks.

6.1 Analytical QC

NSF site personnel measured residual chlorine and visible floating solids onsite due to the relatively short holding times. Aqua-Tech Laboratories, Inc., of Bryan, Texas completed the chemical and biological analyses.[9] Aqua-Tech prepared written data review narratives describing any qualifications of the analytical data. NSF and ERG verified that contract laboratory performance was acceptable by conducting quality control checks of the analytical data as specified by the QAPP. Most of the data were determined to be of acceptable quality. The following data were not considered to be of acceptable quality and were excluded from the data set:

Sample	Analytical Parameter	Reason for Exclusion
Influent, 4/10/2007	BOD_5	Sample not analyzed due to laboratory error.
Electro Scan Effluent, 4/12/2007, 12:15 PM	*E. coli*	Laboratory determined results to be inconclusive.
Electro Scan Effluent, 4/12/2007, 3:48 PM	*E. coli*	
Electro Scan Effluent, 4/19/2007, 8:12 AM	*E. coli*	
Retesting Equipment Blanks, 10/15/2007, 11/29/2007	BOD_5, TSS, Fecal coliform	Equipment blanks were not required for Thermopure-2 retesting as samples were collected directly into sample containers.

[9] NSF's facility located in Ann Arbor, Michigan is currently accepted by the USCG as a Recognized Facility for the evaluation, inspected, and testing of marine sanitation devices under 33 CFR 159.15. However, NSF's Waco, Texas and Aqua-Tech Laboratories, Inc. subfacility currently is not accepted as a Recognized Facility by the USCG.

6.2 Field QC

The field QA/QC measures discussed in this subsection includes equipment blanks and field duplicate results, as specified in Section 6.3 of the Type I MSD QAPP. Tables are presented at the end of this section.

6.2.1 Equipment Blanks

April Testing

NSF test-site personnel collected equipment blank QC samples to evaluate the potential introduction of contaminants by sample collection equipment. The sample collection equipment used to collect the equipment blank was identical to that used at the sampling points: effluent receiving containers for each device and carboys used to collect, mix, and pour the challenge wastewater and MSD effluent samples. Prior to collecting the equipment blanks, the sampling equipment was decontaminated by cleaning with Alconox cleaning solution, and then rinsed with distilled water. Following decontamination, fresh distilled water was added to each container and carboy, lids were put in place, and the equipment was vigorously shaken. This distilled water was decanted into sample bottles and analyzed for the same parameters as the samples collected using the sampling equipment.

Table 6-1 presents the results from equipment blank analyses. The results showed no contamination of the influent carboy or the Electro Scan effluent receiving container. The only analyte detected in the equipment blanks for the Thermopure-2 effluent receiving container and the Electro Scan and Thermopure-2 carboys was nitrate/nitrite, with concentrations ranging from 0.05 to 0.07 mg/L, close to the detection limit of 0.05 mg/L. The source of nitrate/nitrite is likely the Alconox that was used for the cleaning. Alconox contains ethylenediaminetetraacetic acid, which could (per the manufacturer) result in a positive reading for total nitrogen, in this case nitrate. Average nitrate/nitrite concentrations in the effluent samples were 2.4- to 30-times greater than those found in the equipment blanks; therefore, it is unlikely that equipment contamination had a significant impact the sample results.

October and November/December Retesting

Equipment blanks were not required for the Thermopure-2 retesting as samples were collected directly into sample bottles.

6.2.2 Field Duplicates

Field duplicate samples were collected to assess the precision of the sampling and analysis process. Field duplicate samples were collected from the same source, at the same time, and then stored and analyzed independently. The relative percent difference (RPD) between the two duplicate sample results was calculated and compared to the target objective of 30% for each analyte. In the tables presenting the analytical results in Sections 4 and 5, duplicate sample results are presented as averages (calculation uses detection limits for non-detected results).

April Testing

Duplicate samples were collected as split samples poured from the same sample collection carboy to minimize sample waste stream variability. Two duplicate samples of the challenge wastewater were collected on two different days of the 10-day testing period, representing one set of duplicates for every batch of five challenge wastewater samples. Four duplicate samples were also collected of the effluent from each of the two MSDs throughout the 10-day testing period. Effluent duplicate samples represent one set of duplicates for every batch of 10 effluent samples.

Table 6-2 presents analytical results and the RPDs for these duplicate samples. Approximately 45% of the challenge wastewater duplicate pairs either achieved the RPD target, or the RPD could not be calculated because one or both of the sample results was less than the laboratory detection limit. Approximately 70% of the Electro Scan duplicate pairs and approximately 80% of the Thermopure-2 duplicate pairs either achieved the RPD target, or the RPD could not be calculated because one or both of the sample results was less than the laboratory detection limit, respectively. These results are common in complex wastewater samples.

The presence of unmacerated versus macerated solids in the samples appears to affect the ability to achieve the RPD targets. This was demonstrated by the differences in the percentages of duplicate pairs that achieve the RPD target for challenge wastewater versus effluent samples.

November/December Retesting

As a result of the modification to the sampling procedure, duplicate samples were collected as sequential grab samples. This methodology introduced wastewater variability into the assessment of the precision of sample collection and analysis as compared to the

methodology used for the April testing, which used split samples. One duplicate sample of the challenge wastewater was collected for the series of seven challenge wastewater samples. (An additional challenge wastewater duplicate sample was collected during the October retesting period.) Two duplicate samples of the Thermopure-2 effluent were also collected during the nine-day retesting period, and three duplicate samples were collected for visible floating solids. One set of duplicates was collected for every batch of 10 to 15 effluent samples.

Table 6-2 presents analytical results and the RPDs for these duplicate samples. All of the challenge wastewater duplicate pairs achieved the RPD target. Six of the 10 Thermopure-2 duplicate pairs achieved the RPD target, while the remaining four did not. These results are common in complex and variable wastewater samples

6.3 Testing Audit

ERG conducted an audit of NSF's Waco, Texas test facility to evaluate compliance with procedures, testing protocols, and analyses outlined in the *Evaluation of Type I Marine Sanitation Devices (MSDs) Work Plan* dated March 20, 2007 and the *Evaluation of Type I Marine Sanitation Devices (MSDs) Quality Assurance Project Plan (QAPP)* dated March 20, 2007.

During the audit, two days of performance testing and sample collection were observed. This included preparation of the challenge wastewater, device start-up procedures, operation of both devices at peak and off peak dosing cycle, handling of samples, and record keeping for both the Electro Scan and Thermopure-2 devices by NSF. ERG verified device operations, waste dosing, sample collection, field tests, field test documentation, instrument calibrations, daily tilting of devices, sample preservation, and transportation of the samples to the laboratory as outlined in the Audit Checklist provided as Figure 8-2 of the QAPP. Mechanical malfunction, troubleshooting, and the eventual repair of the Thermopure-2 device was also observed and documented on the second day of the audit.

ERG observed some minor issues and their resolutions (as applicable) during the audit, but none of these issues impacted the analytical results from this Type I MSD test program. Further detailed observations, the audit checklists, and a list of issues and resolutions are provided in the Audit Report for Type I MSD Testing (Appendix C).

Table 6-1. Equipment Blank Results

Analyte	Unit	Influent Carboy	Electro Scan Effluent		Thermopure-2 Effluent	
			Receiving Container	Carboy	Receiving Container	Carboy
April Testing						
Fecal Coliform	MPN/100 mL	ND(1.1)	ND(1.1)	ND(1.1)	ND(1.1)	ND(1.1)
Escherichia coli	MPN/100 mL	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
Enterococci	MPN/100 mL	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)
Biochemical Oxygen Demand (5 day)	mg/L	ND(2)	ND(2)	ND(2)	ND(2)	ND(2)
Total Suspended Solids	mg/L	ND(1)	ND(1)	ND(1)	ND(1)	ND(1)
Ammonia as Nitrogen	mg/L	ND(0.05)	ND(0.05)	ND(0.05)	ND(0.05)	ND(0.05)
Total Kjeldahl Nitrogen	mg/L	ND(0.50)	ND(0.50)	ND(0.50)	ND(0.50)	ND(0.50)
Nitrate/Nitrite as Nitrogen	mg/L	ND(0.05)	ND(0.05)	0.06	0.05	0.07
Total Phosphorus	mg/L	ND(0.05)	ND(0.05)	ND(0.05)	ND(0.05)	ND(0.05)

ND – Not detected (number in parentheses is detection limit).

Table 6-2. Field Duplicate Analytical Results

Sample	Collection Date	Time	Analysis	Unit	Original Sample	Duplicate Sample	Average Concentration	Relative % Difference
April Testing								
Influent	4/9/2007	8:00 AM	Ammonia as Nitrogen	mg/L	13	13	13	0.80%
Influent	4/16/2007	8:00 AM	Ammonia as Nitrogen	mg/L	13	14	13	3.0%
Influent	4/9/2007	8:00 AM	Biochemical Oxygen Demand (5 day)	mg/L	2,100	1,800	1,900	16%
Influent	4/16/2007	8:00 AM	Biochemical Oxygen Demand (5 day)	mg/L	850	1,100	990	29%
Influent	4/9/2007	8:00 AM	Enterococci	MPN/100 mL	890,000	1,700,000	1,300,000	64%
Influent	4/16/2007	8:00 AM	Enterococci	MPN/100 mL	300,000	1,600,000	960,000	140%
Influent	4/9/2007	8:00 AM	*Escherichia coli*	MPN/100 mL	5,400,000	7,400,000	6,400,000	31%
Influent	4/16/2007	8:00 AM	*Escherichia coli*	MPN/100 mL	7,400,000	4,800,000	6,100,000	43%
Influent	4/9/2007	8:00 AM	Fecal Coliform	MPN/100 mL	3,000,000	5,000,000	4,000,000	50%
Influent	4/16/2007	8:00 AM	Fecal Coliform	MPN/100 mL	9,000,000	3,000,000	6,000,000	100%
Influent	4/9/2007	8:00 AM	Nitrate/Nitrite as Nitrogen	mg/L	0.13	0.09	0.11	36%
Influent	4/16/2007	8:00 AM	Nitrate/Nitrite as Nitrogen	mg/L	ND(0.05)	ND(0.05)	ND(0.05)	NC
Influent	4/9/2007	8:00 AM	Total Kjeldahl Nitrogen	mg/L	190	140	170	32%
Influent	4/16/2007	8:00 AM	Total Kjeldahl Nitrogen	mg/L	84	62	73	30%
Influent	4/9/2007	8:00 AM	Total Phosphorus	mg/L	63	54	59	15%
Influent	4/16/2007	8:00 AM	Total Phosphorus	mg/L	8.8	12	11	35%
Influent	4/9/2007	8:00 AM	Total Suspended Solids	mg/L	4,500	3,500	4,000	24%
Influent	4/16/2007	8:00 AM	Total Suspended Solids	mg/L	880	1,400	1,100	44%
Electro Scan Effluent	4/10/2007	8:12 AM	Ammonia as Nitrogen	mg/L	8.1	7.3	7.7	10%
Electro Scan Effluent	4/13/2007	1:36 PM	Ammonia as Nitrogen	mg/L	8.2	7.8	8.0	4.9%
Electro Scan Effluent	4/17/2007	8:12 AM	Ammonia as Nitrogen	mg/L	7	4.4	5.7	45%
Electro Scan Effluent	4/20/2007	1:36 PM	Ammonia as Nitrogen	mg/L	7.1	16	12	77%
Electro Scan Effluent	4/10/2007	8:12 AM	Biochemical Oxygen Demand (5 day)	mg/L	1,300	1,000	1,200	24%
Electro Scan Effluent	4/13/2007	1:36 PM	Biochemical Oxygen Demand (5 day)	mg/L	3,100	2,200	2,600	33%
Electro Scan Effluent	4/17/2007	8:12 AM	Biochemical Oxygen Demand (5 day)	mg/L	720	800	760	9.5%
Electro Scan Effluent	4/20/2007	1:36 PM	Biochemical Oxygen Demand (5 day)	mg/L	560	1,600	1,100	95%
Electro Scan Effluent	4/10/2007	8:12 AM	Enterococci	MPN/100 mL	ND(100)	ND(100)	ND(100)	NC
Electro Scan Effluent	4/13/2007	1:36 PM	Enterococci	MPN/100 mL	ND(1.1)	ND(1.1)	ND(1.1)	NC
Electro Scan Effluent	4/17/2007	8:12 AM	Enterococci	MPN/100 mL	ND(1.1)	ND(1.1)	ND(1.1)	NC
Electro Scan Effluent	4/20/2007	1:36 PM	Enterococci	MPN/100 mL	ND(10)	ND(10)	ND(10)	NC

Table 6-2. Field Duplicate Analytical Results (Continued)

Sample	Collection Date	Time	Analysis	Unit	Original Sample	Duplicate Sample	Average Concentration	Relative % Difference
Electro Scan Effluent	4/10/2007	8:12 AM	*Escherichia coli*	MPN/100 mL	ND(100)	ND(100)	ND(100)	NC
Electro Scan Effluent	4/13/2007	1:36 PM	*Escherichia coli*	MPN/100 mL	ND(10)	ND(1.1)	ND(5.6)	NC
Electro Scan Effluent	4/17/2007	8:12 AM	*Escherichia coli*	MPN/100 mL	ND(11)	11	<11	NC
Electro Scan Effluent	4/20/2007	1:36 PM	*Escherichia coli*	MPN/100 mL	ND(10)	ND(10)	ND(10)	NC
Electro Scan Effluent	4/10/2007	8:12 AM	Fecal Coliform	MPN/100 mL	ND(1.1)	ND(1.1)	ND(1.1)	NC
Electro Scan Effluent	4/13/2007	1:36 PM	Fecal Coliform	MPN/100 mL	3.3	ND(1.1)	<2.2	NC
Electro Scan Effluent	4/17/2007	8:12 AM	Fecal Coliform	MPN/100 mL	1.1	ND(1.1)	<1.1	NC
Electro Scan Effluent	4/20/2007	1:36 PM	Fecal Coliform	MPN/100 mL	ND(1.1)	ND(1.1)	ND(1.1)	NC
Electro Scan Effluent	4/10/2007	8:12 AM	Nitrate/Nitrite as Nitrogen	mg/L	1.1	1.4	1.2	26%
Electro Scan Effluent	4/13/2007	1:36 PM	Nitrate/Nitrite as Nitrogen	mg/L	1.5	1.4	1.4	6.4%
Electro Scan Effluent	4/17/2007	8:12 AM	Nitrate/Nitrite as Nitrogen	mg/L	1.6	1.3	1.4	21%
Electro Scan Effluent	4/20/2007	1:36 PM	Nitrate/Nitrite as Nitrogen	mg/L	1.2	1.2	1.2	2.5%
Electro Scan Effluent	4/10/2007	8:12 AM	Total Kjeldahl Nitrogen	mg/L	34	39	37	14%
Electro Scan Effluent	4/13/2007	1:36 PM	Total Kjeldahl Nitrogen	mg/L	54	45	49	17%
Electro Scan Effluent	4/17/2007	8:12 AM	Total Kjeldahl Nitrogen	mg/L	46	50	48	12%
Electro Scan Effluent	4/20/2007	1:36 PM	Total Kjeldahl Nitrogen	mg/L	54	85	69	45%
Electro Scan Effluent	4/10/2007	8:12 AM	Total Phosphorus	mg/L	25	41	33	48%
Electro Scan Effluent	4/13/2007	1:36 PM	Total Phosphorus	mg/L	14	11	13	30%
Electro Scan Effluent	4/17/2007	8:12 AM	Total Phosphorus	mg/L	11	12	11	7.0%
Electro Scan Effluent	4/20/2007	1:36 PM	Total Phosphorus	mg/L	16	24	20	41%
Electro Scan Effluent	4/10/2007	8:12 AM	Total Suspended Solids	mg/L	3,100	3,400	3,300	10%
Electro Scan Effluent	4/13/2007	1:36 PM	Total Suspended Solids	mg/L	1,200	730	960	48%
Electro Scan Effluent	4/17/2007	8:12 AM	Total Suspended Solids	mg/L	800	1,200	1,000	42%
Electro Scan Effluent	4/20/2007	1:36 PM	Total Suspended Solids	mg/L	1,000	1,100	1,000	16%
Electro Scan Effluent	4/12/2007	8:24 AM	Visible Floating Solids	mg/L	67	110	86	45%
Electro Scan Effluent	4/13/2007	1:36 PM	Visible Floating Solids	mg/L	310	41	180	150%
Electro Scan Effluent	4/16/2007	3:48 PM	Visible Floating Solids	mg/L	120	140	130	14%
Electro Scan Effluent	4/18/2007	1:36 M	Visible Floating Solids	mg/L	140	72	110	65%
Thermopure-2 Effluent	4/11/2007	12:15 PM	Ammonia as Nitrogen	mg/L	16	15	15	6.0%
Thermopure-2 Effluent	4/12/2007	3:52 PM	Ammonia as Nitrogen	mg/L	20	20	20	3.0%
Thermopure-2 Effluent	4/18/2007	12:15 PM	Ammonia as Nitrogen	mg/L	20	23	21	14%

Table 6-2. Field Duplicate Analytical Results (Continued)

Sample	Collection Date	Time	Analysis	Unit	Original Sample	Duplicate Sample	Average Concentration	Relative % Difference
Thermopure-2 Effluent	4/19/2007	3:52 PM	Ammonia as Nitrogen	mg/L	22	22	22	0.93%
Thermopure-2 Effluent	4/11/2007	12:15 PM	Biochemical Oxygen Demand (5 day)	mg/L	300	240	270	23%
Thermopure-2 Effluent	4/12/2007	3:52 PM	Biochemical Oxygen Demand (5 day)	mg/L	2,200	2,900	2,600	24%
Thermopure-2 Effluent	4/18/2007	12:15 PM	Biochemical Oxygen Demand (5 day)	mg/L	340	460	400	30%
Thermopure-2 Effluent	4/19/2007	3:52 PM	Biochemical Oxygen Demand (5 day)	mg/L	300	400	350	30%
Thermopure-2 Effluent	4/11/2007	12:15 PM	Enterococci	MPN/100 mL	180,000	130,000	160,000	29%
Thermopure-2 Effluent	4/12/2007	3:52 PM	Enterococci	MPN/100 mL	110,000	100,000	110,000	12%
Thermopure-2 Effluent	4/18/2007	12:15 PM	Enterococci	MPN/100 mL	1,000	ND(1,000)	<1,000	NC
Thermopure-2 Effluent	4/19/2007	3:52 PM	Enterococci	MPN/100 mL	1,000	ND(1,000)	<1,000	NC
Thermopure-2 Effluent	4/11/2007	12:15 PM	*Escherichia coli*	MPN/100 mL	5,100,000	2,700,000	3,900,000	62%
Thermopure-2 Effluent	4/12/2007	3:52 PM	*Escherichia coli*	MPN/100 mL	ND(20,000)	ND(20,000)	ND(20,000)	NC
Thermopure-2 Effluent	4/18/2007	12:15 PM	*Escherichia coli*	MPN/100 mL	ND(20,000)	20,000	<20,000	NC
Thermopure-2 Effluent	4/19/2007	3:52 PM	*Escherichia coli*	MPN/100 mL	ND(20,000)	40,000	<30,000	NC
Thermopure-2 Effluent	4/11/2007	12:15 PM	Fecal Coliform	MPN/100 mL	3,000,000	2,400,000	2,700,000	22%
Thermopure-2 Effluent	4/12/2007	3:52 PM	Fecal Coliform	MPN/100 mL	9,000,000	3,000,000	6,000,000	100%
Thermopure-2 Effluent	4/18/2007	12:15 PM	Fecal Coliform	MPN/100 mL	ND(2,000)	ND(2,000)	ND(2,000)	NC
Thermopure-2 Effluent	4/19/2007	3:52 PM	Fecal Coliform	MPN/100 mL	4,000	ND(2,000)	<3,000	NC
Thermopure-2 Effluent	4/11/2007	12:15 PM	Nitrate/Nitrite as Nitrogen	mg/L	0.15	0.15	0.15	0.00%
Thermopure-2 Effluent	4/12/2007	3:52 PM	Nitrate/Nitrite as Nitrogen	mg/L	0.24	0.24	0.24	0.00%
Thermopure-2 Effluent	4/18/2007	12:15 PM	Nitrate/Nitrite as Nitrogen	mg/L	0.25	0.19	0.22	27%
Thermopure-2 Effluent	4/19/2007	3:52 PM	Nitrate/Nitrite as Nitrogen	mg/L	0.12	0.15	0.14	22%
Thermopure-2 Effluent	4/11/2007	12:15 PM	Total Kjeldahl Nitrogen	mg/L	32	46	39	35%
Thermopure-2 Effluent	4/12/2007	3:52 PM	Total Kjeldahl Nitrogen	mg/L	82	140	110	51%
Thermopure-2 Effluent	4/18/2007	12:15 PM	Total Kjeldahl Nitrogen	mg/L	62	63	62	2.9%
Thermopure-2 Effluent	4/19/2007	3:52 PM	Total Kjeldahl Nitrogen	mg/L	70	50	60	33%
Thermopure-2 Effluent	4/11/2007	12:15 PM	Total Phosphorus	mg/L	9.7	10	10	2.0%
Thermopure-2 Effluent	4/12/2007	3:52 PM	Total Phosphorus	mg/L	28	37	32	26%
Thermopure-2 Effluent	4/18/2007	12:15 PM	Total Phosphorus	mg/L	11	12	12	6.8%
Thermopure-2 Effluent	4/19/2007	3:52 PM	Total Phosphorus	mg/L	9.3	9.4	9.4	1.9%
Thermopure-2 Effluent	4/11/2007	12:15 PM	Total Suspended Solids	mg/L	250	260	260	3.9%
Thermopure-2 Effluent	4/12/2007	3:52 PM	Total Suspended Solids	mg/L	2,200	2,700	2,400	23%

Table 6-2. Field Duplicate Analytical Results (Continued)

Sample	Collection Date	Time	Analysis	Unit	Original Sample	Duplicate Sample	Average Concentration	Relative % Difference
Thermopure-2 Effluent	4/18/2007	12:15 PM	Total Suspended Solids	mg/L	360	360	360	0.00%
Thermopure-2 Effluent	4/19/2007	3:52 PM	Total Suspended Solids	mg/L	280	340	310	19%
Thermopure-2 Effluent	4/10/2007	8:30 AM	Visible Floating Solids	mg/L	100	100	100	0.00%
Thermopure-2 Effluent	4/11/2007	8:30 AM	Visible Floating Solids	mg/L	0	0	0	0.00%
Thermopure-2 Effluent	4/17/2007	3:52 PM	Visible Floating Solids	mg/L	2.0	13	7.5	150%
Thermopure-2 Effluent	4/19/2007	12:15 PM	Visible Floating Solids	mg/L	1.0	8.0	4.5	160%
Thermopure-2 Effluent	4/20/2007	3:52 PM	Visible Floating Solids	mg/L	0	0	0	0.00%
October Retesting								
Influent	10/15/2007	8:05 AM	TSS	mg/L	650	560	600	14.9
November/December Retesting								
Influent	11/29/2007	8:00 AM	TSS	mg/L	1,100	1,000	1,100	9.52
Thermopure-2 Effluent	12/5/2007	12:15 PM	TSS	mg/L	1,800	2,200	2,000	20.0
Thermopure-2 Effluent	12/5/2007	12:15 PM	BOD_5	mg/L	1,500	1,600	1,600	6.45
Thermopure-2 Effluent	12/5/2007	12:15 PM	Fecal coliform	mg/L	1,600	900	1,300	56.0
Thermopure-2 Effluent	12/5/2007	8:30 AM	Visible floating solids	mg/L	0	40	20	200
Thermopure-2 Effluent	12/6/2007	15:52 PM	TSS	mg/L	1,200	1100	1,200	8.70
Thermopure-2 Effluent	12/6/2007	15:52 PM	BOD_5	mg/L	1,000	910	970	9.42
Thermopure-2 Effluent	12/6/2007	15:52 PM	Fecal coliform	mg/L	22,000	22,000	22,000	0.00
Therompure-2 Effluent	12/6/2007	8:50 AM	Visible floating solids	mg/L	0	82	41	200
Therompure-2 Effluent	12/7/2007	2:52 PM	Visible floating solids	mg/L	94	39	67	82.7

ND – Not detected (number in parentheses is detection limit).
< - Average result includes at least one non-detect value (calculation uses detection limits for non-detected results).

7.0 MANUFACTURER RESPONSE

A draft performance evaluation report was provided to the two MSD technology manufacturers on May 30, 2008. Sections 7.1 and 7.2 present the submissions received from Raritan Engineering Company, Inc. and Gross Mechanical Laboratories, Inc., respectively, together with a response to the manufacturer's comments. This final report incorporates manufacturer comments as appropriate.

7.1 Raritan Engineering Company, Inc.

Raritan Submission

It is our understanding that the purpose of this testing was to determine whether or not standards that have remained unchanged since 1975 should be reviewed. It is Raritan's contention that technology exists to treat waste to a much higher standard than the current 1975 standards reflect. The original law stated that standards would be reviewed every five years. Our interpretation of this review was that it would help to encourage the use of continually improved on-board treatment as a viable alternative for conscientious boaters.

As it relates to the testing performed it must also be stated that there are substantial differences in small recreational vessel waste streams as compared to larger commercial vessels and high occupancy vessels such as cruise ships. 33 CFR Sec.159.121 Sewage Processing test does indicate the difference in the two waste streams and it appears testing was done based on section (d) not section (c). Section (c) describes the type of system the Electroscan is and all previous testing had been done based on section (c). Based on the fact that the Electroscan was tested as a unit that continually processes sewage the system was overloaded, Electroscan should have been tested per Coast Guard specifications section (c) of 33 CFR 159.121. In light of that fact the system performed flawlessly with respect to Fecal Coliform, Escherichia coli and Enterococci. These three pathogen indicators were used because they are the most efficient bacterial indicator of water quality. (Fecal streptococcus is a subgroup of fecal coliform used to differentiate human versus animal sources of these microbiologicals.) Epidemiological studies suggest a positive relationship between high concentrations of *E. coli* and enterococci in ambient waters and incidents of gastrointestinal illnesses associated with swimming. The results suggest use of this on-board device is compatible with recreational waters.

The VFS test that was performed must be questioned based on the simple fact the system was overloaded. Normal loading as indicated in the report is based on section (d) of 33 CFR 159.121 and the Electroscan should have been tested based on section (c) of 33 CFR 159.121. Section (d) specified a minimum of 500 mg/L and the average was 2,500 mg/L. We do not agree that the system does not meet current requirements as it was not tested based on requirements. This also brings into question the results of TSS, VFS and BOD_5 as all tend to be inter-related. There are several days where the influent concentration is less than the effluent concentration which is not possible. This is documented in Table 4-5 for BOD_5 where influent was 810 mg/L on 4/12/2007 while effluent concentrations were 920, 1,400, 1,300 and 1,100. In addition to that anomaly it is a documented fact that chlorination reduces BOD_5 therefore we do not fully agree with the statement on page 4-8 that "Consequently, it is likely that apparent BOD_5 and TSS removals are solely a phenomenon of the wastewater, sampling, and analytical variability and not actual removal by Type I devices." If we discard the erroneous data of table 4-5 where effluent is higher than influent total BOD_5 reduction is 58.9%.

Raritan believes this testing is a step in the right direction for all users of recreational vessels. The intention of the law in 1975 was quite clear - continual improvement. By changing standards more companies will see the benefit of providing treatment on-site rather than risk illegal discharges.

Response to Raritan Submission

The performance evaluations of Type I MSDs were conducted in accordance with the Sewage Processing Test contained in the regulations at 33 CFR 159.121. One exception to the USCG's Sewage Processing Test requirements is that, for reasons of practicality, testing was conducted using a feed of fresh domestic human sewage rather than human sewage in a ratio of four urinations to one defecation, as specified in Section (c). Furthermore, for this evaluation, testing was not limited to fecal coliform bacteria and visible floating solids measured in the treated effluent, but rather included a variety of analyses of both influent and effluent samples to measure the effectiveness of each treatment device and to characterize influent and effluent quality. In every other regard, the Raritan device was tested using the 33 CFR 159.121 protocols, including Section (c). The Raritan device was not tested in accordance to Section (d), as this device does not process or discharge sewage continuously, nor was the device modified in any way to operate continuously.

The dosing schedule was well within the average and peak capacity of the Raritan unit as indicated in the unit documentation (see Appendix B of this report for the challenge wastewater dosing schedule). Specifically, peak flow was designated by Raritan as 1 gallon flush of wastewater every six minutes, and a 30-minute cool-down period after every four to five flushes. Off-peak (average) process flow was based on an assumption of four passengers each using the toilet five times in an eight-hour day with 1-gallon per flush. Raritan product specifications indicate a unit capacity of 575 gallons per day, and a maximum total flush volume of 1.5 gallons per flush; these compare to the test conditions of a total daily dose volume of 28 gallons and a total flush volume of 1 gallon per flush.

Anomalies between influent and effluent results were due to the non-homogeneity and high variability of the influent feed and treated effluent (see Section 4.3). Such problems are expected with raw, complex wastewater with high amounts of unmacerated solids.

7.2 Gross Mechanical Laboratories, Inc.

Gross Mechanical Laboratories (GROCO) Submission – 7/15/08

This is in response to ERG's Performance Evaluation Report (draft) of Type I MSDs. While we recognize the good intent of this evaluation, GROCO respectfully objects to the test procedure employed for the re-test, and questions the results. Following are our objections in several specific areas of concern:

1. The dosing system that was employed clearly overloaded Thermopure-2, forcing untreated sewage through the system and causing unacceptable fecal coliform bacteria counts in the effluent. As stated on page 5-1 paragraph-2, the retest dosing was conducted using the same dosing schedule as in the April test. Page 5-4 indicates that Thermopure-2 overflowed, further supporting our claim that the dosing schedule exceeded system capacity. In normal operation, audible and visual alarms alert the user that the holding tank is at (approximately) 75% capacity, but the automatic dosing procedure employed during the retest ignored the built-in warnings. Additionally, by forcing unprocessed sewage through the system, related symptoms such as low temperature measurements reported on Page 5-2 may have been caused. Such readings may be attributed to siphoning of

sewage past a clogged or sticking vacuum breaker (part of the plumbing system to and from the treatment block), and caused by the forced over-dosing.

2. Table 4-15 shows effluent samples contained a greater fecal coliform bacteria count than the influent. This is not possible.

3. Project 0214.00.020 appears to have been conducted in consideration of 33CFR159.121 (d) as it pertains to large vessel systems. Type-I MSDs are intended for use aboard small vessels (smaller than 65-feet in length). Thermopure-2 includes a holding tank that effectively stores influent received at a rate that is in excess of treatment capacity, thereby avoiding system overload as experienced during the retest. In the "real world" of small vessel toilet systems, as little as 1-quart of flush water is required per flush. Testing with peak capacity dosing is not appropriate.

4. Prior to sending a Thermopure-2 unit for retest in November, 2007 GROCO submitted effluent samples to an independent lab for fecal coliform bacteria count. Using test method SM209221E, the results indicated consistently <2 MPN. On July 8, 2008 we submitted additional samples to the same lab and received similarly consistent satisfactory results.

We here-by request that a retest of Thermopure-2 be conducted.

Additional Gross Mechanical Laboratories Submission – 8/14/08

Following are answers to questions from your August 13 e-mail:

1. The heater block used in GROCO's in-house tests is identical to the heater block submitted to ERG. This is a production item for us; one which we have manufactured for years without change. The effluent flow volume in our test is also identical to that of the unit you received for the re-test. Thermopure-2 control software limits pump run time so as not to exceed the volume of the heater block. The resulting effluent measures approximately 500 ml.

2. Attached are copies of results from Chesapeake Labs, Inc. The report from November 14, 2007 was the result of effluent sampling following our software correction, prior to the re-test. The report from July 8, 2008 tests samples from the same GROCO test unit from which the November 2007 samples were produced. These were tested after receiving your re-test test report indicating that we were not eliminating fecal coliform bacteria.

3. Unit testing and sampling was conducted in-house. GROCO has a fully operational unit which has been in operation for approximately 10-years. The test unit receives "live" raw sewage from a marine toilet used by me, not diluted or otherwise controlled test influent. There is no question that the influent used contains ample fecal coliform bacteria. The test unit is not tilted, and our test procedure is simply that the system is used "normally" as follows:
   a. the toilet is used and flushed
   b. the Thermopure-2 unit holding tank receives the influent
   c. the level sensor recognizes increased holding tank level and turns on the heater
   d. when the appropriate level of heat has been achieved, waste is processed and discharged
   e. all samples were collected by me personally, as received directly from the discharge hose from the treatment block. Samples were captured into sterile sample bottles furnished by Chesapeake Labs. Immediately after catching each sample, the bottles were capped, placed into a cooler with ice, and delivered within 1-hour to Chesapeake Labs. for testing in compliance with Fecal Coliform Method SM209221E.

Our test unit does not consider average flow or peak flow; "real world" rates of usage are employed, and the rate of processing effluent does not change with the rate of influent. The holding tank portion of Thermopure-2 is fully capable of handling additional influent volume as might be imposed during peak flow conditions.

If additional information is required please contact me.

Response to GROCO Submissions

The dosing schedule is well within the average and peak capacity of the Thermopure-2 unit as indicated in the unit documentation (see Appendix B of this report for the challenge wastewater dosing schedule). Specifically, peak flow was as designated by the manufacturer as 50 gallons per eight-hour day or about 1 gallon every 10 minutes, based on an assumed challenge wastewater temperature of 68°F (20°C). Off-peak (average) process flow was based on an assumption of four passengers each using the toilet five times in an eight-hour day. This resulted in an off-peak flow of 20 gallons in an eight-hour day or 1 gallon of wastewater every 24 minutes. Thermopure-2 product specifications indicate a maximum treatment capacity ranging from 40 gallons per day (65°F flush water) to 60 gallons per eight-hour day (80°F flush water); there is no specified total flush volume. These compare to the test conditions of a total daily dose volume of 32 gallons and a total flush volume of 1 gallon per flush. Flush water temperature was 68°F (20°C) during April 2007 testing, and 72°F (22°C) during November/December 2007 testing.

The Thermopure-2 holding tank overflowed briefly during one combined “tilt” event/peak flow dose. Neither the dosing schedule, nor the dosed volumes administered, exceeded the treatment capacity of the unit as specified by unit documentation.

The design of the Thermopure-2 unit and placement of components, piping, and connections make it extremely unlikely that wastewater could be forced or siphoned through the system. First, movement of untreated wastewater out of the holding tank into the treatment block occurs only when the macerator pump located inside the holding tank operates to transfer fluid to the treatment block. Therefore, while the dosing system moves wastewater into the holding tank, it does not move or “force” wastewater through the remainder of the system. Gross Mechanical Laboratories, Inc. confirms this in their August 14 response: “the rate of processing effluent does not change with the rate of influent. The holding tank portion of Thermopure-2 is fully capable of handling additional influent volume as might be imposed during peak flow conditions.” Second, the treatment system design incorporates discharge vented loops, which are essentially atmospheric vacuum breakers that function to prevent siphoning of fluids. These vented loops were installed in accordance with the configuration indicated in the manufacturer’s literature. A Gross Mechanical Laboratories, Inc. representative visited the test facility and verified proper device installation (see Section 4.1.1). Third, as experienced during day eight of the original test, a malfunction caused the vacuum breaker to leak when under pump pressure and did not allow

siphoning. Fourth, the sample technician monitored all unit discharges during testing, and no siphoning or other inappropriate discharges were observed.

Anomalies between influent and effluent results were due to the non-homogeneity and high variability of the influent feed and treated effluent (see Section 4.3). Such problems are expected with raw, complex wastewater with high amounts of unmacerated solids.

The performance evaluations of Type I MSDs were conducted in accordance with the Sewage Processing Test contained in the regulations at 33 CFR 159.121. One exception to the USCG's Sewage Processing Test requirements is that, for reasons of practicality, testing was conducted using a feed of fresh domestic human sewage rather than human sewage in a ratio of four urinations to one defecation, as specified in Section (c). Furthermore, for this evaluation, testing was not limited to fecal coliform bacteria and visible floating solids measured in the treated effluent, but rather included a variety of analyses of both influent and effluent samples to measure the effectiveness of each treatment device and to characterize influent and effluent quality. Specific to the retesting, testing that was not at least 10 days within a 20-day period. In every other regard, the Raritan device was tested using the 33 CFR 159.121 protocols, including Section (c). The Raritan device was not tested in accordance to Section (d), as this device does not process or discharge sewage continuously, nor was the device modified in any way to operate continuously.

The Sewage Processing Test contained in the regulations at 33 CFR 159.121 specifies that systems must process sewage at peak capacity during three periods of each day of testing. Although the cause of the unit not performing to the specified manufacturer's standard is unknown, the cause may be a discrepancy between the unit's design pump-out flow, versus actual pump-out flow. In their August 14 submission, Gross Mechanical Laboratories, Inc, states that the "Thermopure-2 control software limits pump run time so as not to exceed the volume of the heater block" and that "the resulting effluent measures approximately 500 ml." Actual pump-out volumes measured by test facility personnel using a graduated cylinder were a constant 1,000 mL to 1,200 mL over the two-second pump-out period. An actual pump-out volume of more than twice the design rate suggests that unheated (untreated) wastewater may have been pumped out along with treated wastewater, which could account for the unit not performing to specified manufacturer's standard.

Appendix A

33 CFR 159 Excerpts

33 CFR § 159.53 General requirements.

A device must:

(a) Under the test conditions described in §§159.123 and 159.125, produce an effluent having a fecal coliform bacteria count not greater than 1,000 per 100 milliliters and no visible floating solids (Type I),

(b) Under the test conditions described in §§159.126 and 159.126a, produce an effluent having a fecal coliform bacteria count not greater than 200 per 100 milliliters and suspended solids not greater than 150 milligrams per liter (Type II), or

(c) Be designed to prevent the overboard discharge of treated or untreated sewage or any waste derived from sewage (Type III).

33 CFR § 159.121 Sewage processing test.

(a) The device must process human sewage in the manner for which it is designed when tested in accordance with this section. There must be no sewage or sewage-treating chemicals remaining on surfaces or in crevices that could come in contact with a person using the device or servicing the device in accordance with the instructions supplied under §159.57(b)(7).

(b) During the test the device must be operated and maintained in accordance with the manufacturer's instructions. Any initial start-up time specified by the manufacturer must be allowed before test periods begin. For 1 hour of each 8-hour test period, the device must be tilted to the maximum angles specified by the manufacturer under §§159.55 and 159.57.

(c) Except for devices described in paragraph (d) of this section, the devices must process and discharge or store human sewage over at least an 8-consecutive hour period on at least 10 days within a 20-day period. The device must receive human sewage consisting of fecal matter, urine, and toilet paper in a ratio of four urinations to one defecation with at least one defecation per person per day. Devices must be tested at their average rate of capacity as specified in §159.57. In addition, during three periods of each day the system must process sewage at the peak capacity for the period of time it is rated at peak capacity.

(d) A device that processes and discharges continuously between individual use periods or a large device, as determined by the Coast Guard, must process and discharge sewage over at least 10-consecutive days at the average daily capacity specified by the manufacturer. During three periods of each day the system must process sewage at the peak capacity for the period of time it is rated at peak capacity. The sewage for this test must be fresh, domestic sewage to which primary sludge has been added, as necessary, to create a test sewage with a minimum of 500 milligrams of suspended solids per liter.

33 CFR § 159.123 Coliform test: Type I devices.

(a) The arithmetic mean of the fecal coliform bacteria in 38 of 40 samples of effluent discharged from a Type I device during the test described in §159.121 must be less than 1000 per 100 milliliters when tested in accordance with 40 CFR Part 136.

(b) The 40 samples must be taken from the device as follows: During each of the 10-test days, one sample must be taken at the beginning, middle, and end of an 8-consecutive hour period with one additional sample taken immediately following the peak capacity processing period.

33 CFR § 159.125 Visible floating solids: Type I devices.

During the sewage processing test (§159.121) 40 effluent samples of approximately 1 liter each shall be taken from a Type I device at the same time as samples taken in §159.123 and passed expeditiously through a U.S. Sieve No. 12 as specified in ASTM E 11 (incorporated by reference, see §159.4). The weight of the material retained on the screen after it has been dried to a constant weight in an oven at 103 °C must be divided by the volume of the sample and expressed as milligrams per liter. This value must be 10 percent or less of the total suspended solids as determined in accordance with 40 CFR Part 136 or at least 38 of the 40 samples.

Note: 33 U.S.C. 1321(b)(3) prohibits discharge of harmful quantities of oil into or upon the navigable waters of the United States or adjoining shorelines or into or upon the waters of the contiguous zone. Under 40 CFR 110.3 and 110.4 such discharges of oil include discharges which:

(a) Violate applicable water quality standards, or

(b) Cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines. If a sample contains a quantity of oil determined to be harmful, the Coast Guard will not certify the device.

Appendix B

CHALLENGE WASTEWATER DOSING SCHEDULE

NSF International Waco Test Facility
Marine Sanitation Device Evaluation 2007
Dosing and Sample Schedule for Test Device #1 - The Electro Scan Device

Dose #	Time	Description	Tilt [a]	Sample [b]	Peak Flow Dose #	Off-Peak Dose #
	07:45	Challenge wastewater batch				
1	08:00	Peak Flow Dose		#1-Infl.	1	
2	08:06				2	
3	08:12			#ES-1 (beginning)	3	
4	08:18				4	
5	08:24			#ES-2pm; #ES-2pth	5	
	08:30	End of processing 08:24 dose				
	08:30-09:00	30-min. Cool Down	T1-mw-1			
6	09:00	Off-Peak Dose (1 HR)	T2-tw-1			1
7	09:24		T3-ww-1			2
8	09:48					3
9	10:12	Peak Flow Dose			6	
10	10:18				7	
11	10:24				8	
12	10:30				9	
13	10:36			#ES-2ptu	10	
	10:42	End of processing 10:36 dose				
	10:42-11:12	30-min. Cool Down	T4-thw-1			
14	11:12	Off-Peak Dose (2 HRs)	T1-mw-2			4
15	11:36		T2-tw-2			5
16	12.00					6
17	12.15			#ES-3m (mid-day Mon. /Tues. /Thurs.); ES-2m (Wed/Fri.)		7
	12:30			Lab Pickup		
18	12:48					8
19	13:12	Peak Flow Dose			11	
20	13:18				12	
21	13:24				13	
22	13:30				14	
23	13:36			#ES-3pw; #ES-3pf	15	
	13:42	End of processing	T3-ww-2			

NSF International Waco Test Facility
Marine Sanitation Device Evaluation 2007
Dosing and Sample Schedule for Test Device #1 - The Electro Scan Device

Dose #	Time	Description	Tilt [a]	Sample [b]	Peak Flow Dose #	Off-Peak Dose #
		13:26 dose				
	13:42-14:12	30-min. Cool Down	T4-thw-2			
24	14:12	Off-Peak Dose (2 HRs)				9
25	14:36					10
26	15:00		T5-fw-1 T5-fw-2			11
27	15:24					12
28	15:48			#ES-4e (end of day)		13
	15:54	End of processing 15:48 dose				
	16:30			Lab Pickup		
Dose Volumes					15 Gallons	13 Gallons
TTL Dose Volume					28 Gallons	
TTL Influent Sample Volume					6 Liters	
TTL Effluent Sample Volume					48 Liters	

[a] Tilting: Based upon tilting the device for one hour each day at a 30° angle from horizontal axis along each side and end of the device, alternating each day to ensure tilting on each side or end at least twice during the test: Tilt#1 = Device tilted 30° to the left of vertical axis as viewed from the inlet end elevation (to the 10:00 o'clock position); #2 = 30° to right of vertical axis as viewed from the inlet end elevation (to the 2:00 o'clock position); #3 = Device tilted 30° to the left of vertical axis as viewed from the inlet side elevation (to the 10:00 o'clock position); #4 = Device tilted 30° to the right of vertical axis as viewed from the inlet side elevation (to the 2:00 o'clock position). T1-mw-1 = Tilt #1, Mon. /week #1, T1-mw-2 = Tilt #1, Mon. /week #2, etc.

[b] Sample # & Description: #1 = Influent prior to dosing; #ES-1 = Effluent at beginning of dosing; #ES-2pm = Effl. following peak dosing on Monday; #ES-2pth = Effl. following peak dosing on Thurs.; #ES-2ptu = Effluent following peak dosing on Tues.; ES-3m = Effl. at mid-day on Mon/Tues/Thurs; ES-2m = Effl. at mid-day on Wed/Fri; #2e = Effluent at end of dosing; #ES-3pw = Effl. following peak dosing on Wed.; #ES-3pf = Effl. following peak dosing on Fri.

NSF International Waco Test Facility
Marine Sanitation Device Evaluation 2007
Dosing and Sample Schedule for Test Device #2 - The Thermopure Device

Dose #	Time	Description	Tilt [a]	Sample [b]	Peak Flow Dose #	Off-Peak Dose #
	07:45	Challenge Wastewater Batch		#1 Infl		
1	08:00	Peak Flow Dose (1 HR)			1	
2	08:10				2	
3	08:20				3	
4	08:30			#TP-1 (beginning)	4	
5	08:40				5	
6	08:50		T1-mw-1	#TP-2pm; #TP-2pth	6	
	08:56	End of processing 08:50 dose				
7	08:56	Off-Peak Dose (2 HR)	T2-tw-1			1
8	09:20		T3-ww-1			2
9	09:44					3
10	10:08					4
11	10:32					5
12	10:56	Peak Flow Dose (1 HR)			7	
13	11:06				8	
14	11:16				9	
15	11:26				10	
16	11:36				11	
17	11:46			#TP-2ptu	12	
		End of processing 11:46 dose	T4-thw-1			
18	11:52	Off-Peak Dose (2 HR)	T1-mw-2			6
19	12:16		T2-tw-2	#TP-3m (mid-day Mon/Tues/Thurs); #TP-2m Wed/Fri		7
	12:30			Lab Pickup		
20	12:40					8
21	13:04					9
22	13:28					10
23	13:52	Peak Flow Dose (1 HR)	T3-ww-2		13	
24	14.02		T4-thw-2		14	
25	14.12				15	
26	14:22				16	
27	14:32				17	
28	14:42				18	
29	14:52			#TP-3pw; #TP-3pf	19	
		End of processing 14:52 dose				

NSF International Waco Test Facility
Marine Sanitation Device Evaluation 2007
Dosing and Sample Schedule for Test Device #2 - The Thermopure Device

Dose #	Time	Description	Tilt [a]	Sample [b]	Peak Flow Dose #	Off-Peak Dose #
30	14:58	Off-Peak Dose (1 HR)				11
	15:00		T5-fw-1 T5 fw-2			
31	15:22					12
32	15:46					13
	15:52	End of processing 15:46 dose		#TP-4e (end of day)		
	16:30			Lab Pickup		
Dose Volumes by Flow					19 Gallons	13 Gallons
TTL Dose Volume					32 Gallons	
TTL Influent Sample Volume					6 Liters	
TTL Effluent Sample Volume					48 Liters	

[a] Tilting: Based upon tilting the device for one hour each day at a 30° angle from horizontal axis along each side and end of the device, alternating each day to ensure tilting on each side or end at least twice during the test: Tilt#1 = Device tilted 30° to the left of vertical axis as viewed from the inlet end elevation (to the 10:00 o'clock position); #2 = 30° to right of vertical axis as viewed from the inlet end elevation (to the 2:00 o'clock position); #3 = Device tilted 30° to the left of vertical axis as viewed from the inlet side elevation (to the 10:00 o'clock position); #4 = Device tilted 30° to the right of vertical axis as viewed from the inlet side elevation (to the 2:00 o'clock position). T1-mw-1 = Tilt #1, Mon./week #1, T1-mw-2 = Tilt #1, Mon./week #2, etc.

[b] Sample # & Description: #1 = Influent prior to dosing; #TP-1 = Effluent at beginning of dosing; #TP-2pm = Effl. following peak dosing on Monday; #TP-2pth = Effl. following peak dosing on Thurs.; #TP-2ptu = Effluent following peak dosing on Tues.; TP-3m = Effl. at mid-day on Mon/Tues/Thurs; #TP-2m = Effl. mid-day on Wed/Fri; #TP-4e = Effluent at end of dosing; #TP-3pw = Effl. following peak dosing on Wed.; #TP-3pf = Effl. following peak dosing on Fri.

Appendix C

AUDIT REPORT FOR TYPE I MSD TESTING

MEMORANDUM

TO: Ray Frederick, EPA

FROM: Kathleen Wu, ERG

DATE: May 10, 2007

SUBJECT: **Audit Report for Type I MSD Testing**

INTRODUCTION

ERG, in support of EPA's STREAMS Program Task Order #20, is evaluating the effectiveness of Type I MSDs. The two devices identified are Gross Mechanical Laboratories' Thermopure-2 device and Raritan Engineering Company's Electro Scan device. ERG prepared a Work Plan and a Quality Assurance Project Plan to evaluate these devices and subcontracted the setup and testing phase of the project to NSF International.

AUDIT

Kathleen Wu, ERG Scientist, conducted an audit of NSF International's test facility to evaluate compliance with procedures, testing protocols, and analyses outlined in the *Evaluation of Type I Marine Sanitation Devices (MSDs) Work Plan* dated March 20, 2007 and the *Evaluation of Type I Marine Sanitation Devices (MSDs) Quality Assurance Project Plan (QAPP)* dated March 20, 2007. The audit was conducted at the Waco Metropolitan Area Regional Sewage System (WMARSS) Treatment Facility in Waco, Texas and at Aqua-Tech Laboratories, Inc. in Bryan, Texas. The first two days of the audit, April 9, 2007 to April 10, 2007, were spent at the test facility, while the last day, April 11, 2007, was spent in the lab.

Date	Location	Sample Description	Sampling/Laboratory Personnel
4/09/2007	WMARSS Waco, Texas	Influent, peak, and off peak samples from Electro Scan and Thermopure-2 devices	David Jumper, NSF Dustin Patton, NSF Jim Patton, NSF
4/10/2007	WMARSS Waco, Texas	Influent, peak, and off peak samples from Electro Scan and Thermopure-2 devices	David Jumper, NSF Dustin Patton, NSF Jim Patton, NSF
4/11/2007	Aqua-Tech Laboratories Bryan, Texas	Microbiological and TSS samples from Electro Scan and Thermopure-2 devices	June Brien, Aqua-Tech John Brien, Aqua-Tech

During the audit, Ms. Wu observed two days of performance testing and sample collection. This included preparation of the challenge wastewater, device start-up procedures, operation of both devices at peak and off peak dosing cycle, handling of samples, and record keeping for both the Electro Scan and Thermopure-2 device by NSF International. She verified device operations, waste dosing, sample collection, field tests, field test documentation, instrument calibrations, daily tilting of devices, sample preservation, and transportation of the

samples to the laboratory. She was also present during the mechanical malfunction, troubleshooting, and eventual repair of the Thermopure-2 device on the second day of the audit.

The Audit evaluated the following elements:

- Overall level of organization, professionalism, and understanding of the project;
- Start-up and operation of both devices at peak and off peak dosing cycles per manufacturer instructions for 8 hours per day;
- Set-up and preparation of challenge wastewater from the influent tank through the dosing system prior to testing;
- Compliance and understanding of all activities and goals described in the Work Plan;
- Compliance with all procedures outlined in the QAPP;
- Documentation of samples, analysis activity, and observations;
- Condition of field test equipment and materials;
- Appropriate transport of the samples to the laboratory; and
- Overall satisfaction with environment and procedures of the laboratory.

AUDIT RESULTS

Ms. Wu recorded her observations on the Type I MSD Testing Audit Checklists provided in Attachment 1.

The site manager prepared appropriate challenge wastewater that was fed to the devices using an automated the dosing system following testing procedure guidelines. Facility personnel operated each device at start-up, during peak and off peak flows, and at the end of the testing day per manufacturer instructions and requirements of the Work Plan. Moreover, sample collection, field tests, sample handling, and paperwork requirements were administered according to the Work Plan and QAPP.

Samples were transported to Aqua-Tech Laboratories, where Ms. Wu spent her third day of the audit observing lab procedures, documentation, and reporting, and reviewing preliminary TSS and *E. coli* results. She reviewed the lab's documentation process and obtained the most recent audit report conducted by the state of Texas. Review of Aqua-Tech's audit revealed three positive findings and two negative findings in their quality assurance program. Negative findings were resolved with corrective actions.

Memorandum
10 May 2007
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Ms. Wu observed the following minor issues and their resolutions (if applicable) during the audit, none of which should have any impact on the analytical results or quality of the data obtained from this Type I MSD test program.

- On the first day of testing, the Thermopure-2 device required more time than predicted to reach warm-up temperature at the beginning of the day and the target treatment temperature for each treatment cycle. The ambient temperature in Waco, Texas was cold (approximately 39°F). However, neither the dosing nor sampling schedule was delayed as the treatment system design includes a holding tank that stores influent wastewater in queue for the treatment chamber. There was more than enough effluent flow from the device to allow sampling to proceed as scheduled. Additionally, as testing progressed and continued on subsequent days, this issue was observed less and less as ambient temperatures increased.

- Each treatment device had its own designated sampling equipment to minimize cross contamination between samples. This equipment included the field test container, sampling container, Alconox solution, effluent sampling tap, and all container lids, which were originally labeled with its designated treatment device. As sampling progressed, these labels were being constantly rinsed with Alconox solution and deionized water and began to peel off. The samplers reprinted all the labels and covered them with clear plastic tape to maintain their integrity.

- Field test data sheets and total chlorine residual data sheets were originally formatted in a way that did not facilitate data collection over multiple days. New data sheets were designed to correct this error. Previously collected data were transferred to new sheets.

- At around noon on the second day of performance testing, the Thermopure-2 device's 75% capacity warning light came on. Troubleshooting identified the problem as mechanical failure of the pump to the treatment chamber and a blown fuse. NSF personnel replaced both and resumed treatment within 40 minutes. In all, 3 one-gallon doses during the peak flow of the Thermopure-2 device were missed. No partially treated or untreated wastewater passed through the device, and sampling times were not affected.

Attachment 1

AUDIT CHECKLISTS FOR THERMOPURE-2 AND ELECTRO SCAN DEVICES

Type I MSD Testing Audit Checklist

MSD Names **Thermopure-2, Groco**

Auditor **Kathleen Wu, ERG**

Date(s) of Audit **April 9th and 10th, 2007**

Samplers **David Jumper, Dustin Patton, & Jim H. Patton Ph.D., NSF**

Testing Procedures	Yes	No
Is the MSD setup performed in accordance with manufacturer instructions to simulate, as close as possible, installation onboard a vessel? **The device was bolted and strapped down to elevated wood boards that had the influent tank on the highest board and with each progressive step of the treatment system at a lower elevation.** **The piping chosen was designed to withstand 250°F.**	X	☐
Are MSDs started and operated as described in the devices' operating manuals? **Correct voltages were used as monitored by a voltmeter.** **The device was started by first preparing the challenge wastewater and recirculation loop and then connecting battery power to the dosing and treatment devices.**	X	☐
Are MSD maintenance instructions conducted according to the devices' operating manuals? **No short term maintenance operations are required by the device.**	X	☐
Are challenge wastewater batches prepared with a minimum concentration of 500 mg/L TSS? **Preliminary TSS results in the influent on the first day of sampling were approximately 4000 mg/L.**	X	☐
Is challenge waste water continuously mixed to ensure consistent feed? **A pump circulates challenge wastewater out of and then back into the influent tank through a recirculation hose.**	X	☐

Type I MSD Testing Audit Checklist for Thermopure-2 (Continued)

Testing Procedures	Yes	No
Are the devices dosed for a minimum of 8 hours each day? Is the dosing pattern based on the design hydraulic capacity of the devices with three periods each day when devices are dosed at their peak capacities? **The dosing system is designed to dose for 8 hours each day. On the second day of testing, the pump on the Thermopure-2 device that draws wastewater from the holding tank to the treatment chamber experienced a mechanical failure. The dosing system was shut down for about 45 minutes during its peak flow to prevent the device from overflowing. Although all samples were collected as scheduled, three one-gallon doses were missed.**	☐	X
Is there a mechanism to allow tilting of the device to an angle of 22.5° from horizontal along one side? **The device was designed to allow tilting in all directions**. **The tilting angle was approximately 30°.**	X	☐
Are the devices periodically tilted during testing?	X	☐
Are any operational problems and maintenance provided recorded in a field log book? **All operational problems were summarized and recorded site personnel.**	X	☐

Type I MSD Testing Audit Checklist for Thermopure-2 (Continued)

Sampling Procedure	Yes	No
Are the challenge wastewater samples collected immediately prior to dosing the device? If more than one challenge wastewater batch is dosed in one day, are the batch samples appropriately composited, mixed, and transferred to appropriate sample containers? **Only one challenge wastewater batch was prepared each day and dosed to both devices, so there was no need to composite or mix influent samples.**	X	☐
Are the effluent samples collected with a clean pitcher that is thoroughly decontaminated using Alconox solution and rinsing with deionized/distilled water after each use? **The device had two dedicated effluent containers, which were used to transport samples to the lab to be poured into sample bottles.**	X	☐
Are flow rates monitored and accurate for the collection type? **The automatic dosing system is programmed to switch between peak and off peak as specific times. The system can be programmed to the minute.**	X	☐
Is the Electro Scan allowed to cool down for 30 minutes after 4 to 5 cycles? **Not Applicable for Thermopure-2.**	☐	☐
Are the sampling locations appropriate (i.e., off the recirculation loop on the feed tank and a sample tap on the effluent piping from each device)?	X	☐
Are the effluent samples taken at the appropriate time intervals (i.e., beginning, middle, and end of daily dosing period with one additional during peak dosing period)?	X	☐
Are the sample containers used to collect the samples appropriately labeled? **Sample labels listed the following information: NSF, device name, sample number, analyte, volume, date, time, and name of sampler.**	X	☐
Are sample collection containers and volumes appropriate for planned analysis per Table 2 of the work plan?	X	☐
Are the sample labels adequate to prevent tampering, abrasion, smearing, or loss during transit? **Labels were plastic and printed with water proof ink. Anything hand written was done with indelible ink.**	X	☐

Type I MSD Testing Audit Checklist for Thermopure-2 (Continued)

Sampling Procedure	Yes	No
Are the sample containers for analysis appropriately stored between sample aliquots (e.g., kept on ice and stored in a cooler to minimize the impact of possible inadvertent contamination or tampering)? **Samples were kept in a refrigerator with a temperature setting of 4°C.**	X	☐
Are samplers following good sampling practices (i.e., being careful not to touch the inside of sample container and lid, wearing new gloves for each sample to prevent cross contaminations, etc.)?	X	☐
Are all collected samples preserved according to Table 2 of the work plan? **Aqua-Tech pre-preserved the sample containers per Table 2.**	X	☐
Is residual chlorine tested promptly following sample collection? **Not applicable for Thermopure-2, which does not use chlorine.**	☐	☐
Is a container, separate from the sample container, used to collect sample for conducting pH, temperature, and salinity (Electro Scan device only) field tests on each sample aliquot? **The device had a dedicated field test container that was cleaned with Alconox and deionized water after each use.** **A probe was used to measure temperature, pH, conductivity (even though it was not required for the Thermopure-2 Device), and dissolved oxygen for each sample.**	X	☐
Is the pH meter rinsed adequately between sampling points? Verify that the pH meter has been calibrated. **The pH meter was calibrated at the start of each day and sits in pH of 4 buffer solution when not in use.**	X	☐
Are microbiological samples transported to the lab within 6 hours of collection? **Samples were picked up within 5-6 hours after the first sample is taken.**	X	☐
Is the field test container appropriately stored between sample aliquots?	X	☐
Are the correct QC samples and duplicate samples collected?	X	☐

Type I MSD Testing Audit Checklist for Thermopure-2 (Continued)

Sampling Procedure	Yes	No
Are all equipment blanks and field duplicates prepared, collected, and stored appropriately after sampling? **Field duplicates were stored with regular samples and treated as such. Equipment blanks were taken the week before sampling and already processed by the lab.**	X	☐
Are the processes and sample information, such as flow rates (peak and off peak) and field measurements and sample collection times recorded appropriately in a field log book? **These were all programmed into the dosing system. A print out of the detailed schedule was provided, listing dosing times, times for peak/off peak flows, sample collection time, tilting times, etc**	X	☐
Are the sample bottles maintained on ice and packed well enough to avoid breakage during transport to the laboratory? **Bottles were all plastic, placed in zip-lock bags in the coolers, and covered with ice.**	X	☐

Type I MSD Testing Audit Checklist

MSD Names **Electro Scan, Raritan**

Auditor **Kathleen Wu, ERG**

Date(s) of Audit **April 9th and 10th 2007**

Samplers **David Jumper, Dustin Patton, & Jim H. Patton Ph.D., NSF**

Testing Procedures	Yes	No
Is the MSD setup performed in accordance with manufacturer instructions to simulate, as close as possible, installation onboard a vessel? **The device was bolted and strapped down to elevated wood boards that had the influent tank on the highest board and with each progressive step of the treatment system at a lower elevation.** **Flexible hosing used to allow for tilting. On a vessel the piping would likely be rigid.**	X	☐
Are MSDs started and operated as described in the devices' operating manuals? **Correct voltages were used as monitored by a voltmeter.** **The device was started by first preparing the challenge wastewater and recirculation loop and then connecting battery power to the dosing and treatment devices.** **The salt water feed system was installed as described in the manual. The salt used was 98% pure water softening tablets.**	X	☐
Are MSD maintenance instructions conducted according to the devices' operating manuals? **No short term maintenance operations are required by the device.**	X	☐
Are challenge wastewater batches prepared with a minimum concentration of 500 mg/L TSS? **Preliminary TSS results for the influent on the first day of sampling were approximately 4,000 mg/L.**	X	☐

Type I MSD Testing Audit Checklist for Electroscan (Continued)

Testing Procedures	Yes	No
Is challenge waste water continuously mixed to ensure consistent feed? **A pump circulates challenge wastewater out of and then back into the influent tank through a recirculation hose.**	X	☐
Are the devices dosed for a minimum of 8 hours each day? Is the dosing pattern based on the design hydraulic capacity of the devices with three periods each day when devices are dosed at their peak capacities? **The dosing system is designed to dose for 8 hours each day.**	X	☐
Is there a mechanism to allow tilting of the device to an angle of 22.5° from horizontal along one side? **The device was designed to allow tilting in all directions. The tilting angle was approximately 30°.**	X	☐
Are the devices periodically tilted during testing?	X	☐
Are any operational problems and maintenance provided recorded in a field log book? **All operational problems were summarized and recorded by samplers.**	X	☐

Type I MSD Testing Audit Checklist for Electroscan (Continued)

Sampling Procedure	Yes	No
Are the challenge wastewater samples collected immediately prior to dosing the device? If more than one challenge wastewater batch is dosed in one day, are the batch samples appropriately composited, mixed, and transferred to appropriate sample containers? **Only one challenge wastewater batch is prepared each day in one influent holding tank and dosed to both devices automatically, so there was no need to composite or mix influent samples.**	X	☐
Are the effluent samples collected with a clean pitcher that is thoroughly decontaminated using Alconox solution and rinsing with deionized/distilled water after each use? **The device had two dedicated effluent containers, which were used to transport samples to the lab to be poured into sample bottles.**	X	☐
Are flow rates monitored and accurate for the collection type? **The automatic dosing system is programmed to switch between peak and off peak as specific times. The system can be programmed to the minute.**	X	☐
Is the Electro Scan allowed to cool down for 30 minutes after 4 to 5 cycles? **The cool-down cycles specified by the operating manual were preprogrammed into the dosing schedule.**	X	☐
Are the sampling locations appropriate (i.e., off the recirculation loop on the feed tank and a sample tap on the effluent piping from each device)?	X	☐
Are the effluent samples taken at the appropriate time intervals (i.e., beginning, middle, and end of daily dosing period with one additional during peak dosing period)?	X	☐
Are the sample containers used to collect the samples appropriately labeled? **Sample labels listed the following information: NSF, device name, sample number, analyte, volume, date, time, and name of sampler.**	X	☐
Are sample collection containers and volumes appropriate for planned analysis per Table 2 of the work plan?	X	☐

Type I MSD Testing Audit Checklist for Electroscan (Continued)

Sampling Procedure	Yes	No
Are the sample labels adequate to prevent tampering, abrasion, smearing, or loss during transit? **Labels were plastic and printed with water proof ink. Anything hand written was done with indelible ink.**	X	☐
Are the sample containers for analysis appropriately stored between sample aliquots (e.g., kept on ice and stored in a cooler to minimize the impact of possible inadvertent contamination or tampering)? **Samples were kept in a refrigerator with a temperature setting of 4°C.**	X	☐
Are samplers following good sampling practices (i.e., being careful not to touch the inside of sample container and lid, wearing new gloves for each sample to prevent cross contaminations, etc.)?	X	☐
Are all collected samples preserved according to Table 2 of the work plan? **Aqua-Tech pre-preserved the sample containers per Table 2.**	X	☐
Is residual chlorine tested promptly following sample collection?	X	☐
Is a container, separate from the sample container, used to collect sample for conducting pH, temperature, and salinity (Electro Scan device only) field tests on each sample aliquot? **The device had a dedicated field test container that was cleaned with Alconox and deionized water after each use.** **A probe was used to measured temperature, pH, conductivity, and dissolved oxygen for each sample.**	X	☐
Is the pH meter rinsed adequately between sampling points? Verify that the pH meter has been calibrated. **The pH meter was calibrated at the start of each day and sits in pH of 4 buffer solution when not in use.**	X	☐
Are microbiological samples transported to the lab within 6 hours of collection? **Samples were picked up within 5-6 hours after the first sample is taken.**	X	☐
Is the field test container appropriately stored between sample aliquots?	X	☐

Type I MSD Testing Audit Checklist for Electroscan (Continued)

Sampling Procedure	Yes	No
Are the correct QC samples and duplicate samples collected?	X	☐
Are all equipment blanks and field duplicates prepared, collected, and stored appropriately after sampling? **Field duplicates were stored with regular samples and treated as such. Equipment blanks were taken the week before testing and already processed by the lab.**	X	☐
Are the processes and sample information, such as flow rates (peak and off peak) and field measurements and sample collection times recorded appropriately in a field log book? **These were all programmed into the dosing system. A printout of a detailed schedule was provided, listing dosing times, times for peak/off peak flows, sample collection time, tilting times, etc**	X	☐
Are the sample bottles maintained on ice and packed well enough to avoid breakage during transport to the laboratory? **Bottles were all plastic, placed in zip-lock bags in the coolers, and covered with ice.**	X	☐