STATE OF MAINE
DEPARTMENT OF HUMAN SERVICES
DIVISION OF HEALTH ENGINEERING
10 STATE HOUSE STATION
AUGUSTA, MAINE
04333-0010

July 7, 2003

ANGUS S. KING, JR.
GOVERNOR

KEVIN W. CONCANNON
COMMISSIONER

F. R. Mahony & Associates, Inc.
Attn.: Keith Dobie, President
~~131~~ 273 Weymouth Street
Rockland, MA 02370

per Bruce Stevens, local representative. JAJ

Subject: Product Registration, Amphidrome Wastewater Treatment System

Dear Sirs:

Thank you for your letter dated May 19, 2003 and accompanying data regarding your company's product. This information was submitted pursuant to Section 1802 of the Maine State Plumbing Code, Subsurface Wastewater Disposal Rules (Rules), for code registration, for use in Maine.

The Amphidrome Wastewater Treatment System has been installed in numerous locations, principally in Massachusetts. Additionally, the system has been tested and verified by the National Sanitation Foundation International (NSFI) pursuant to an Environmental Technology Verification test performed by the Barnstable County (Massachusetts) Department of Health and Environment.

Product Description

The Amphidrome consists of three components: a 2,000 gallon settling and primary clarification tank, a reactor tank, and a 1,000 gallon storage tank/clear well. The Amphidrome is designed for use with conventional onsite sewage disposal areas.

The reactor tank consists of a stainless steel underdrain, supporting the graduated gravel and sand media upon which a biomass is formed. The aeration and influent distribution manifolds are located beneath the underdrain. The aeration system operates on an intermittent basis, in order to induce a cycle of oxygen rich and anoxic conditions.

Raw wastewater enters the primary clarification tank, where solids separation occurs. Effluent from the primary clarification tank than flows by gravity to the reactor tank, where it is aerated and passed through graduated gravel and sand filter media. The treated effluent then flows by gravity to a storage tank/clear well, where it is stored for redistribution to the reactor tank.

Claim

According to the information you provided, the Amphidrome achieves a high degree of total nitrogen removal through denitrification in the reactor tank, by using effluent from the primary clarification tank as a carbon source for the stored treated flow from the clear well. Additionally, $CBOD_5$ and TSS levels typically are reduced to less than 10 percent of influent levels, each.

Determination

On the basis of the data submitted in support of this product, including the NSFI report, the Division has determined that the Amphidrome is acceptable for use in the State of Maine on a General Use basis, provided that it is installed, operated, and maintained in conformance with the manufacturer's directions.

In the event that the product fails to perform as claimed by the applicant, use of the new or experimental technology in Maine, including all installations approved pursuant to Section 1801.7 of the Rules, shall cease. Use of the new or experimental technology shall not resume until the applicant and the Division have reached a mutually acceptable agreement for resolving the failure to perform as claimed.

Because installation and owner maintenance has a significant effect on the working order of onsite sewage disposal systems, including their components, the Division makes no representation or guarantee as to the efficiency and/or operation of Amphidrome . Further, registration of this product for use in the State of Maine does not represent Division preference or recommendation for this product over similar products.

If you have any questions please feel free to contact me at (207) 287-5695.

Sincerely,

James A. Jacobsen, Environmental Specialist IV
Wastewater and Plumbing Control Program
Division of Health Engineering
e-mail: james.jacobsen@state.me.us

/jaj

Enc: Chapter 18, CMR 241

xc: Product File

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CHAPTER 18

SEASONAL CONVERSION

SECTION 1800.0 GENERAL

1800.1 Scope: This chapter governs the conversion of seasonal dwelling units into year-round residences if the system serving the structure is within the shoreland zone areas of major waterbodies/courses.

1800.2 Exemptions: This Chapter does not apply to a dwelling that:

1800.2.1 Occupation: Will be occupied seasonally; or,

1800.2.2 Principal dwelling: Is the principal dwelling place of the occupant; or

1800.2.3 Outside shoreland zoning: Has its system located outside the shoreland zone of major waterbodies/courses area.

1800.3 Seasonal dwelling defined: A dwelling which existed on December 31, 1981, and which was not used as a principal or year-round residence during the period from 1977 to 1981. (Title 30-A MRSA §4201).

1800.4 Principal or year-round residence defined: *A dwelling which existed on December 31, 1981, and which was used as a principal or year-round residence during the period from 1977 to 1981.* Evidence of use as principal or year round residence includes, but is not limited to, the listing of that residence as an occupant's legal residence for the purpose of either voting, filing a state tax return, or automobile registration. (Title 30-A MRSA §4201).

SECTION 1801.0 SEASONAL CONVERSION PERMIT

1801.1 Seasonal conversion permit required: Before converting a seasonal dwelling that has a system located in the shoreland zone of major waterbodies/courses area (as defined in Title 38 MRSA §435) to a year-round or principal dwelling, a seasonal conversion permit shall be obtained from the plumbing inspector (as required by Title 30-A MRSA §4215(2).

1801.2 Unorganized areas of the State: Seasonal conversion permits for structures within unorganized areas of the state will be issued by the LPI, or the Division of Health Engineering, Bureau of Health, Department of Human Services in coordination with the Land Use Regulatory Commission.

1801.3 Holding tanks prohibited: A seasonal conversion permit shall not be approved if a holding tank is used as a means of waste water disposal or storage. (30-A §4215 subsection 2)

1801.4 Permit for seasonal conversion: The plumbing inspector shall issue a permit for conversion of a seasonal dwelling to a year-round or principal dwelling if one of the following requirements is met:

1801.4.1 Existing legal system: A subsurface waste water disposal application, dated after July 1, 1974, exists showing that the dwelling's system substantially complies with this code and applicable municipal ordinances. The system shall have been installed with the required permit and a certificate of approval shall have been issued; or

1801.4.2 Legal replacement system: A replacement for an existing waste water system has been installed so that it complies with Section 1802.0 and applicable municipal ordinances; or

1801.4.3 Public sewer available: The dwelling unit's waste water is connected to an approved sanitary sewer system.

SECTION 1802.0 SUBSTANTIAL COMPLIANCE

1802.1 General: A system is deemed to be in substantial compliance with this code, providing the requirements in this Section are met.

1802.2 Municipal ordinances: The system meets applicable municipal ordinances;

1802.3 Septic tank: The septic tank meets the requirements of Chapter 9;

1802.4 Disposal field: The disposal field meets the applicable requirements of Chapter 6. See Table 600.4;

1802.5 Site conditions: The site meets the siting requirements in Chapter 4;

1802.6 Setbacks: The setbacks shall meet or exceed the minimum horizontal setback distances in Table 700.4.

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f.r. mahony & associates inc.
frma water supply and pollution control equipment
273 Weymouth Street • Rockland, MA 02370

AUG 08 2003

August 5, 2003

Mr. James A. Jacobsen
Environmental Specialist IV
Division of Health Engineering
State House Station 11
Augusta, ME 04333-0011

Dear Mr. Jacobsen:

Enclosed please find our ETV Joint Verification Statement being sent to you at the request of Mr. Keith Dobie.

Please do not hesitate to contact this office with any questions that you may have.

Very truly yours,

F. R. Mahony & Associates, Inc.

Tracey Wahlberg

Tracey Wahlberg

Enclosure
Sent via US Mail

tel. 781.982.9300 • fax. 781.982.1056 • frma@compuserve.com • www.frmahony.com

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**BIOLOGICAL WASTEWATER TREATMENT – NITRIFICATION AND DENITRIFICATION FOR NITROGEN REDUCTION**
APPLICATION:	**REDUCTION OF NITROGEN IN DOMESTIC WASTEWATER FROM INDIVIDUAL RESIDENTIAL HOMES**
TECHNOLOGY NAME:	**AMPHIDROME™ MODEL SINGLE FAMILY SYSTEM**
COMPANY:	**F.R. MAHONY & ASSOCIATES, INC.**
ADDRESS:	**273 WEYMOUTH STREET ROCKLAND, MA 02370** — **PHONE: (781) 982-9300 FAX: (781) 982-1056**
WEB SITE:	http://www.frmahony.com
EMAIL:	keithdobie@frmahony.com

NSF International (NSF) operates the Water Quality Protection Center (WQPC) under the U.S. Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) Program. The WQPC evaluated the performance of a submerged growth biological filter treatment system for nitrogen removal for residential applications. The Barnstable County (Massachusetts) Department of Health and the Environment (BCDHE) performed the verification testing. This verification statement provides a summary of the test results for the F.R. Mahony & Associates, Inc. (FRMA), Amphidrome™ Model Single Family System.

The ETV program was created to facilitate deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by substantially accelerating the acceptance and use of improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

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

ABSTRACT

Verification testing of the Amphidrome™ Model Single Family System was conducted over a thirteen-month period at the Massachusetts Alternative Septic System Test Center (MASSTC) located at Otis Air National Guard Base in Bourne, Massachusetts. Sanitary sewerage from the base residential housing was used for the testing. An eight-week startup period preceded the verification test to provide time for the development of an acclimated biological growth in the Amphidrome™ System. The verification test included monthly sampling of the influent and effluent wastewater, and five test sequences designed to test the unit response to differing load conditions and power failure. The Amphidrome™ System proved capable of removing nitrogen from the wastewater. The influent total nitrogen (TN), as measured by TKN, averaged 37 mg/L with a median of 37 mg/L. The effluent TN (TKN plus nitrite/nitrate) concentration averaged 15 mg/L over the verification period, with a median concentration of 14 mg/L, with an average TKN concentration of 8.5 mg/L and a median concentration of 8.3 mg/L. The system operating conditions (pump and float settings, aeration cycles), are controlled by a programmable logic controller (PLC) and were adjusted four times during the first two months of the verification test, and after six months of test operation. In general, the mechanical equipment, pumps, level switches and alarms operated properly during the test, except for a discharge pump failure after nine months of operation, and the return pump slipping off its pedestal in June 2001. The Amphidrome™ System is sophisticated and requires a trained operator to monitor the system and ensure the pump cycle times, aeration periods, and backwash settings are set to the site specific conditions.

TECHNOLOGY DESCRIPTION

The following description of the F.R. Mahoney Amphidrome System was provided by the vendor and does not represent verified information.

The Amphidrome™ System consists of a submerged growth sequencing batch reactor used in conjunction with an anoxic/equalization tank (standard 2,000 gallon tank, but a 1,500 gallon two compartment septic tank for this test), and a clear well tank for wastewater treatment. The anoxic tank provides solid-liquid separation, and anoxic conditions for denitrification. The bioreactor consists of a deep bed sand filter, which alternates between aerobic and anoxic treatment. The reactor operates similar to a biological aerated filter, except that the reactor changes from aerobic to anoxic conditions during sequential cycling of the unit. Air, supplied by a blower, is introduced at the bottom of the filter by a distribution system that produces fine bubbles to enhance oxygen transfer. According to the vendor, the unique system design allows soluble organic removal, nitrification, and denitrification to occur in one reactor.

The cyclical action of the system is created by allowing a batch of wastewater to pass by gravity flow from the anoxic/equalization tank through the submerged sand filter (down flow mode) and into the clear well. The flow is then reversed using a pump to move water from the clear well up through the filter and into a return pipe, which carries the wastewater back to the anoxic tank. These cycles are repeated multiple times during a 24-hour period. The conditions in the filter change from aerobic to anoxic based on the timing of the aeration cycles, with a typical cycle being 3 to 5 minutes of aeration, followed by 15 minutes without aeration. The filter is backwashed using a combination of aeration and pumped water from the clear well. Treated wastewater is discharged once per day from the clear well by pumping to the receiving location. The Amphidrome™ System is supplied with a programmable logic controller (PLC), which controls the frequency and duration of pump operation, aeration cycles, backwash, and discharge, as well as all alarm functions and data collection.

VERIFICATION TESTING DESCRIPTION

Test Site

The MASSTC site is located at the Otis Air National Guard Base in Bourne, Massachusetts. The site uses domestic wastewater from the base residential housing, and sanitary wastewater from other military buildings in testing. A chamber located in the main interceptor sewer to the base wastewater treatment facility provides a location to obtain untreated wastewater that is pumped to the site dosing channel after passing through a one-inch bar screen. The channel is equipped with four recirculation pumps that are spaced along the channel length to ensure mixing and wastewater of similar quality in the channel. Wastewater is dosed to the test unit using a pump submerged in the dosing channel. A programmable logic controller (PLC) is used to control the pumps and the dosing sequence or cycle.

Methods and Procedures

The Amphidrome™ System was installed by a contractor in December 1999 as part of an earlier test program. The unit was installed in accordance with the installation instructions supplied by FRMA. In order to prepare for ETV testing, the entire system was emptied of wastewater and cleaned. Solids were removed from the septic tank and the clear well, all pumps, lines, and associated equipment were cleaned, and the sand filter was flushed repeatedly by recirculating clean water through the system. The entire system was then drained and remained off until the startup period. On January 15, 2001, the septic tank was filled with wastewater and the standard dosing sequence began. An eight-week startup period allowed the biological community to become established and the operating conditions to be monitored.

System monitoring during the startup period included visual observations, routine calibration of the dosing system, and collection of influent and effluent samples. Six sets of samples were collected for analysis over the startup period. Influent samples were analyzed for pH, alkalinity, temperature, BOD_5, TKN, NH_3, and TSS analyses. Effluent samples were analyzed for pH, alkalinity, temperature, $CBOD_5$, TKN, NH_3, TSS, dissolved oxygen, NO_2^- and NO_3^-.

Verification testing consisted of a thirteen-month period, with five stress test sequences simulating household conditions. The five stress sequences were performed at two-month intervals, and included washday, working parent, low load, power/equipment failure, and vacation conditions. Monitoring for nitrogen reduction was accomplished by measuring the nitrogen species (TKN, NH_3, NO_2, NO_3), while biochemical and carbonaceous oxygen demand (BOD_5/$CBOD_5$) and other basic parameters (pH, alkalinity, TSS, temperature) were monitored to provide information on overall system performance. Operational characteristics, such as electric use, residuals generation, maintenance tasks and labor, hardware durability, noise and odor production were also monitored.

The Amphidrome™ System was tested at the design capacity of 400 gallons per day (± 10 percent) for the entire thirteen-month test, except during the low load and vacation stress tests. The Amphidrome™ System was dosed 15 times per day with approximately 26.7 gallons of wastewater per dose. The unit received five morning doses, four mid-day doses, and six evening doses. Dosing volume was controlled by adjusting pump run time for each cycle, based on twice-weekly calibration of the dosing pump.

The sampling schedule included collection of twenty-four hour flow weighted composite samples of the influent and effluent wastewater once per month under normal operating conditions. Stress test periods were sampled on a more intense basis with six to eight composite samples collected during and following each stress test period. Five consecutive days of sampling occurred in the twelfth month of the verification test. All composite samples were collected using automatic samplers located at the dosing channel (influent sample) and at the discharge of the unit. Grab samples were collected on each sampling day to monitor the system pH, dissolved oxygen, and temperature.

Samples were collected and preserved as appropriate, and transported to the laboratory. All analyses were performed according to "*Standard Methods for the Examination of Water And Wastewater*", 19th Edition, 1998. Washington, D.C. or other EPA approved methods. An established quality assurance/ quality control (QA/QC) program was used to monitor field sampling and laboratory analytical procedures. QA/QC requirements included field duplicates, laboratory duplicates and spiked samples, and appropriate equipment/instrumentation calibration procedures. Details on the analytical methods and QA/QC procedures are provided in the full Verification Report.

PERFORMANCE VERIFICATION

Overview

Evaluation of the Amphidrome System at MASSTC began on March 13, 2001, when the system pumps were activated and the wastewater dosing started. Verification testing continued for thirteen months until April 17, 2002. During the verification test, 53 sets of samples of the influent and effluent were collected to determine the system performance.

Startup

The unit started up with no difficulty. The installation instructions were easy to follow and installation proceeded without difficulty. FRMA representatives setup the PLC, which controlled all recirculation, aeration, backwash, and discharge times. No changes were made to the unit during the startup period and no special maintenance was required.

The Amphidrome™ System showed a reduction in $CBOD_5$ and TSS after the first week of operation, and continued to improve over the next seven weeks. At the end of the eight-week startup, effluent $CBOD_5$ was 5.0 mg/L and TSS was 4 mg/L. There was some TN reduction occurring, with effluent concentrations varying between 21 and 28 mg/L, compared to influent concentrations of 34 to 46 mg/L. However, it did not appear that the nitrifying organisms were firmly established in the system. Low wastewater temperature was considered the primary reason for the slow trend toward improved reduction in TN as the wastewater temperature was no higher than about 8 °C through March 13.

Verification Test Results

The verification protocol requires sampling during and following the major stress periods. This results in a large number of samples being clustered during five periods, with the remaining samples spread over the remaining months (monthly sampling). Both average (mean) and median results are presented, as the median values compared to average values can help in analyzing the impacts of the stress periods.

The TSS and $BOD_5/CBOD_5$ results for the verification test, including all stress test periods, are shown in Table 1. The influent wastewater had an average BOD_5 of 210 mg/L (median of 200 mg/L) and average TSS of 150 mg/L (median of 130 mg/L). The Amphidrome™ effluent had an average $CBOD_5$ of 4.9 mg/L, with a median $CBOD_5$ of 4.4 mg/L. The average effluent TSS was 5 mg/L and the median was 3 mg/L. During the thirteen-month test, effluent $CBOD_5$ concentrations typically ranged from 1 to 10 mg/L, except for two samples, and TSS ranged from 1 to 11 mg/L, except for 3 samples.

Table 1. BOD_5/$CBOD_5$ and TSS Data Summary

	BOD_5 Influent (mg/L)	$CBOD_5$ Effluent (mg/L)	Percent Removal	TSS Influent (mg/L)	TSS Effluent (mg/L)	TSS Percent Removal
Average	210	4.9	97	150	5	96
Median	200	4.4	98	130	3	98
Maximum	370	20	>99	340	40	>99
Minimum	67	<2.0	90	61	1	64
Std. Dev.	73	3.5	1.5	67	7	6.0

Note: The data in Table 1 are based on 53 samples.

The nitrogen results for the verification test, including all stress test periods, are shown in Table 2. The influent wastewater had an average TKN concentration of 37 mg/L (median of 37 mg/L) and an average ammonia nitrogen concentration of 23 mg/L (median of 23 mg/L). The average TN concentration in the influent was 37 mg/L (median of 37 mg/L), based on the assumption that the nitrite and nitrate concentrations in the influent were negligible. The Amphidrome™ System effluent had an average TKN concentration of 8.5 mg/L (median of 8.3 mg/L) and an average NH_3-N concentration of 7.0 mg/L (median of 6.1 mg/L). The nitrite concentration in the effluent averaged 0.27 mg/L, while effluent nitrate concentrations averaged 6.4 mg/L (median of 5.5 mg/L). Total nitrogen was determined by adding the daily concentrations of the TKN (organic plus ammonia nitrogen), nitrite, and nitrate. Average TN in the Amphidrome™ System effluent was 15 mg/L (median 14 mg/L) for the thirteen-month verification period. The System averaged a 59 percent reduction of TN for the entire test, with a median removal of 62 percent.

Table 2. Nitrogen Data Summary

	TKN (mg/L)		Ammonia (mg/L)		Total Nitrogen (mg/L)		Nitrate (mg/L)	Nitrite (mg/L)	Temperature (°C)
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Effluent	Effluent	Influent
Average	37	8.5	23	7.0	37	15	6.4	0.27	15
Median	37	8.3	23	6.1	37	14	5.5	0.25	14
Maximum	45	31	29	25	45	31	19	1.3	22
Minimum	24	1.0	18	0.4	24	10	<0.1	0.08	8.4
Std. Dev.	4.1	6.4	2.4	4.7	4.1	3.6	4.5	0.20	4.3

Note: The data in Table 2 are based on 53 samples, except for temperature, which is based on 42 samples.

Verification Test Discussion

Beginning in late March and early April, temperatures began to increase and the nitrifying population clearly became more firmly established, as indicated by the decrease in the effluent TKN and ammonia concentrations to 10 mg/L or less. Nitrate concentrations increased somewhat in this same period, but the data show that denitrification was also occurring. Organic concentration in the effluent was low, as measured by $CBOD_5$ concentrations of 4.0-5.0 mg/L. During May and June, the TN concentration in the effluent was in the range of 13 to 16 mg/L. The washday stress test in May 2001 showed no negative impact on nitrogen reduction.

In early July 2001, the data show that there was loss of the nitrifying population in the unit, with TKN and ammonia nitrogen levels in the effluent increasing to 31 and 25 mg/L, respectively. The nitrate levels dropped to less than 0.1 mg/L, which would be more typical of influent wastewater. On June 21, it was discovered that the return pump had slipped off its pedestal, disconnecting the return line and stopping the return flow through the sand filter to the anoxic tank. It is estimated that the wastewater was treated by only a single pass through the sand filter for about two weeks before the return pump problem was corrected and proper operation was restored. The lack of recycle flow apparently caused the loss of nitrification in the system.

The working parent stress test started on July 9 and continued until July 13, 2001. The Amphidrome System began to recover from the June upset with improved $CBOD_5$ and TSS performance, but the nitrification process was much slower in its recovery. Some removal of TKN, ammonia and TN occurred during the working parent stress test monitoring in mid-July, but at a lower performance level than during the previous two months. During the stress test, there was no sign that the stress test itself was having any additional impact on the system.

The monthly samples on August 1 and September 5 showed an improvement in the removal of TKN and ammonia, indicating that the nitrifying population was re-established. Nitrate levels in the effluent increased somewhat (from 3.3 to 7.9 mg/L) and TN in the effluent was in the 14 to 15 mg/L range.

The low load stress test began on September 17 and continued until October 8, 2002. During this stress period, the nitrification process became very efficient, dropping the TKN and ammonia levels in the effluent to less than 1 mg/L. Nitrate concentrations increased to 14 to 19 mg/L and TN was 14 to 20 mg/L. As the low load stress test ended, virtually all of the TN in the effluent was in the form of nitrate. Once the system returned to normal full flow conditions, the TKN and ammonia concentrations in the effluent rose slightly (from 1.2 to 4.8 mg/L), and nitrate concentrations decreased to 10 to 14 mg/L. Overall, the TN removal performance was steady at the end of the monitoring period with effluent concentrations of 10 to 14 mg/L, similar to the results obtained in May prior to the upset, except that the primary component of the TN concentration was nitrate. The vendor decreased the aeration time by ten percent to try to improve denitrification performance.

During the November 2001 to January 2002 period, including the power/equipment failure stress test in December, the Amphidrome System produced steady results, with TN in the effluent of 10 to 16 mg/L, a removal efficiency of 57 to 77 percent. TN in the effluent was composed of TKN and nitrate, similar to the two month period prior to the June upset condition. The power/equipment failure stress test, performed on December 3 did not have a major impact on the system.

The vacation stress test (no influent flow for eight days) was performed in February 2002. The effluent TKN and ammonia concentrations decreased in the samples taken immediately after flow was resumed to the system. The nitrate levels increased in a manner similar to the findings following the low load stress test. TN concentrations remained steady in the effluent ranging from 12 to 17 mg/L. By the end of the post stress test monitoring period, effluent concentrations consisted of TKN at 5.5 mg/L and nitrate at 6.8 mg/L. These data, supported by the results from the low load stress test, suggest that the Amphidrome™ System responded to decreases in flow by exhibiting improved nitrification and less denitrification. The TN performance, however, did not change much, with effluent concentrations remaining near the long-term average and median of 15 mg/L and 14 mg/L, respectively.

The Amphidrome System performance remained consistent for the duration of the verification test, with TKN and ammonia nitrogen effluent concentration consistently in the 7.6 to 9.5 mg/L range. The nitrate levels remained in the 3.0 to 4.8 mg/L range. The TN concentration in the effluent ranged from 11 to 15 mg/L.

The verification test provided a sufficiently long test period to collect data that included both a long run of steady performance by the Amphidrome™ System and a period of reduced nitrification and denitrification efficiencies. During the months of April through June, following startup, the TN removal was in the 45 to 71 percent range, with effluent concentrations typically in the 13 to 16 mg/L range. The June upset condition, caused by the problem with the return pump, dramatically impacted the nitrification process in early July. The system recovered from the upset by the end of July and continued to remove TN. During the last eight months of the verification test, the TN removal was in the 52 to 77 percent range. Effluent TN concentration ranged from 10 to 20 mg/L, with most concentrations in the 13 to 15 mg/L range. Data collected from the two low or no flow stress tests indicated that overall system performance for TN was not significantly impacted, but the effluent concentrations of TKN, ammonia and nitrate changed significantly during these lower flow periods.

Operation and Maintenance Results

Noise levels associated with mechanical equipment were measured once during the verification period using a calibrated decibel meter. Measurements were made one meter from the unit, and one and a half meters above the ground, at 90° intervals in four (4) directions. The average decibel level was 56.7, with a minimum of 54.3 and maximum of 60.0. The background level was 37.7 decibels.

Odor observations were made monthly for the last eight months of the verification test. The observation was qualitative based on odor strength (intensity) and type (attribute). Observations were made during periods of low wind velocity (<10 knots), at a distance of three feet from the treatment unit, and recorded at 90° intervals in four directions. There were no discernible odors during any of the observation periods.

Electric power use was monitored by a dedicated electric meter serving the Amphidrome™ System. The average electrical use was 4.1 kW/day. However, there was one two-week period of high electrical use in June 2001, when the return pump slipped off its pedestal, disconnecting the return line and pumping continuously for about two weeks.

During the verification test, one other mechanical problem occurred when the discharge pump failed. The high water alarm sounded and a service call was placed to FRMA. They responded within twenty-four hours and replaced the pump. Overall, the treatment unit appeared to be a durable design. The piping is PVC, which is appropriate for the applications. Pump and level switch life is always difficult to estimate, but the components used were made for wastewater applications. The PLC, which is critical to the operation of the system, functioned properly throughout the test. The system does not require or use any chemicals as part of normal operating conditions.

The Amphidrome™ System is a somewhat complex, PLC controlled wastewater treatment system, using a sophisticated operating cycle that must be setup and optimized to site specific and changing conditions. During the first two months of verification testing (April and May), the vendor adjusted the PLC on four occasions. The airflow was adjusted in early April and the backwash cycle was adjusted in mid-May. On May 24, the cycle times were adjusted to try to improve the performance, but were returned to the initial conditions on June 1. The anoxic cycle was adjusted on October 21, and the fixed airflow time was reduced by 10 percent on October 25, 2001 to try to improve denitrification. These adjustments were made to try to match the aerobic/anoxic cycles to the wastewater and system conditions. Based on these observations, it will be necessary for homeowners to have a qualified maintenance organization operate and maintain the system.

Quality Assurance/Quality Control

NSF International completed QA audits of the MASSTC and BCDHE laboratory during testing. NSF personnel completed a technical systems audit to assure the testing was in compliance with the test plan, a performance evaluation audit to assure that the measurement systems employed by MASSTC and the

BCDHE laboratory were adequate to produce reliable data, and a data quality audit of at least 10 percent of the test data to assure that the reported data represented the data generated during the testing. In addition to quality assurance audits performed by NSF International, EPA QA personnel conducted a quality systems audit of NSF International's QA Management Program, and accompanied NSF during audits of the MASSTC and BCDHE facilities.

Original signed by *Hugh W. McKinnon*	*7/23/03*	*Original signed by* *Gordon E. Bellen*	*7/23/03*
Hugh W. McKinnon Director National Risk Management Research Laboratory Office of Research and Development United States Environmental Protection Agency	Date	Gordon E. Bellen Vice President Research NSF International	Date

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

Availability of Supporting Documents

Copies of the *ETV Protocol for Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction,* dated November 2000, the Verification Statement, and the Verification Report are available from the following sources:

ETV Water Quality Protection Center Manager (order hard copy)
NSF International
P.O. Box 130140
Ann Arbor, Michigan 48113-0140
NSF web site: http://www.nsf.org/etv (electronic copy)
EPA web site: http://www.epa.gov/etv (electronic copy)

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

EPA's Office of Wastewater Management has published a number of documents to assist purchasers, community planners and regulators in the proper selection, operation and management of onsite wastewater treatment systems. Two relevant documents and their sources are:

1. *Handbook for Management of Onsite and Clustered Decentralized Wastewater Treatment Systems* http://www.epa.gov/owm/onsite

2. *Onsite Wastewater Treatment Systems Manual* http://www.epa/gov/owm/mtb/decent/toolbox.htm

f.r. mahony & associates inc.
frma water supply and pollution control equipment
273 Weymouth Street • Rockland, MA 02370

AMPHIDROME® FACILITY REPORT

Plant & Location: Easton Crossing Condominiums, Easton, Massachusetts

Details: 36,500 gpd Title 5 flow. The plant is designed to meet secondary treatment standards and in addition to reduce total nitrogen to less than 10 mg./L.

Operating Experience: The plant had a challenging start because of some field changes made to the design during construction, valves that were improperly designed and, operator inexperience with operating a modem BNR System (biological nutrient removal system). Once the construction problems were resolved and the operator became comfortable with the system, excellent results have been obtained. This is one of the few systems, designed using Title 5 low guidelines, that we have ever seen exceed the design flows. Despite this, the average total nitrogen for the past 36 months has been 6.5 mg./L. which is well within the design target of 10 mg./L.

	BIOCHEMICAL OXYGEN DEMAND	TOTAL SUSPENDED SOLIDS	TOTAL NITROGEN	FATS, OIL, AND GREASE
PERMIT LIMIT	30 mg./L.	30 mg./L.	10 mg./L	15 mg./L.
EFFLUENT	7.9 mg./L.	3.2 mg./L.	6.5 mg./L	1.5 mg./L.*

*One obviously erroneous data point of 71 mg./L. was eliminated from this calculation. The influent concentration on that date was only 44 mg./L. On other days when influent FOG was in the range of 45 mg./L., effluent FOG was 1.5 mg./L.

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AMPHIDROME® FACILITY REPORT

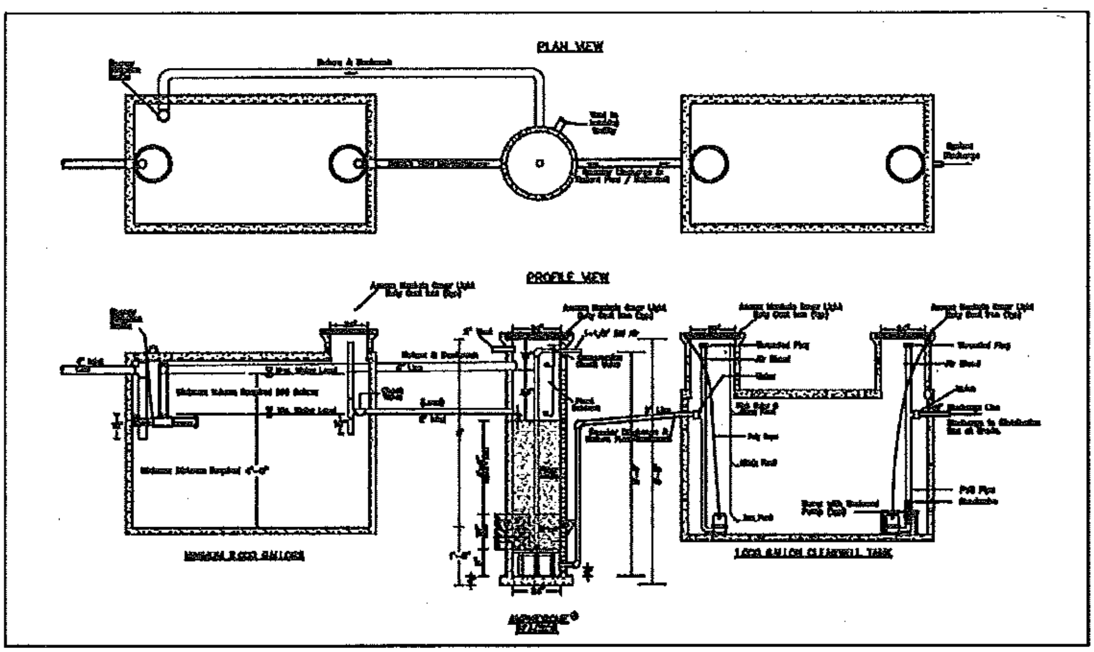
Plant & Location: Single Family Dwelling - Waquoit, Massachusetts

Details: 330 gpd Title 5 flow. The plant is designed to meet secondary treatment standards and, in addition, to reduce total nitrogen to less than 19 mg./L.

Operating Experience: This was the first Amphidrome® system ever installed, and as such it does not reflect some of the refinements of later units. However, this unit has provided stellar performance both from a reliability standpoint (there have been no equipment failures) and effluent quality. The effluent data average for the years 1999, 2000, 2001, 2002 and 2003 are reflected in the table below.

	BIOCHEMICAL OXYGEN DEMAND	TOTAL SUSPENDED SOLIDS	TOTAL NITROGEN
PERMIT LIMIT	30 mg./L.	30 mg./L.	19 mg./L.
EFFLUENT	3.7 mg./L.	3.8 mg./L.	6.5 mg./L.

The system is below grade and the media is always flooded as shown in the diagram below; therefore, atmospheric temperature variations have little effect on system performance. The incoming wastewater and the heat generated by the biomass sustain a bed temperature sufficient for the needed biological activity.



State of Maine
Department of Human Services
Division of Health Engineering
11 State House Station
Augusta, Maine
04333-0011

John Elias Baldacci
Governor

DATE 7/28/03	TIME	AM/PM
TO: Bruce Stevens		
FROM: Jim Jacobsen, DHS-DHE		

PAGES INCLUDING THIS COVER SHEET: 3

MESSAGE:

Amphidrome registration

f.r. mahony & associates inc.
frma water supply and pollution control equipment
273 Weymouth Street • Rockland, MA 02370

May 19, 2003

James Jacobsen
Bureau of Health
Division of Health Engineering
10 State House Station
Augusta, ME 04333-0010

Re: Amphidrome®

Dear Mr. Jacobsen:

We are hereby submitting for registration and approval as an experimental wastewater treatment system. Amphidrome® is designed to prevent public health problems by greatly reducing the chances of a discharge to the surface of the ground. The reason there is less chance of a surface discharge is that the load to the leaching field of both BOS and suspended solids is greatly reduced. All wastewater is filtered through a minimum of four feet of sand. Coliform concentration is also greatly reduced. In addition Amphidrome® protects the public health and the environment by greatly reducing nitrate contamination of Groundwater.

The attached information is included for your use in reviewing Amphidrome®. An installation list is included and we have laboratory data on most of the installations. If you would like lab data in addition to the reports submitted please let us know.

Yours very truly,
F.R. Mahony & Associates, Inc.

Keith Dobie
President

tel. 781.982.9300 • fax. 781.982.1056 • frma@compuserve.com • www.frmahony.com

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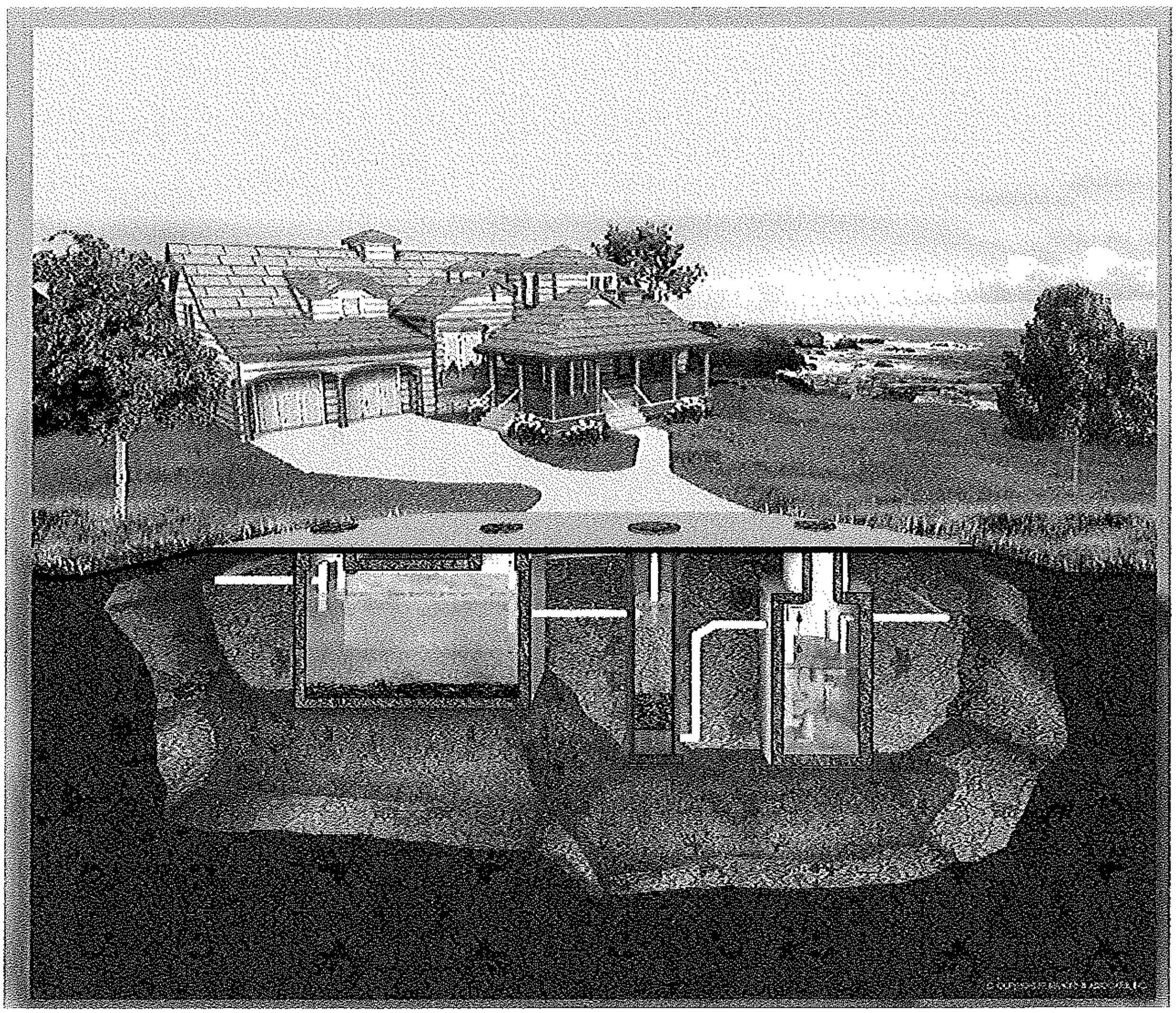

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273 Weymouth Street·Rockland, MA 02370

Phone 781.982.9300 **Fax 781.982.1056**
Email FRMA@compuserve.com **Web page: www.frmahony.com**

Waste Water Treatment Systems

Partial Installation List (11/02)

Project Name	Design Flow (GPD)	Year	Application	Comment
Sterling Health Care Facility Sterling, MA	21,500	2002	Health Care	RBC Nitrification Submerged RBC Denite
Freetown-Lakeville Middle School Lakeville, MA	35,000	2002	School	Amphidrome®Plus
Alewood Meadows Boxborough, MA	16,000	2002	Housing Development	RBC Denite Filter
Black Rock Development Hingham, MA	56,000	2002	Golf Course and Homes	Amphidrome® Plus
Silver Brook Farm Norwell, MA	9,900	2002	Adult Community Homes	Amphidrome®
Merchants Row Hanover, MA	18,000	2002	Mercantile	Amphidrome® Plus
65 Summit Street	440	2002	Single Family Dwelling	Amphidrome®
Debettencourt Property Oak Bluffs, MA	440	2002	Single Family Dwelling	Amphidrome®
Lapine, OR	440	2002	(3) Single Family Dwellings	Amphidrome®
Valley Shore YMCA Westbrook, CT	10,700	2002	YMCA	Denite Filter

Chatham Bars Inn Chatham, MA	35,000	2002	Inn and Restaurant	Amphidrome®Plus
Ridder Farm Whitman, MA	50,000	2002	Golf Course	Amphidrome® Plus
Full Service Retirement Community Acton, MA	22,000	2001	Senior Living Center	Amphidrome® Plus
Fuller Pond Condominiums Middleton, MA	50,000	2001	Condominiums	Denite Filter
Westford Technology Park Westford, MA	18,750	2001	Office Park	RBC Nitrification Denite
Nashoba View Office Park Westford, MA	80,000	2001	Office Park	RBC Nitrification Submerged RBC Denite
Windchime Point Mashpee, MA	40,000	2001	Condominiums	Amphidrome® Plus
Trestle Way & Laurel Clusters Georgetown, MA	19,000	2001	Condominiums	Amphidrome® Plus
Donovan Farms Norwell, MA	6,000	2001	Town Houses	Amphidrome®Plus
Norwell High School Norwell, MA	9,000	2001	School	Amphidrome®Plus
Little's Hill Georgetown, MA	24,000	2000	Housing Development	RBC Denite Filter
RHCI Sandwich, MA	12,000	2000	Hospital	Amphidrome® Plus
Brook Village Boxboro, MA	33,000	2000	Condominiums	Amphidrome® Plus
Hearthside of Plymouth Plymouth, MA	14,000	2000	Senior Living Center	Amphidrome® Plus
Marshfield High School Marshfield, MA	50,000	2000	School	RBC Denite Filter
Victory Market	13,540	2000	Retail Food Market	Amphidrome® Plus

Norwell, MA				
Stop & Shop Madison, CT	6,350	2000	Retail Food Market	Denite filter
Pond Home Wrentham, MA	17,000	1999	Health Care	Amphidrome® Plus
Weston High School Weston, MA	30,000	1999	School	Amphidrome® Plus
Eastham Lobster Pool Eastham, MA	8,500	1999	Restaurant	Amphidrome®
Hildreth Hills Westford, MA	44,000	1999	Condominiums	Denite filter
Meadows at Mainstone Wayland, MA	25,000	1999	Condominiums	Amphidrome® Plus
Plymouth South High School Plymouth, MA	18,000	1999	School	Denite Filter
Greenways Wayland, MA	25,000	1999	Condominiums	Amphidrome® Plus
Westford Academy Westford, MA	38,000	1999	School	RBC Denite Filter
Apple Hill Topsfield, MA	20,000	1999	Health Care	RBC Denite Filter
Meadowview North Reading, MA	17,000	1999	Health Care	RBC Denite Filter
Ocean Edge Brewster, MA	25,000	1999	Resort	Amphidrome® Plus
Sandwich High School Sandwich, MA	31,000	1999	School	Amphidrome® Plus
Wengren Property Nantucket, MA	440	1999	Single Family Dwelling	Amphidrome®
West Island WWTF Fairhaven, MA	100,000	1998	Municipal	RBC Nitrification Submerged RBC Denite
Neville Property Holliston, MA	550	1998	Single Family Dwelling	Amphidrome®

Easton Crossing Easton, MA	40,000	1998	Condominiums	Amphidrome® Plus
Case High School Swansea, MA	10,000	1998	School	Amphidrome® Plus
Hamilton-Wenham Regional School Hamilton, MA	14,469	1997	School	Amphidrome® Plus
Shaker Lane Elementary School Littleton, MA	5,500	1997	School	Amphidrome®
Walmart Halifax, MA	30,000	1997	Shopping Plaza	RBC Submerged Denite
Norton High School Norton, MA	19,200	1997	School	RBC Submerged Denite
Stratford Ponds Mashpee, MA	36,000	1997	Condominiums	Amphidrome® Plus
First Federal Savings Bank Swansea, MA	5,000	1996	Corporate Office	Amphidrome®
Golder Property Falmouth, MA	440	1996	Private Residence	Amphidrome®
Stuart's Plaza Swansea, MA	15,000	1996	Shopping Mall	Amphidrome®
Easton School Easton, MA	40,000	1996	High School	RBC Nitrification Submerged RBC Denite
Aquinnah Wampanoag Tribal Gay Head, MA	30,000	1995	Tribal Housing	RBC Nitrification Submerged RBC Denite
Orchard Hill Oxford, MA	45,000	1995	Condominiums	RBC Nitrification
Holiday Inn (Host Hotel) Boxborough, MA	40,000	1994	Hotel	RBC Nitrification Submerged RBC Denite
Seacrest Hotel & Conference Center N. Falmouth, MA	100,000	1994	Resort	RBC Nitrification Submerged RBC Denite

Barnstable Middle School Barnstable, MA	32,000	1994	School	RBC Nitrification Denite
Willowbend Mashpee, MA	140,000	1994	Golf	RBC Nitrification Submerged RBC Denite
Suburban Manor Acton, MA	30,000	1994	Health Care Facility	RBC Nitrification Submerged RBC Denite
Norumbega Point Weston, AM	40,000	1994	Health Care Facility	RBC Nitrification Submerged RBC Denite
Arlington School Arlington, VT	20,000	1993	School	RBC Nitrification
U.S. Embassy Bangkok, Thailand	5,000	1993	Office Bldg & Residence	BOD Removal RBC
Demoulas Market Basket Raynham, MA	25,000	1993	Shopping Center	RBC Nitrification
South Shore Pumping Carver, MA	100,000	1993	Septage Treatment	Filter Presser RBC Nitrification Submerged RBC Denite
The Village at Duxbury Duxbury, MA	55,000	1993	Condominiums	RBC Nitrification Submerged RBC Denite
Ann & Hope Seekonk, MA	30,000	1993	Shopping Center	RBC Nitrification
Martha's Vineyard Martha's Vinyard, MA	65,000	1992	Airport & Industrial Park	RBC Nitrification Submerged RBC Denitrification
Spofford Hall Spofford, NH	25,000	1992	Health Card	RBC Nitrification
Chester Village West Chester, CT	15,000	1992	Assisted Living	RBC Nitrification Submerged RBC Denitrification
Mt. Everett School Scheffield, MA	35,000	1992	School	RBC Nitrification
West Stockbridge,	80,000	1991	Municipal	RBC Phosphorus

MA				Removal
St. Mark's School Southborough, MA	40,000	1991	School	Denite Submerged RBC
Westford Middle School Westford, MA	25,000	1991	School	Denite Submerged RBC
The Gables at Edgewood Guilford, CT	15,000	1990	Nursing Home	Denite Submerged RBC
Evanswood Kingston, MA	65,000	1990	Nursing Home	Denite Submerged RBC
Harwich Nursing home Harwich, MA	12,000	1990	Nursing Home	RBC 30/30
Southport Mashpee, MA	160,000	1990	Condominiums	Denite Submerged RBC
The Littleton Littleton, MA	29,000	1989	Condominiums	Denite Submerged RBC
Battle Road Farm Lincoln, MA	33,000	1989	Condominiums	Denite Submerged RBC Phosphorus Removal
Mayflower on the Bay Plymouth, MA	30,000	1989	Condominiums	RBC 30/30
Independence Mall Kingston, MA	80,000	1989	Shopping Center	Denite Submerged RBC
Heritage Inn Chelmsford, MA	50,000	1988	Hotel - Conference Center	RBC 30/30
Thirwood Place Yarmouth, MA	2,000	1988	Condominiums	Denite Submerged RBC Phosphorus Removal
The Woodlands Lunenburg, MA	25,000	1988	Condominiums	Denite Submerged RBC Phosphorus Removal
Sullivan Farms New Milford, CT	30,000	1987	Condominiums	RBC w/ Phosphorus Removal
Maple Brook Bellingham, MA	55,000	1987	Condominiums	Denite by Recycle Submerged RBC

Berkshire Mall Lanesboro, MA	70,000	1987	Shopping Center	Denite Submerged RBC
Dartmouth Commons Manchester, NH	13,350	1987	Condominiums	RBC 30/30
Timberwood Goffstown, NH	50,000	1987	Condominiums	RBC 30/30
Brick Kiln Meadows Chelmsford, MA	34,000	1987	Condominiums	Denite Submerged RBC
Ipswich Country Club Ipswich, MA	80,000	1987	Condominiums	Denite Submerged RBC
Williamsburg Chelmsford, MA	110,000	1987	Condominiums	RBC
Kings Way Yarmouth, MA	165,000	1987	Condominiums	Denite Submerged RBC
Indian Brook Hopkinton, MA	24,600	1986	Condominiums	Denite by Recycle
Snow Inn Harwichport, MA	85,000	1986	Restaurant-Hotel	Denite by Recycle
Carver High School Carver, MA	30,000	1986	High School	RBC
UPS Distribution Center Chelmsford, MA	15,000	1986	UPS Warehouse	RBC
The Cove Yarmouth, MA	39,900	1986	Condominiums	RBC
Apollo Computer Chelmsford, MA	85,000	1986	Office Park	Denite Submerged RBC
The Mill Chelmsford, MA	29,000	1986	Condominiums	RBC
Summer Hill Plymouth, MA	50,000	1985	Condominiums	RBC
Fuller Pond Village Middletown, MA	48,000	1985	Condominiums	RBC

Sturbridge Isle Sturbridge, MA	25,000	1985	Office Park	RBC
Newtown Mill Newtown, CT	12,000	1985	Office Park	RBC
Great Road Apts Acton, MA	28,000	1985	Apartment Complex	RBC
Adams Farm Chelmsford, MA	16,300	1985	Condominiums	RBC
Town & Country Kingston, MA	64,000	1985	Mobile Home Park	RBC
Friends Crossing Easton, MA	30,000	1985	Condominiums	RBC
Powder Mill Plaza Acton, MA	12,000	1985	Shopping Center	Extended Air
Yankee Village Acton, MA	8,000	1984	Condominiums	RBC
Fox Hunt Chelmsford, MA	15,000	1984	Condominiums	RBC
Genrad Bolton, MA	16,000	1984	Office Park	RBC
Brookside Apts Acton, MA	14,000	1984	Apartment Complex	RBC
Omni Way Chelmsford, MA	39,000	1983	Office Park	RBC
Seacrest Hotel & Motor Inn Falmouth, MA	50,000	1983	Motel	RBC
Parlmont Realty Chelmsford, MA	25,000	1983	Motel	RBC
100 Pond Street Cohasset, MA	10,000	1983	Condominiums	RBC
Sunflower Electric Corp Holcomb, KS	17,000	1980	Power Plant	RBC
Beaver Valley Power	22,800	1979	Nuclear Power	RBC

Plant Shippingport, PA			Plant	
City of Bridgewater Bridgewater, VT	63,000	1979	Municipal	RBC
Swansea Mall Swansea, MA	50,000	1979	Shopping Center	RBC
Buck Island Village Yarmouth, MA	30,000	1978	Condominiums	RBC
Yankee Greyhound Seabrook, NH	14,500	1978	Racetrack	RBC

Amphidrome®

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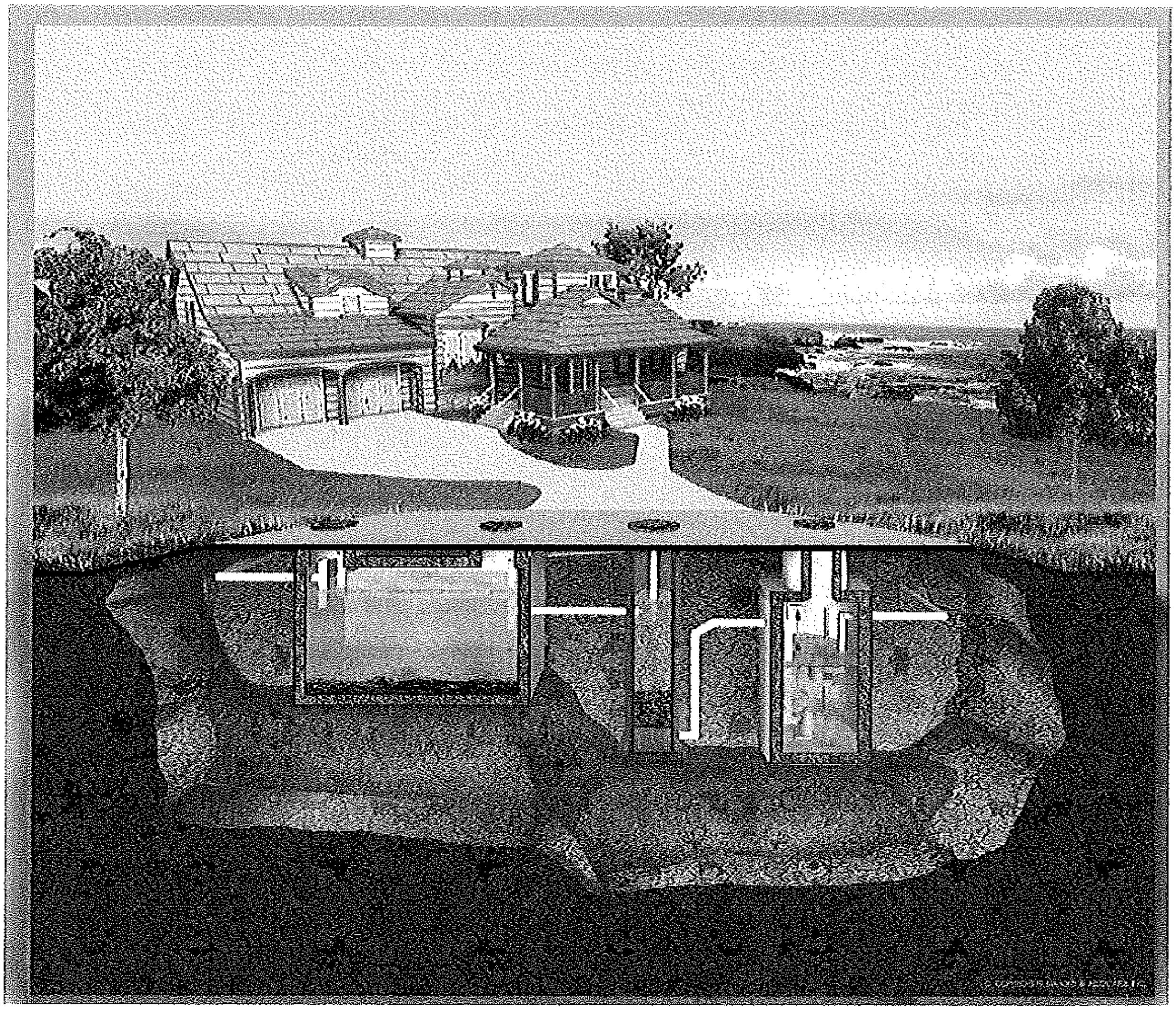

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INDEX

Amphidrome®

Operation & Maintenance Manual

The highest level of Nitrogen removal available...

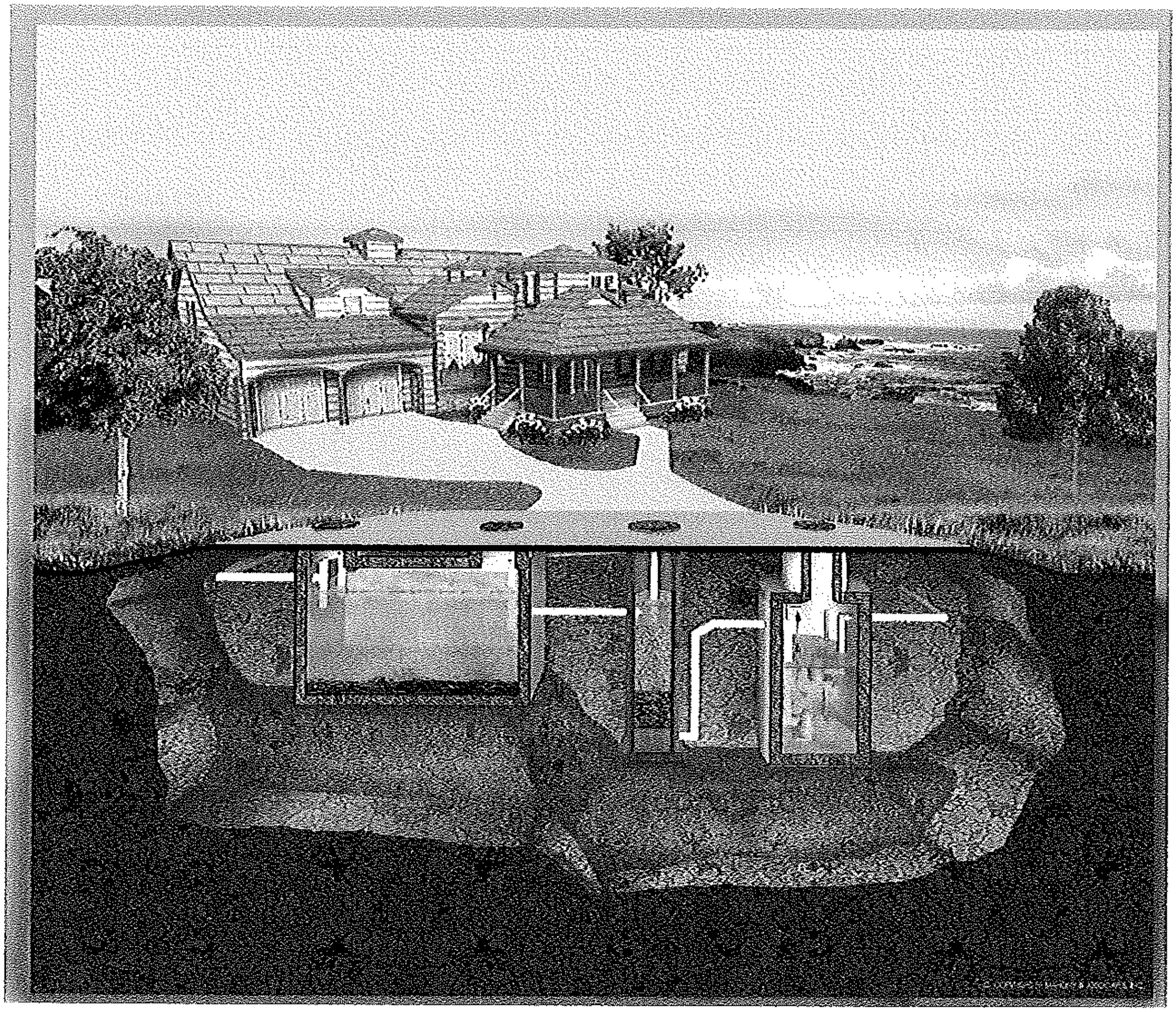

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Table of Contents

Forward

This manual has been prepared to help meet the objectives of long equipment life, minimal equipment maintenance, and cost-effective performance. This manual must be read and understood by those responsible for the operation and maintenance of an Amphidrome® Wastewater Treatment System. Non-recommended, or unauthorized operating or maintenance procedures may result in damage to the equipment, down time, substandard treatment, and voidance of any warranties. Included in this manual is a brief summary of biological nutrient removal, a description of the Amphidrome® process, and a detailed description of the control programming. Operation and maintenance procedures for all of the equipment used in an Amphidrome® system are also included. The specific manufacturer's literature should always be referenced when performing any maintenance or troubleshooting. This manual should be used in conjunction with the design or the "As-built" plans, when provided. All standard safety procedures must be observed.

If any special information, regarding the care and operation of the Amphidrome® Wastewater Treatment System, is desired, F.R. Mahony will furnish it upon request.

Requests for information should be directed to

F.R. Mahony & Associates
273 Weymouth Street
Rockland, MA 02370

Phone (781) 982-9300
(800) 791-6132

Introduction

The removal of soluble organic matter (SOM) from wastewater streams has been the major application of biochemical operations for many years. For typical domestic waste streams, which have a biodegradable chemical oxygen demand (COD) range between 50 - 4,000 mg/l, aerobic cultures of microorganisms are especially suitable. Removal occurs as microorganisms use a portion of the carbon in the waste stream as a food source, converting it to new biomass and converting the remaining into carbon dioxide (CO_2). The CO_2 is released as a gas and the biomass is removed by sedimentation. To accomplish the removal of soluble organics a culture of heterotrophic bacteria must be maintained in suitable environmental conditions. The microorganisms are classified as hetertrophic because they derive their carbon from an organic source, such as the incoming waste stream, or from supplemental methanol, or ethanol.

Since the effect of eutrophication have been shown to be detrimental to receiving waters, the removal of inorganic nutrients from wastewater has become a consideration in the design of wastewater treatment plants. The prime causes of eutrophication are the inorganic nutrients, nitrogen and phosphorus. In sea water and in tidal estuaries, nitrogen is typically the limiting nutrient. Therefore, nitrogen discharge limits, in coastal areas, have been made especially stringent in recent years. Biological removal of nitrogen, to very low levels is easily accomplished. Biological removal of phosphorus is also possible; however, it is more difficult and has a limit, after which, chemical removal is required.

In domestic waste water, nitrogen is present as ammonia (NH_3) and as organic nitrogen (NH_2^-) in the form of amino groups. The organic nitrogen is released as ammonia, in the process of ammonification, as the organic matter containing it, undergoes biodegradation. Two groups of bacteria are responsible for converting ammonia to the innocuous form, nitrogen gas (N_2). The completion of this process occurs in two steps, by completely different bacteria, and in very different environments. In the first step, nitrifying bacteria oxidize ammonia to nitrate (NO_3^-) in a process called nitrification. The bacteria responsible for nitrification are chemolithotrophic, autotrophs that are also obligate aerobes; therefore, requiring an aerobic environment. Chemolithotrophic bacteria obtain energy from the oxidation of inorganic compounds, which in the nitrogen cycle, are ammonia (NH_3) and nitrate (NO_3^-). Autotrophic bacteria obtain their carbon source from inorganic carbon, such as carbon dioxide. In the second step, denitrification, facultative, heterotrophic bacteria convert nitrate to nitrogen gas, which is released to the atmosphere. This is accomplished only in an anoxic environment in which the bacteria use NO_3^- as the final electron acceptor. The ultimate electron acceptor being nitrogen, as it undergoes a stepwise conversion from an oxidation state of +5 in NO_3^- to 0 in N_2. This process may be carried on by some of the same facultative, heterotrophic bacteria that oxidize the soluble organic matter under aerobic conditions. However, the presence of any dissolved oxygen will inhibit denitrification, since the preferential path, for electron transfer, is to oxygen instead of to nitrate.

Since biological removal of nitrogen is both possible and economically viable, many of today's waste water treatment plants require the removal of both soluble organic matter and nitrogen. To achieve this requires: a heterotrophic population of bacteria, operating in an aerobic environment to remove the SOM; a chemolithotrophic autotrophic population of bacteria, also operating in an aerobic environment, to convert the ammonia to nitrate; and finally a facultative heterotrophic population of bacteria, to convert nitrate to nitrogen gas, but in an anoxic environment. Therefore, typical treatment plant designs approach the removal of organics and nutrients, in one of three ways. The first, method is to combine the aerobic steps, (i.e. SOM removal and nitrification), into one operation and design the anoxic denitrification process as a separate unit operation. The second method is to design three separate unit operations for each step. The third method to is to design a sequencing batch reactor (SBR), which has both aerobic zones and anoxic zones. The type of technology utilized greatly influences the number of unit operations to reach the desired effluent treatment level.

Biochemical operations have been classified according to the bioreactor type because the completeness of the biochemical transformation is influenced by the physical configuration of the reactor. Bioreactors fall into two categories, depending on how the biological culture is maintained within, suspended growth, or attached growth, (also called fixed film). In a suspended growth reactor the biomass is suspended in the liquid being treated. Examples of suspended growth reactors include activated sludge and lagoon. In a fixed film reactor the biomass attaches itself to a fixed media in the reactor and the wastewater flows over it. Examples of attached growth reactors include rotating biological contactor, (RBC), trickling filter, and submerged attached growth bioreactor, (SAGB), also called biological aerated filter, (BAF).

During the last twenty years different configurations of SAGBs have been conceived and modest advances in the understanding of the systems have been made. The advantages of biological aerated filters are that they may operate without a solids separation unit process after biological treatment, and with high concentrations of viable biomass. Removal of sludge is usually achieved by backwashing the filter. In such bioreactors the hydraulic retention time (HRT) is less than the minimum solids retention time (SRT) required for microbial growth on the substrates provided. This means that the growth of suspended microorganisms is minimized and the growth of attached microorganisms is maximized. The low hydraulic retention time results in a significantly smaller required volume, to treat a given waste stream, than would be achieved with either a different fixed film reactor, or a suspended growth reactor, for the same waste stream.

The Amphidrome®Process

The Amphidrome® system is a submerged attached growth bioreactor process, operating in a batch mode. It is a deep, bed, sand filter designed for the simultaneous removal of soluble organic matter, nitrogen and suspended solids, within a single reactor. However, if stringent total nitrogen limits, (i.e. less than 10 mg/l), are required, a second smaller polishing reactor is required. Since it removes nitrogen, it is also a biological nutrient removal (BNR) process.

To achieve simultaneous: oxidation of soluble material, nitrification, and denitrification in a single reactor, the process must provide aerobic and anoxic environments for the two different populations of microorganisms. The Amphidrome® system utilizes two tanks and one submerged attached growth bioreactor, subsequently called Amphidrome® reactor. The first tank, the anoxic/equalization tank, is where the raw wastewater enters the system. The tank has an equalization section, a settling zone, and a sludge storage section. It serves as a primary clarifier before the Amphidrome® reactor.

This Amphidrome® reactor consists of the following four items: underdrain, support gravel, filter media, and backwash trough. The underdrain, constructed of stainless steel, or HDPE encased concrete block, is located at the bottom of the reactor. It provides support for the media and even distribution of air and water into the reactor. The underdrain has a manifold and laterals to distribute the air evenly over the entire filter bottom. The design allows for both the air and water to be delivered simultaneously, or separately, via individual pathways, to the bottom of the reactor. As the air flows up through the media the bubbles are sheared by the sand; producing finer bubbles as they rise through the filter. On top of the underdrain is 18", (five layers), of four different sizes of gravel. Above the gravel is a deep bed of coarse, round, silica sand media. The media functions as a filter; significantly reducing suspended solids, and provides the surface area for which an attached growth biomass can be maintained.

To achieve the two different environments required for the simultaneous removal of soluble organics and nitrogen, aeration of the reactor is intermittent, rather than continuous. Depending on the strength and the volume of the wastewater, a typical aeration scheme may be three to five minutes of air and ten to fifteen minutes without air. Concurrently, return cycles are scheduled every hour, regardless of the aeration sequence. During a return, water from the clear well is pumped back up through the filter and overflows into the trough. A check valve in the influent line prevents the flow from returning to the anoxic/equalization tank, via that route. The trough is set at a fixed height above both the media and the influent line; and the flow is by gravity back to the front of the anoxic/equalization tank.

The cyclical forward and reverse flow of the waste stream, and the intermittent aeration of the filter, achieve the required hydraulic retention time and create the necessary aerobic and anoxic conditions to maintain the required level of treatment.

Biochemical Reactions

The following equations describe the biochemical reactions that are occurring simultaneously within the Amphidrome® reactor.
The reactions governing the removal of soluble matter and ammonification are as follows:

1) $COHNS + O_2 + nutrients \Rightarrow CO_2 + NH_3 + C_5H_7O_2N$ + other end products
(organic matter) (new cells)

2) $C_5H_7NO_2 + 5O_2 + \Rightarrow 5CO_2 + 2H_2O + NH_3$ + energy

Equation one accounts for the biodegradation of organic material, including ammonification, and cell synthesis. Equation two represents the endogenous respiration of the biomass. The carbon source for cell synthesis is provided from an organic compound; therefore, the bacteria are heterotrophic. The equations also indicate that oxygen is required for both reactions to occur.

Nitrifying bacteria are chemolithotrophic autotrophic microorganisms that obtain their energy from the oxidation of ammonia and nitrite and their carbon source from carbon dioxide. Below are the two equations for nitrification.

3) $55NH_4^+ + 76O_2 + 109HCO_3^- \Rightarrow C_5H_7O_2N + 54NO_2^- + 57H_2O + 104H_2CO_3$

4) $400NO_2^- + NH_4^+ + 4H_2CO_3 + HCO_3^- + 195O_2 \Rightarrow C_5H_7O_2N + 3H_2O + 400NO_3^-$

Equation three describes the oxidation of ammonia to nitrite by the bacteria *Nitrosomonas*. Equations four describes the oxidation of nitrite to nitrate by the bacteria *Nitrobacter*. Both steps must occur in an aerobic environment.

The final step in the removal of nitrogen from the waste stream occurs when the nitrates produced in the nitrification process are converted to nitrogen gas by the process of denitrification, described below:

5) $NO_3^- + 2CH_3OH \Rightarrow 6NO_2^- + 2CO_2 + 4H_2O$

6) $6NO_2^- + 3CH_3OH \Rightarrow 3N_2 + 3CO_2 + 3H_2O + 6\ OH^-$

7) $6NO_3^- + 5CH_3OH \Rightarrow 5CO_2 + 3N_2 + 7H_2O + 6\ OH^-$ (Overall Reaction)

The above equations show methanol as the organic carbon source; however, any organic carbon source could be used. The Amphidrome® process is designed to use the organic carbon in the waste stream, by returning flow back to the anoxic/equalization tank, to mix with the influent. Equation five is an energy reaction in which nitrate is converted to nitrite. Equation six is also an energy equation for which nitrite is converted to nitrogen gas. The overall reaction is shown in equation seven.

This Amphidrome® process is designed to achieve the above reactions simultaneously within one reactor. The aerobic environment within the filter promotes reactions shown in equations one through four. The return flows, back to the anoxic/equalization tank, mix the nitrates with organic carbon in the raw influent, and with organic carbon, that has been released from the stored sludge, as solute. The anoxic environment within the filter promotes denitrification, (i.e. the reactions shown in equation seven.)

Wastewater Characteristics

The Amphidrome® process, like all wastewater processes, is designed to operate within design parameters for flow and wastewater characteristics. The first step to successful operation of any treatment facility is to characterize the wastewater through various analyses, which include: BOD, total suspended solids, settleable solids, COD, pH, alkalinity, DO, temperature, total solids, dissolved solids, nitrogen and phosphorus. Some of these parameters may not specified by any imposed discharge limits; however, occasional sampling may prove prudent, should any problems arise. Maintaining a history of these analyses will prove helpful in following trends or anticipating changes in the treatment efficiency. Samples should be taken in the same locations and testing should follow "Standard Methods" or other approved regulatory testing procedures. Consistent techniques will provide more useful and valid information.

Wastewater Flow

Large fluctuations in wastewater flow may effect the treatment process; however, daily flows will fluctuate and should be expected. Major changes should be limited to the design capabilities of the treatment process. Wastewater flows may be monitored through water meter, or pump run time. However, effluent flow metering is the most common and will provide an accurate measure of the flow actually processed at the facility.

Treatment plants are often designed, based on expected flow rates from established literature, or from regulatory standards. These standards usually result in design flows that are greater than the actual flows. Once the facility is constructed, operating parameters must be set to treat actual flows; therefore, some adjustment may be required. Flows should not exceed the design permit flow.

pH, Alkalinity and Temperature

Typical domestic wastewater has a pH between 6.5 and 8.0. Biological microorganisms are effected by extreme variations in pH and in temperature. It has been shown experimentally that the reactions, of both nitrification and denitrification, are optimized at pH values in the range of 8. Therefore, it is recommended that supplemental alkalinity be used to maintain such a pH, as long as this does not put the plant in violation of any effluent limits. Maintaining such a pH will also insure that sufficient alkalinity is present for nitrification. The bacteria responsible for nitrification, consume the inorganic carbon supplied by the bicarbonate dissolved in the wastewater. High bicarbonate alkalinity values indicate sufficient amounts for complete nitrification. Therefore, alkalinity is important parameter in the monitoring treatment process in an Amphidrome® system. Two general rules may be used as operational guidelines first, 7.4 mg/l of alkalinity is needed for each mg of ammonia to be nitrified, and second a residual alkalinity value of

100 mg/l should be left after complete nitrification. Typically, both these conditions will be met if supplemental alkalinity is used to maintain the pH level at approximately 8. Temperature fluctuations from weather conditions should not effect the Amphidrome® process since the process tanks are all underground. The anoxic/equalization tank provides buffering of influent temperature prior to the reactor. This should serve to permit reasonable temperature fluctuations in the waste stream.

BOD, COD and Suspended Solids
Organic and solids loading are fundamental characteristics governing the size of treatment processes. BOD and COD are measures of the strength of the wastewater.

BOD (biochemical oxygen demand) measures the rate of oxygen uptake from the wastewater by microorganisms in biological reactions. These microorganisms are converting the waste materials to carbon dioxide, water and inorganic nitrogen compounds. The oxygen demand is related to the rate of increase in microorganism activity resulting from the presence of food (organic waste) and nutrients.

COD (chemical oxygen demand) measures the presence of carbon and hydrogen, but not amino nitrogen in organic materials. COD does not differentiate between biologically stable and unstable compounds. COD tests can be inhibited by chloride. Thus, wastewater containing high salt concentrations, such as brine, cannot be readily analyzed without modification.

Suspended solids measures the solids in wastewater that floats or suspends in the liquid stream. This does not measure the total solids loading to the facility that includes settleable and dissolved solids. The settleable solids are normally removed in the anoxic/equaliztion tank while suspended and dissolved solids are to be treated in the filtering and biological processes in the Amphidrome® reactor. As solids breakdown and are backwashed from the reactor, they settle and form a layer of sludge at the bottom of the anoxic/equalization tank. Periodic removal of the sludge is required.

Nitrogen
In domestic waste water, nitrogen is present as ammonia (NH_3) and as organic nitrogen (NH_2^-) in the form of amino groups. The organic nitrogen is released as ammonia, in the process of ammonification, as the organic matter containing it, undergoes biodegradation. To achieve biological nitrogen removal bacteria must convert ammonia to the innocuous form, nitrogen (N_2) gas. However the stepwise process produces nitrate (NO_3^-) as an intermediate compound. Nitrate in drinking water is of concern to infants because it has been widely stated in literature, to be linked to "methemaoglobinemia" which may result in death for infants. Monitoring of both ammonia and nitrate is extremely useful for process control and should be done once or twice weekly after the plant is in compliance.

Sampling

The sample collection location shall be located at the discharge end of the Amphidrome® clear well. A sample chamber shall be provided to collect the most resent discharge to the subsurface disposal field. As-built records by the contractor/installer and/or design engineer of record shall indicate the location of access covers to final sample points as well as the Amphidrome® reactor and Anoxic Tank. The design engineer is responsible to identify the final sample point as (PP1) on the final scaled engineering design plans and its location shall be provided by triangulation to two fixed reference points (e.g., building corners) at the site. The final effluent sample shall be accessible by removing a manhole cover supplied by the installer of the system. Failure to provide proper access covers will impede the operator and manufacturer from accessing these key components for sampling, monitoring and inspection of the system and shall nullify the manufacturer's warranty.

The sample point shall be shown on the final design plans and subject to approval of the manufacturer and by the approving authority. Engineering plans shall provide adequate detail to clearly illustrate the physical configuration of the sample collection port. The manufacturer shall provide standard details for use by the design engineer for the execution of the final design plans.

Sample collection and analysis shall be in accordance with the standards of the approving authority.

Programmable Controllers

The Amphidrome® system is controlled by a programmable logic controller (PLC). PLCs are solid state members of the computer family that use integrated circuits instead of electromechanical devices, to implement control functions. PLC's allow for the storing of instructions, such as sequencing, timing, counting, arithmetic, data manipulation, and communication, to control machines and processes.

The first programmable logic controller was specified in 1968, by the Hydramatic Division of General Motors Corporation. The requirements included a solid state system with computer flexibility, the ability to survive in an industrial environment, be easily programmed, and be reusable. The early PLCs replaced the hardwired relay logic, which used electrically operated devices to mechanically switch electric circuits.

Programmable logic controllers today include many technological advances, in both hardware and software, that have resulted in more capabilities then were ever anticipated. However, despite the level of sophistication in the design and construction they still retain the simplicity and ease of operation that was intended in their original design.

FRMA will provide a direct logic programmable logic computer with integral modem which will have dial out capabilities for alarms and dial in capabilities for troubleshooting. The system owner will provide a telephone line for this purpose.

Principles of Operation

A programmable logic controller consists of two basic sections, the central processing unit, (CPU) and the input/output interface system, (I/O). **Refer to Figure 1**. The CPU consists of the processor, the memory system, and the system power supply. It governs all the PLC activities. The I/O system is physically connected to the machinery (i.e. field devices) used in the control of a process. The field devices may be discrete or analog input/output devices, such as limit switches, pressure transducers, motor starters, solenoids, etc. The I/O interfaces provide the connection between the CPU and the information provided by the inputs and the controllable devices (i.e. outputs, such as pumps or blowers). **Refer to Figure 2**.

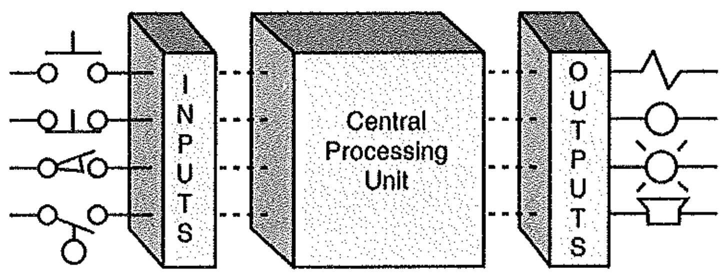


Figure 1. PLC Block Diagram

During operation the CPU does three things. First it reads the input data from the field devices via the input interfaces. Second, it executes the control program stored in the memory system, and finally, it updates the out devices via the output interfaces. The process of reading inputs, executing the program, and updating the outputs is known as scanning.

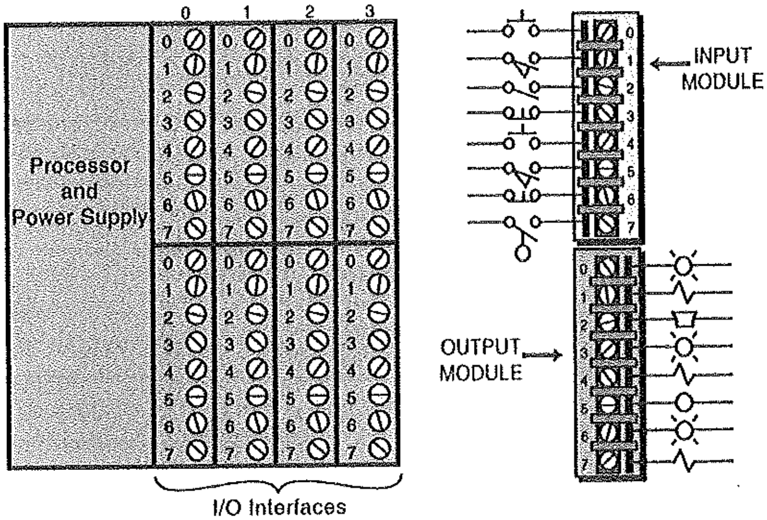


Figure 2. Input/Output Interfaces

The input/output (I/O) section of the PLC acts as the interface to field devices and the CPU. Field sensing devices and controllers are wired to the I/O wiring terminals. The PLC power supply provides the necessary voltages for operation of the CPU and the I/O section of the controller.

Programmable controllers are available with either fixed or expandable I/O. Fixed I/O models, also referred to as "bricks", contain a fixed amount of I/O and are generally limited to about 20 or less I/O points in various configurations. Fixed I/O systems are well suited to applications with limited I/O requirements.

For systems with a large number of I/O points, expandable models are available. Expandable versions are modular in construction and consist of a rack or chassis containing a power supply and an assortment of I/O modules. The I/O modules are selected to meet the requirements of the various sensing devices and controllers used by the system. If the number of I/O points exceed the number of points that can be accommodated by a single chassis, further expansion is possible through the use of additional expansion racks.

The fixed programmable controller used in the residential Amphidrome® system is shown in **Figure 3.**

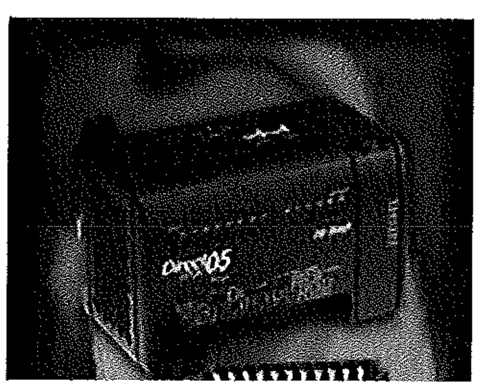


Figure 3. Fixed Programmable Controller

Programming of a PLC is usually done with a personal computer or a manufacturer's mini-programmer, or "hand held programmer". All functions can be accomplished with either; however, it is more convenient with the computer. Programming and program changes refer only to modifications that effect the logic written into the program memory, not the operational settings that allow for optimization of the process.

The Amphidrome® System and Its PLC Control Panel

All Amphidrome® systems, typically employ PLC□**Direct**™ by Koyo. This is a specific manufacturer's PLC hardware and software. Access to the main program logic is **not** possible, but access to all memory registers effecting the optimization of the process is possible. Thus the operator has a great deal of operational control over the process; however, in order to take advantage of this, a thorough understanding of both the Amphidrome® system and the biological processes involved is required.

To control the Amphidrome® process, the PLC continuously executes a 0 to 1440 minute cycle which corresponds to a 24 hour day. The time at which specific events occur during the process cycle are controlled by entering values into memory location of the PLC referred to as V-memory registers. A listing of available V-registers with the associated function for each register is included with the Operation and Maintenance manual provided with the system.

As an example of how V-registers are used to control the process, assume that register V2200 has been assigned the function of initiating a backwash cycle and that the backwash cycle is to occur four hours into the cycle. The operator would load a value of 240 into register V2200, i.e. 4 hours x 60 minutes per hour = 240 minutes. If the system is set to reset to time zero at 5:00 AM, the backwash cycle would take place at 9:00 AM.

Access to the V-registers is through the hand held program loader (HP) shown in **Figure 4.** The HP connects to the PLC through the programming port using the cable supplied with the loader. The HP can be used to view the current status of all V-registers as well as changing the value of V-registers allocated for process control.

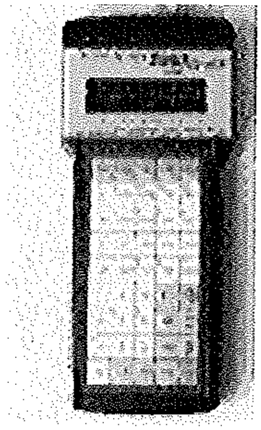


Figure 4. Hand Held Program Loader

To view the status of any register, enter the following keystrokes on the HP:

SHFT, V, X, X, X, X, STAT

Where "X" is the number of the register to be monitored, the above keystrokes will display the current value of the selected register. Once a register is displayed, consecutive registers can be monitored through the use of the **prev** and **next** keys.

Once a register is shown in the display, its value can be changed using the following keystrokes:

SHFT, K, #, #, #, #, ENT

Where "#" is the new value for the register, the new value for the selected register will now appear in the display.

Monitoring V-Memory Locations

The hand held programmer (HP) may be used to monitor and change V-memory locations. This is an especially useful feature, since almost all of the programmable controller's system data is mapped into V-memory. The following steps show how to monitor V-memory locations.

Press these Keystrokes

1. Select the location to monitor.

	V	**C**	**A**	**A**	**A**	
SHFT	**AND**	**2**	**0**	**0**	**0**	**STAT**

HP Display Results

		V		**2**	**0**	**0**	**1**		**V**		**2**	**0**	**0**	**0**
				4	**5**	**5**	**2**				**4**	**F**	**5**	**0**

2. Use the PREV and NEXT keys to scroll through adjacent memory locations.

NEXT

HP Display Results

		V		**2**	**0**	**0**	**1**		**V**		**2**	**0**	**0**	**0**
				4	**5**	**5**	**2**				**4**	**F**	**5**	**0**

Changing V-Memory Values

Press these Keystrokes

1. Select the location to monitor.

	V	**C**	**A**	**A**	**A**	
SHFT	**AND**	**2**	**0**	**0**	**0**	**STAT**

HP Display Results

		V		**2**	**0**	**0**	**1**		**V**		**2**	**0**	**0**	**0**
				4	**5**	**5**	**2**				**4**	**F**	**5**	**0**

2. Use K (constant) to load a new value in memory location V2000.

	K	**B**	**C**	**D**	**E**
SHFT	**JMP**	**1**	**2**	**3**	**4**

HP Display Results

		V		**2**	**0**	**0**	**1**		**V**		**2**	**0**	**0**	**0**
K	**1**	**2**	**3**	**4**										

3. Press ENT to enter new value.

ENT

HP Display Results

		V		**2**	**0**	**0**	**1**		**V**		**2**	**0**	**0**	**0**
				4	**5**	**5**	**2**				**1**	**2**	**3**	**4**

Features of the Single Family Amphidrome® Control Panel

1) The Amphidrome® system operates on a 0 – 1440-minute cycle.
2) All Amphidrome® filters have the capability of 16 backwashes.
3) The total number of discharges is recorded.
4) The total number of backwashes is recorded.
5) The total number of failed backwashes is recorded.

6) All submersible pump total run times are recorded.
7) Total run times for both the process blowers and backwash blowers are recorded.
8) The panel interface is provided for field connection of modem to transmit operating data to FRMA home office for diagnostic analysis and emergency trouble shooting.

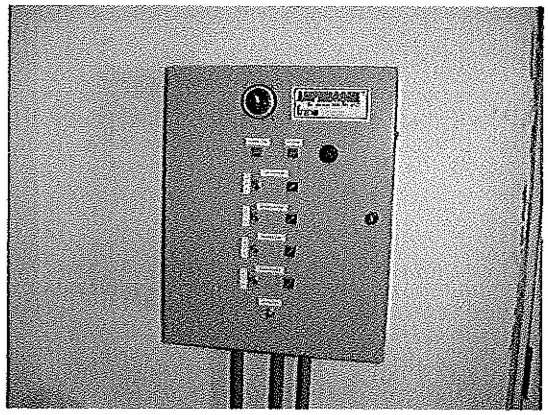


Figure 5. Single Family Amphidrome® Control Panel

Automatic Voice/Pager Alarm Dialer System (Optional)

The voice/pager alarm dialer system is used to transmit high clear well or filter high level alarms to one or more remote locations. The dialer features busy line and no answer detection to ensure prompt transmission of a prerecorded message, delivered sequentially to as many as four standard telephones, cellular telephones, voice and/or numeric pagers.

The dialer is fully programmable, offering personalized customization for each individual project. Programming options include but are not limited to:

- Store up to four telephone/pager numbers.
- Choose 1 to 9 calling efforts for the numbers dialed.
- Select 1 to 3 message repeats.
- Voice record an outgoing message in any language.
- Program voice messages to telephones and numeric code to pagers.

The voice pager/alarm dialer is a stand alone unit operating 24 hours per day. Monitoring fees are not required.

Operational Control Features of Amphidrome® Systems

Cycle Control

The 24 hour Amphidrome cycle is controlled by a 0 to 1440 minute counter CT0 in the programmable controller (PLC). This counter is reset by the internal clock/calendar of the PLC. Two V-registers are allocated for entering the desired time in hours and minutes for resetting the system to time zero.

In addition to the 24 hour counter the program also includes a day of week counter in the PLC for selecting the days that backwash and discharge cycles will occur. The day of the week counter is CT30 and is advanced by 1 when the external 24 hour clock is activated.

Setting the day of the week is done by entering a value of 0 to 6 in register V2077 and pressing the alarm silence button for 15 seconds. The numbers 0 through 6 represent the days Sunday through Saturday.

The day of the week can be viewed in register V2006.

Backwash Cycle
The system is capable of 16 backwash cycles per day and backwashes can be set to occur on any or every day of the week. V2260 through V2266 are provided to enable\disable backwash cycles on Sunday through Saturday respectively. Backwash cycles are enabled for the day if the associated register for that day is set to a value of 1. If backwash cycles are disabled for any particular day, all backwash cycles for that day will be disabled.

Registers V2110 through V2113 are provided for setting the time to backwash for backwash cycles 1 through 4. The time to backwash for cycles 5 through 16 are set in registers V2230 through V2243.

For the remainder of the description on control of the backwash cycle we will assume that registers V2260 through V2266 are set to 1 enabling the backwash cycles for every day of the week.

Entering valid times into the backwash cycle control registers does not mean that all backwash cycles will occur daily.

Backwash cycles 1 through 16 are enabled automatically by the (PLC) logic depending on the amount of incoming flow. A measure of the incoming flow is how long it takes the system to return flow to the 2nd float in the clearwell. A counter in the PLC (CNT20) records how long it takes for the system to return to the 2nd float. This counter is automatically reset to zero at the beginning of any return flow cycle. If the time to return to the 2nd float for the current cycle is greater than the time for the previous cycle the value in register V2252 is updated to reflect the longer return time. Register V2252 always contains the longest time to return to the 2nd float for a given day and is used to select the number of backwash cycles required for the next day. The value in V2252 is recorded and stored in register V2307 at the beginning of a new day for use in selecting the number of backwash cycles for that day. Once the previous days value is loaded in V2307 register V2252 is reset to zero and set to record the longest time to return to the 2nd float for the new day.

Note: If any return flow time is terminated by the high float in the filter before the system has returned to the 2nd float in the clearwell the recorded value in CNT20 and V2252 will be equal to the total return flow time for that cycle.

If the system has discharged to the 2nd float in the clearwell and there is little or no flow to elevate it again backwash there will be no backwash cycles for the day. If flow is sufficient to elevate the 2nd float, but, not long enough to cause a the time to return to the 2nd float to be more than 1 minute backwash cycles 1,2,and 3, will take place.
The next 13 backwash cycles are selected based on the value stored in V2307 which represents the longest time to return to the 2nd float for the previous day.

- If V2307 is equal to or greater than 1 backwash cycles 4, 5, and 6 are enabled.
- If V2307 is equal to or greater than 2 backwash cycles 7, 8, and 9 are enabled.
- If V2307 is equal to or greater than 3 backwash cycles 10,11, and 12 are enabled.
- If V2307 is equal to or greater than 4 backwash cycles 13,14, 15, and 16 are enabled.

Once a backwash cycle is initiated it is controlled by the values entered in registers V2101 through V2104. Typical values for these registers are listed below:

- V2101 - Time to start blowers for backwash - set for 1 minute
- V2102 - Time to stop blowers for backwash - set for 11 minutes
- V2103 - Time to start pump for backwash - set for 6 minutes
- V2104 - Time to backwash over trough – 5 minutes

With the above settings the blowers will start 1 minute into the backwash cycle and run alone. At 6 minutes into the cycle the backwash pump will start and run with the blowers. At 11 minutes into the cycle the blowers will stop and the backwash pump will run alone until the high float in the filter is elevated for 5 minutes.

Return Flow Cycles
There are provisions for 16 return flow cycles. The time for these cycles are set in registers V2050 through V2067. The return flow cycles will be automatically locked out for ½ hour prior to a backwash.

Once a return flow cycle is initiated it will continue to run until the low float in the clearwell drops out, or until the high float in the filter has been elevated for the amount of time entered in register V2250 (time to return after high float in filter).

Process Air Cycle
There are 12 adjustable process air enable\disable periods. Enable\disable times for the 12 cycles are set in registers V2020 through V2047.

The process air off time is set in register V2017 and is common to all 12 individual process air cycles.

The process air on time is automatically calculated by the PLC logic and is dependent to some degree on the position of the 2nd float in the clearwell.

If the system has discharged to the 2nd float in the clearwell and this float has not become elevated again due to a lack of incoming flow the process air on time will be equal to the value in seconds entered in register V2115.

If the system has discharged to the 2nd float in the clearwell and the 2nd float has become elevated again because of incoming flow the on time becomes a calculated value based on the amount of time to return flow to the 2nd float in the clearwell. This calculated value is automatically adjusted throughout the day and at any given time is the product of the longest time to return to the 2nd float in the clearwell times a multiplier in register V2117 plus a fixed run time in register V2116.
An option to disable the process air blower during a return flow\backwash cycle is provided. If register V2114 is set to 1 the process air blower will automatically shut down during a return flow\backwash cycle.

Discharge Cycle
Discharge cycles can be set to occur on any or all days of the week by entering a 0 through 6 into registers V2070 through V2076. The numbers 0 through 6 represent the days Sunday through Saturday respectively.

To disable the discharge cycle for any given day set the value in the associated V register for that day to 9999.

If enabled, the discharge cycle will occur at the beginning of a new day when the clock resets the system. The discharge will be to the 2nd float in the clearwell.

If at any time during the day, a high level condition should occur in the clearwell the system will automatically discharge for 3 minutes or until the 2nd float in the clearwell drops out regardless of whether or not the discharge cycle was enabled for that day.

If the clearwell high level float does not drop out within 3 minutes a high level alarm will be activated.

Filter High Level Alarm
If the high level float in the filter is elevated for 20 minutes a high level alarm is initiated.

The high level alarm timer is disabled whenever the backwash pump is in operation.

Clearwell High Level Alarm

If the high level float in the clearwell becomes elevated a discharge cycle will be initiated. If the high level condition is not corrected in 3 minutes the high level alarm will be activated.

Accumulated Run Times
The following run times are recorded:

Description	Seconds (0 to 3600)	Minutes
Effluent Pump	V2012	V2000
Backwash Air Blower	V2013	V2001
Backwash Pump	V2014	V2002
Process Air Blower	V2015	V2003

Event Recorders
The following events are recorded:

Clearwell High Level Alarm Counter	V2004
Backwash Cycle Counter	V2005
Day of Week	V2006
Time Into Cycle	V2007
Number of Discharge Cycles	V2011
Filter High Level Alarm Counter	V2107
Number of Times Clearwell High Level Float is Activated	V2106

Note: In addition to the above registers V2200 through V2227 record the longest return flow times for the previous 24 days. Register V2200 contains the most recent data.

Operational Scenario Of The Amphidrome® System

To achieve simultaneous: oxidation of soluble material, nitrification, and denitrification in a single reactor, the process must provide aerobic and anoxic environments for the two different populations of microorganisms. The Amphidrome® system achieves this by using two tanks and one submerged attached growth bioreactor whose process is controlled by a sophisticated PLC computer program. The following outline provides a description of the structural framework of any Amphidrome® system. The control details of each particular Amphidrome® configuration are described in the controls' section of the Forward and in the Controls' section of the O & M manual.

- All Amphidrome® systems are setup with the ability to return flow from the clear well to the anoxic/equalization tank sixteen (16) times per day. The cycle clock operates on a time of 0 –1440 minutes. The returns are set up to occur every hour on the hour, (i.e. at times 0, 60, 120, 180,....).
- Typically, the systems are setup to treat in one batch per day.
- The programmable controller (PLC) includes an internal clock/calendar for control of the process cycle. Registers are allocated for setting the time of day in hours and minutes at which the cycle time will be reset to time zero. The PLC clock is adjusted and records time in the 24 hour format. Refer to the memory allocation sheet specific to the system to be adjusted for the registers assigned to this function. For example, assume that register **V2200** is allocated for setting the "hour to reset the cycle to time zero" and that the desired time for the cycle to reset to zero is 2:45 PM. Using the hand held loader, the operator would load a value of 14 into register **V2200** (2:00 = 14 hours) and a value of 45 into register **V2201**.

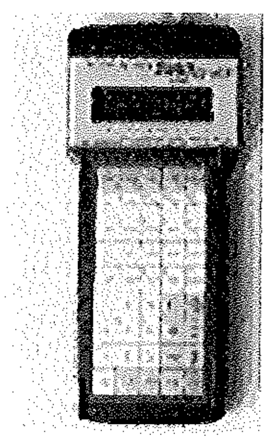


Figure 4. Hand Held Program Loader

Setting the Clock and Calendar

The **AUX 52** function allows you to set the Real-time clock and calendar using the following format.

- Date - Year, Month, Date, Day of week (0-6, Sunday through Saturday)
- Time - 24 hour format, Hours, Minutes, Seconds

If the date is changed without updating the day of the week (0-6), the CPU will not automatically correct any discrepancy between the date and the day of the week. For example, the date is changed to the 15th of the month and the 15th is on a Thursday. The day of the week will also need to be changed unless the CPU already shows the date as Thursday. Use the following example to change any component of the date or time settings.

Note: Verify that the clock and calendar is supported by your CPU before attempting to use this Auxiliary function.

Press these Keystorkes

1. Clear Complete Display Screen

CLR	CLR

HP Display Results

2. Select AUX 57

F 5	C 2	AUX

HP Display Results

A	U	X		5	*		C	P	U		C	F	G	
A	U	X		5	2		C	A	L	E	N	D	A	R

3. Select Date and Clock Display

ENT

HP Display Results

A	U	X		5	2		C	A	L	E	N	D	A	R
9	6	/	0	1	/	0	1	/	6	(	S	A	T	)

4. Enter New Date if Required

→	→	→	→	A 0	C 2

HP Display Results

A	U	X		5	2		C	A	L	E	N	D	A	R
9	6	/	0	1	/	0	2	/	7	(	S	U	N	)

5. To Accept Press ENT Twice

ENT	ENT

HP Display Results

A	U	X		5	2		C	A	L	E	N	D	A	R
T	I	M	E		0	0	:	0	6	:	0	0		

6. Enter New Time if Required

B 1	C 2	D 3	A 0

HP Display Results

A	U	X		5	2		C	A	L	E	N	D	A	R
T	I	M	E		1	2	:	3	0	:	0	0		

7. To Accept New Entry Press ENT Twice

ENT	ENT

HP Display Results

					9	6	/	0	1	/	0	2		
						1	2	:	3	0	:	1	5	

- The shaded area indicates cursor position.
- Press the CLR key to exit date and clock function.

Note: If the CPU is without power for an extended period of time a battery is required to maintain the proper date and time.

- Typically, at startup all aeration periods are utilized and the sequences are set up so that process blower fixed on time is 3 – 5 minutes and the process blower off time is 10 – 15 minutes.

- The cyclical forward and reverse flow, of the waste stream, and the intermittent aeration of the filter, should be used in conjunction with one another to achieve the necessary aerobic and anoxic conditions required to meet the effluent permit requirements.

Operation

The Amphidrome® system is a submerged attached growth bioreactor, (SAGB) process, designed around a deep, bed, sand filter. Most systems have all the tanks and reactors installed underground. The only way to access, or visually inspect the tanks is through manholes or access hatches. Therefore, it is essential for the operator to always be aware, that because it may currently be operating well, and is out of sight, that it does not mean that it may be ignored.

Start Up and Initial Tests

Upon taking over operation of an Amphidrome® system, the operator should conduct three tests on each Amphidrome® filter in the plant. The tests are designed to determine the volume flow rates of water through the filters, one in the forward direction and two in the reverse direction.

After the following tests are completed, the unit should be started and allowed to run for one month. At the end of the first month of operation, the operator should begin bimonthly inspections of the system. During these inspections the operator should perform field tests to determine ammonia and nitrate concentrations on the effluent and adjust the air and backwashes accordingly. Once the field tests indicate the desired levels the results should be corroborated with laboratory analysis. Sampling should then be conducted in accordance with the regulatory guidelines.

Test 1: Forward Flow Test:

The purpose of the test is to determine the flow rate through the filter, (i.e. hydraulic loading). This test must be conducted at the end of an automatically scheduled return flow cycle, or after a manually initiated return flow. After the return flow pump shuts off, the liquid level decrease in the Amphidrome® filter should be measured over equal increments of time until the forward flow slows down to less than a 1 inch change in ten minutes. During the first portion of the test in which the liquid level in the filter is high and the flow rate through the filter is also high, measurements should be taken every 1 –2 minutes. As the flow rate slows down the measurements may be recorded every 5 – 10 minutes. The total time, total change in height, and the surface area of the reactor can be used to calculate the hydraulic loading. The data should be recorded on a table similar to that labeled *Filter Flow Through Rate*, and shown in Appendix A.

Test 2: Return Flow Test:

The purpose of this test is to estimate the average volume flow rate for a return cycle. This value is necessary to control the amount of wastewater returned during each return cycle. This test must be conducted at the beginning of an automatically scheduled return flow cycle, or at the beginning of a manually initiated return flow cycle. The level in the Amphidrome® filter should be low before the start of this test. After an initial measurement of the liquid level in the filter is recorded. The return flow pump should start, or be started. During the test the liquid level in the filter should be measured and recorded every minute. Once the liquid starts to flow over the return flow/backwash trough, the test may be stopped. The total time to reach the trough should be recorded. The data should be recorded on a table similar to that labeled *Filter Flow Through Rate*, as shown in Appendix 1.

Process Control

Efficient operation and effective process control of an Amphidrome® System, as with any wastewater treatment plant, requires comprehensive methods for collecting and recording all pertinent information regarding plant performance and equipment maintenance. This is accomplished with an equipment log, a sampling and analysis plan for both the required sampling and all field sampling, and meticulous records of all observations regarding the daily operation of the plant. Examples of equipment logs are included in this manual.

Sample Collection

Since the Amphidrome® system is a batch treatment process, effluent samples must be collected at the end of each batch. Effluent sample devices furnished with this process are designed to capture the most recent discharge from the Amphidrome® system. A standpipe discharge pipe with check valve may be provided to hold a clean sample below the discharge pipe elevation. A removable threaded pipe plug is provided to access this standpipe to draw samples with a disposable sample bailer. The effluent or discharge pump should be in the "Off" position during this procedure. The individual taking the sample must be sure to replace the threaded plug and to put the effluent pump back in the "Auto" position before leaving the site.

The standard discharge line of 1-1/2 inch diameter will hold approximately 700 – 800 Ml of effluent sample. Samples must be drawn in accordance with New Jersey DEP guidelines by a trained and certified individual. Sample protocols must be followed to assure proper handling and "Chain-of-Custody" measures are followed. Effluent samples must not be collected from the anoxic/equalization tank since recycle to this occurs every hour.

Equipment Run Times:

All the equipment run times are recorded and stored by the PLC. These values are totals; therefore, the operator should record both the total time and the difference between the previous and the current readings, (i.e. the daily average). By averaging the daily run time of equipment it is possible to detect any potential problems and to verify that the equipment is operating for the approximate prescribed time in the program. For example, the process blower, daily average run time can be used to confirm that aeration is occurring, as programmed. Additionally, averaging equipment run time shows trends in the process. For example, the duration of the aeration is a function of the fixed air on time, and the flow based multiplier; therefore, aeration times vary with flow. Meticulous records of actual aeration times, which may be compared with the results of sample analyses, will allow for accurate process control decisions. **Recording of equipment run time is a critical and necessary part of operations and maintenance and should be performed diligently by the operator.**

Sludge Wasting and Sludge Removal:
Sludge wasting refers to the removal of sludge from the Amphidrome® reactor and is achieved by backwashing. Both the frequency and duration of the backwash are operator adjustable. Unlike an activated sludge system in which the amount of viable biomass within the vessel is controlled by monitoring the MLVSS, no such single parameter exists for monitoring biomass in a submerged attached growth bioreactor. Four parameters must be used to determine whether or not enough biomass exists: one, an effluent ammonia, (NH_3) analysis, two, the forward and reverse flow rates, three, the aeration pattern, and finally, both a visual and a laboratory analysis of the TSS in the backwash stream.

- The first parameter that is influenced by insufficient biomass is the ammonia level in the effluent. Therefore, if all the other factors effecting nitrification, (i.e. alkalinity, air, pH...) are sufficient, and nitrification is incomplete the quantity of biomass within the filter must be suspect.

- A significant decrease in the forward and reverse flow rates, from the original tests, conducted by operator, may indicate that the filter is plugging. This may be resolved by increasing the frequency and/or duration of the backwashes.

- The aeration pattern in the filter should be inspected with approximately 3 - 6 inches of water covering the media. **Even bubbles over the entire surface area should be observed.** Air bubbles that occur in separate discreet areas may indicate that the reactor is plugging or is plugged. In severe cases, air may be seen escaping several minutes after the blowers have been shut off. This may be resolved by increasing the frequency and/or duration backwash cycles.

- Finally, to gauge the quantity of solids within the reactor a sample at the beginning and ending of a backwash cycle should be collected and examined both visually and analytically for TSS. The first sample should be collected during a backwash just as the water starts to flow over the return flow/backwash trough. The second sample should be collected at the end of the backwash, just before the pumps shut off. Typically TSS values for the second sample range from 200 mg/l to 500 mg/l. However, it must be stressed that these numbers are typical, not absolute. Therefore, if a plant is meeting all discharge requirements with different values, than those specific values should be used for a guideline at that particular plant.

Sludge wasting is achieved by pumping stored sludge from the anoxic/equalization tank. The level of sludge within the anoxic/equalization tank should be checked every month.

Observation:
Several operational parameters may be determined by simple observation, which in conjunction with field-testing, can be extremely useful for process control. The Amphidrome® process should not have suspended solids in the effluent, nor should strong offensive odors be present in any of the tanks. Therefore, visual inspection of

effluent turbidity and color may be an indication of process problems. It is recommended that along with the field sampling (i.e. test kit sampling), that the color and clarity of the effluent be noted in the operator's log.

Strong odors indicating a highly septic environment should not be present in the Amphidrome® system. Any odor present in any of the tanks should also be noted in the operator's log and should be investigated, as this indicates a potential problem.

Troubleshooting Guidelines

Equipment

Blowers

Problem	Possible Cause	Solution
No air supply to reactor, when called for OR	Blower not operating	Ensure blower switch is on. Check circuit breaker and reset. If breaker continues to trip have circuit checked by qualified technician
	Incorrect rotation	Check for proper rotation.
	Broken/missing drive belt	Replace belt
	Closed valve	Ensure correct valve is open Ensure check valves have been installed correctly and are working properly.
Low air supply	Blockage in air line	Check operating pressure clear blockage Check pressure relief for open or closed condition
	Broken air discharge line	Investigate for breaks in discharge line and repair
Blower does not operate or ceases to operate	Not called for	Check program to confirm blower should be operating
	Switch in the off position	Ensure correct switch is in the on or auto position
	Breaker tripped	Check circuit breaker and reset. If breaker continues to trip have circuit checked by qualified technician.
Blower running abnormally hot	Inadequate lubrication	Ensure proper lubrication – consult manufacturers lubrication instructions
	Low inlet air supply	Check inlet piping for blockage Check inlet filter(s) and replace if necessary

Blowers (cont'd)

Problem	Possible Cause	Solution
Blower running abnormally hot (continued)	Poor ventilation	Ensure adequate ventilation
High discharge pressure	Valve closed Obstruction in discharge line Check valve installed improperly, broken or stuck Reactor plugged Relief valve improperly set	Check valves Clear obstruction Inspect check valve Backwash (filter) reactor Adjust relief valve
Blower abnormally noisy	Improper lubrication Bearing noise (could be the blower or the motor) Belt hitting guard Loose belts, guards, etc. Valve closed	Ensure proper lubrication Replace bearings if necessary Adjust guard Tighten all equipment Check discharge valves

Submersible Pumps

Problem	Possible Cause	Solution
Pump will not operate	Circuit breaker tripped or switch in off position (If it continues to trip)	Check breaker. Reset if tripped. Check switch. Circuit should be checked by a qualified technician. If necessary, remove pump from tank and inspect
Pump will not operate in automatic	Switch not in auto position Low float not made	Check switch Check floats
Low flow rate	Improper rotation Valve partially closed Pump not seated properly Check valve stuck or clogged Discharge line clogged Discharge head too high Pump dirty or clogged Impeller spinning on shaft	Check rotation Check valves Check pump connections Inspect check valve and discharge line Review pump curve Check discharge head Remove pump from tank and inspect

Flow Sensor and Meter

Problem	Possible Cause	Solution
No display on screen	Circuit breaker tripped	Check breaker and reset
	Improper wiring	Have wiring checked by a qualified technician
	Meter malfunctioning	Replace meter
Improper flow rate and totalization	Meter programmed improperly	Consult manufacturer's literature for proper programming
	Sensor malfunctioning or broken	Remove sensor and inspect
	Incorrect sensor installation	Consult manufacturer's installation instructions
	Pump malfunctioning	Troubleshoot pump
No flow rate or totalization	Sensor broken or clogged	Remove sensor, inspect and clean if necessary
	Improper wiring	Check wiring
	Pump off	Check pump

Controls
Floats

Problem	Possible Cause	Solution
Equipment not responding to floats	Bad wiring or connections	Check wiring and connections for complete circuit
	Improper float application (Normally open)	Make sure floats are correct for application
	Improper signal input location	Have qualified technician troubleshoot signal input at panel
	Bad float	Replace float
	Equipment not in automatic position	Check H/O/A switches
	Float hung up in improper position	Check float positions

Process Control

BOD Removal

Problem	Possible Cause	Solution
High effluent BOD	High organic loading	Check actual vs. design organic loading Investigate abnormally high influent organic loading. Increase number of returns and possibly decrease number of batches.
	Insufficient dissolved oxygen	Troubleshoot air supply system Increase air supply
	High hydraulic loading	Check actual vs. design hydraulic loading Investigate abnormally high hydraulic loading Increase number of batches Limit 2 / 24 hour period if possible
	Insufficient biomass	Decrease number of backwashes if possible Check BOD: N: P ratio
	Total suspended solids in effluent	Troubleshoot TSS problem
	Toxic material in influent	Investigate for toxins or biocides

TSS Removal

Problem	Possible Cause	Solution
High Effluent TSS	High influent TSS	Check depth of blanket in anoxic tank – if within two feet of bottom of outlet tee, pump out anoxic tank.
	Dirty Amphidrome® reactor	Increase backwash of Amphidrome®

Nitrogen Removal -TKN

Problem	Possible Cause	Solution
High effluent TKN	Insufficient D.O	Increase air supply either by adjusting the fixed or the multiplier
	High influent TKN loading	Check actual vs. design TKN loading
	Insufficient biomass	Decrease Amphidrome® backwash if possible Check BOD: N: P ratio
	Low return frequency	Increase number of returns if possible
	Toxic material in influent	Investigate influent for toxins or biocides
	Low pH and or temperature	Check pH and temperature of process

Nitrogen Removal – NH_3

Problem	Possible Cause	Solution
High effluent ammonia	Insufficient dissolved oxygen	Increase air supply Troubleshoot air system if necessary
	High influent ammonia loading	Check actual vs. design ammonia loading Investigate abnormally high loading
	Insufficient biomass	Decrease backwash of Amphidrome® if possible Check BOD: N: P ratio
	Insufficient alkalinity	Check effluent alkalinity If less that 100 mg/l add sodium bicarbonate to system.
	Low temperature	Check temperature of process If abnormally low, investigate cause
	Excessively high return rate over trough	Check the return flow to influent flow ratio
	Toxic material present in process wastewater of influent	Investigate influent and process water for toxins and or biocides
	High hydraulic loading	Check actual vs. design hydraulic loading Investigate abnormally high hydraulic loading Increase number of batches to 2/24 hr. period maximum if necessary

Nitrogen Removal – NO_3^-

Problem	Possible Cause	Solution
High nitrate in effluent and fractional ammonia level	Excess dissolved oxygen in system	Decrease air supply and recheck both nitrate and ammonia Check anoxic tank, maintain anoxic conditions Check return flow volume to influent ratio, adjust accordingly (i.e. DO ≤ .5 mg/e)

Appendix 1. Filter Flow Through Rate

Project/Location:
Date:

Filter

Size	Diameter (ft)	Area (sq ft)

Forward Flow Rate

Time (min.)	Level (in.)	Change (in.)	Del. Vol. (gal.)	Flow Rate (gpm)
0-3				
3-6				
6-9				
9-12				
12-15				
15-18				

Average Flow Rate: ____________gpm
Average Hydraulic Loading: ____________gpm/sq ft

Backwash Flow Rate

Time (min.)	Level (in.)	Change (in.)	Del. Vol. (gal.)	Flow Rate (gpm)
0-2				
2-4				
4-6				
6-8				
8-10				
*				

*** Continue for every two minutes until liquid reaches the overflow pipe.**

Average Flow Rate: ____________gpm
Average Hydraulic Loading: ____________gpm/sq ft

Appendix 2.
AUTOMATIC VOICE/PAGER DIALER SYSTEM*
MODEL AD2001 OPERATING INSTRUCTIONS

HOW IT WORKS

The AD2001 dialer features busy-line and no-answer detection to ensure prompt transmission of up to 2 prerecorded messages delivered sequentially to as many as 4 standard telephones, cellular phones, voice and/or numeric pagers. Messages to both local and long-distance calls can be transmitted. When activated, the dialer instantly begins calling the numbers in sequence, delivering each message 1 to 3 times in a row, in accordance with the pre-selected number of dialing attempts. The AD-2001 is extensively programmable, offering personalized customization to fulfill virtually any residential or business requirement. Plain-English prompts walk the user through the process in a timely manner. Programming options abound, allowing the user to:

· Store up to 4 telephone/pager numbers.
· Choose 1- 9 calling efforts for the numbers dialed.
· Select 1-3 message repeats.
· Record a variable combination (maximum: 3) of instructional outgoing messages (total elapsed time: 51 seconds).

Program up to 2 separate input channels with individually enable/disable, entry/exit delay and activation options (Normally Open (N.O.), Normally Closed (N.C.) (dry contact or voltage activation) including momentary and continuous activation for each).

Further individualize each channel by selecting the delay times, telephone/pager numbers to be dialed and the specific outgoing messages to be played.

PROGRAMMING THE DIALER

Overview

Please study this section thoroughly before beginning to program the dialer, referring to the Sample Program Planner on page 13. Then, select from among the options for each feature, listing each choice in pencil on the blank Program Planner on page 14. Once the dialer is correctly programmed, list each choice in ink. One copy of the Planner should be kept by the installer; one copy should remain with the end user.

A look At The Keypad

· Callout for Numerals:
Press these keys to enter telephone numbers and other programming information as specified in this manual. A maximum of 50 digits can be input in each phone/pager location.

*The manufacturer's <u>Ower's Manual and Operating Instructions</u> for Model AD-2001, the Automatic Voice/Pager Dialer System, has been modified to fit the format of this manual. An original copy of the manufacturer's <u>Owner's Manual and Operating Instructions</u> will be included with the equipment furnished to each homeowner.

· Callout for P:
Press this key to program in a pause. Each "P" provides a 2-second pause.

· **Callout for R:**
Press this key to record the combination of identification and directional outgoing messages (OGMs). The total elapsed OGM time cannot exceed 51 seconds.

· **Callout for M:**
Press this key to change the Mode of the dialer, in sequence: **PROGRAM TEST OPERATE OFF.**

Once the unit has been programmed, removing power or placing the dialer in the OFF mode will not affect the programming.

Programming the Dialer
First Time Installation to Initialize Dialer Follow Steps 1 & 2.

STEP 1 Apply power to the unit. The LCD will read: NOT PROGRAMMED PRESS KEYPAD #1.

STEP 2 Press 1. The LCD will change to read: USP AD2001 X.X.
then: PROGRAM: NUMBERS.
then: SELECT: 1-4, 0(DONE).

Programming Telephone And/Or Pager Numbers
You are now ready to begin programming the dialer. All programming can be input before connecting the dialer to a telephone line. Check the unit's LCD as you program numbers in the dialer to ensure accuracy. Please complete all programming instructions before attempting to operate the unit. Before programming your dialer to call the police, fire department or 9-1-1 directly, you must check with these agencies for their approval.

A maximum of 50 digits (including pauses) can be programmed in at each location.

***PROGRAM: NUMBERS**	**SELECT: 1-4**
1(YES) 2(NO)	**0(DONE)**

*This prompt will appear after a number has been programmed and this section has been exited.

STEP 1 Press location number 1-4 to program the first number. This can be any location 1-4. You do not have to program locations in sequence. For example, you can program numbers in locations 2 and 4. When you are done programming all the desired telephone and/or pager numbers, press "O" to exit this section.

The LCD will read:	**PAGER**
	1(YES) 2(NO)

STEP 2 Press "1" if you wish to program in a numeric pager number (step 3A). Press "2" if you wish to program in a telephone number (step 3B), cellular phone numer (step 3B), or a voice pager (step 3C).

STEP 3A- NUMERIC PAGERS

NOTE: WHEN PROGRAMMING NUMERIC PAGERS, YOU MUST PROGRAM IN ONE OR MORE PAUSES. EACH "P" PROVIDES A 2-SECOND PAUSE. BEFORE PROGRAMMING IN A PAGER, CALL THE NUMBER TO DETERMINE THE NUMBER OF 2-SECOND PAUSES TO BE PROGRAMMED IN.

If you pressed "1" to program in a numeric pager...
Press the digits of the pager to be called. The numbers will appear on the LCD, as will the following key designations. Press "P" one or more times in accordance with the number of seconds needed to accommodate the pager. **(Remember, each "P" provides a 2-second pause).** Press the digits of the numeric pager code.

NOTE: SOME PAGER SERVICES REQUIRE A "#" SIGN FOR SEPARATION OF THE NUMERIC CODE OR AT THE END OF THE NUMERIC CODE FOR PROPER TRANSMISSION.

Press "*" to store the sequence.
Example: To store numeric pager number 555-1212, a 4-second Pause and code 3456:
Press: 5 5 5 1 2 1 2 P P 3 4 5 6 *

STEP 3B – TELEPHONE NUMBERS
If you pressed "2" and wish to program in a telephone number...
Press the digits of the number to be dialed. For long-distance numbers, first press "1" followed by the area code and then the number. The number will appear on the LCD.
Press "*" to store the sequence.
Example: Store telephone number 1-800-555-1212:
Press: 1 8 0 0 5 5 5 1 2 1 2 *

REMEMBER/NOTE: Before programming your dialer to call the police, fire department 0r 9-1-1 directly, you must check with these agencies for their approval.

STEP 3C – VOICE PAGERS
If you pressed "2" and wish to program in a voice pager...
Press the digits of the pager to be called. Press "P" one or more times in accordance with the number of seconds needed to accommodate the pager.
(Remember each "P" provides a 2-second pause).
Press "*" to store the sequence. The number will appear on the LCD.
Example: To store voice pager 555-1212 and a 4-second pause:
Press: 5 5 5 1 2 1 2 P P *

STEP 4 Repeat steps 1-3 for each number to be programmed in each location. Select any of 4 location numbers in Step 1 (SELECT: 1-4) for each number to be programmed.

STEP 5 When you are done programming all desired telephone and/or pager numbers, press "0" to exit this section.

NOTE: IF YOU ENTER THE WRONG CHOICE, PRESS "M" KEY REPEATEDLY AND RETURN TO THE "PROGRAM MODE", THEN SELECT THE SECTION TO CHANGE ("1" ACCEPT SECTION, "2" FOR NEXT SECTION), THEN ENTER CORRECT INFORMATION.

Programming Auxiliary Information

The dialer is preset at the factory to typical telephone line (TLINE), PBX, Dialing Attempts and Message Repeat options. If you choose to accept the following default prompts, simply press "2" to scroll to the next section. If your phone system requires dialing a digit to get an outside line or dial tone, similar to PBX, then turn PBX on and enter digit to program.

PRESETS

T-LINE...............TONE
PBX....................OFF
ATTEMPTS...............2
MESSAGE................2

To change the presets, follow these steps.

T-LINE

The LCD will display: **PROGRAM: T-LINE 1(YES) 2(NO)**

Press "1" to program T-LINE.
Press "2" to scroll to the next section.

The LCD will display: **PROGRAM: T-LINE 1(TONE) 2(PULSE)**

Press "1" for TONE. Press "2" for PULSE.

PBX

The LCD will display: **PROGRAM: PBX 1(ON) 2(OFF)**

Step 1: Press "1" for ON. Press "2" for OFF.
Step 2: If "1" is entered, the LCD will display: **PROGRAM: PBX ENTER PBX NUMBER**

Enter PBX number (1 digit).

Attempts

Attempts refers to the number of times the dialer will call each designated number. Both successful and unsuccessful (busy or no answer) call are considered attempts.

The LCD will display: **PROGRAM: ATTEMPTS ENTER 1-9**

Step 1: Press the digit (1-9) corresponding to the number of times you wish the dialer to call each number.

Message

Message refers to the number of times each message will be delivered to each designated number.

The LCD will display: **PROGRAM: MESSAGE REPEAT ENTER 1-3**

Step 1: Press the digits (1-3) corresponding to the number of times you wish the message(s) to be delivered.

After selecting the number of message repeats, the dialer will automatically exit this section.

Structuring Your Outgoing Messages

The AD-2001 dialer was designed with optimum versatility and functionality in mind. Nowhere is this more apparent than in the matrix of outgoing messages (OGMs). The user's ability to "mix and match" OGMs allows complete system customization and provides ultimate efficiency.

Typically, each OGM will have a specific purpose. For instance, OGM 1 can alert the person notified to contact the fire department while OGM 2 can alert the person to contact the police department. Typically the dialer is programmed to notify family, friends or another responsible party. Before programming your dialer to call the police, fire department or 9-1-1 directly, you must check with these agencies for their approval.

OPTION #1 No OGM. Select this option if you do not wish to record any outgoing messages.

OPTION #2 1 OGM. Select this option if you wish to record one OGM, which may be as long as 51 seconds.

OPTION #3 2 OGMs. Select this option if you wish to record two OGMs, each of which may be as long as 25.5 seconds.

OPTION #4 ID plus 2 OGMs. Select this option if you wish to record one ID of up to 15 seconds in length, and two OGMs, each of which may be as long as 18 seconds. *

*If your ID message is less than 15 seconds in length, the remaining time will be evenly divided among the OGMs.

Example: OPTION #4: ID plus 2 OGMs.

If the ID is 10 seconds, then each OGM can be (51 minus 10 equals 41 divided by 2 equals) 20.5 seconds in length.

Programming And Recording Your Outgoing Messages
Follow these steps to program and record your outgoing messages. Skip this portion if you have programmed in only numeric pagers, which rely on coded DTMF messages. As with all AD-2001 programming, the unit need not be connected to a phone line when information is programmed in. Remember that "OPT" on the LCD stands for option; "OGM" stands for outgoing message.

NOTE: IF YOU ENTER THE WRONG CHOICE, PRESS "M" KEY REPEATEDLY AND RETURN TO THE "PROGRAM MODE", THEN SELECT THE SECTION TO CHANGE ("1" ACCEPT SECTION, "2" FOR NEXT SECTION), THEN ENTER CORRECT INFORMATION.

STEP 1 Decide which of the four options you prefer.

STEP 2 Before programming in this option, write down all your messages. Time them carefully, changing them if ecessary to fit the alotted time frame. Practice saying them, clearly enunciating each message for maximum clarity in case of an emergency. Keep a final recording script.

STEP 3 Program your option.
A) The LCD will read: **PROGRAM: OGMS**
1(YES) 2(NO)
B) Press "1" to program your OGMs. Press "2" to scroll to the next section.
C) Press "1" to select the option (#1- #4) displayed or press "2" to scroll to the desired option.

STEP 4 After selecting your option as explained above, record your message.
A) The word RECORD will appear in the upper left corner of the LCD, above the instruction: PRESS R. The option selected will appear in the upper right corner. For instance, if you selected option #2, the LCD will read:

RECORD **OGM1**
PRESS R

B) Speak 6-12 inches away from the microphone. Referring to your script and speaking in a normal voice, press and hold R (the word RECORDING will be displayed), releasing the key after you have completed enunciating your messages. The word DONE will appear on the LCD when the maximum allotted time has been reached.

C) The LCD will read: **PLAY OGM(S)**
1(YES) 2(NO)

Press "1" to play back your recording.

D) The LCD will read: **ACCEPT**
1(YES) 2(NO)

Press "1" to accept the recorded OGM(s). Press "2" if you wish to re-record the messages, beginning with Step 4.

Changing The OGMs After your system is up and operating, you may change one or more of the recorded OGMs and/or choose a completely different option. To do so, simply scroll to the programming section on your display:

PROGRAM: OGMS
1(YES) 2(NO)

Select the option, then begin again from Step 3 above to record your new message(s).

Programming The Channels
The AD-2001 is designed to be adaptable to a complete range of personalized applications. Each of the two input channels can be programmed individually for full system customization. In addition to setting enable/disable options, entry/exit delays and type of activation (N.O., N.C., & momentary or continuous), each user can specify which emergency messages will be delivered and which numbers will be dialed. The first channel activated will be the priority channel. Numbers programmed to that channel will be completed before the dialer moves on to the next channel. Although comprehensive in scope, the system is easy to program. Just follow these simple steps.

NOTE: IF YOU ENTER THE WRONG CHOICE, PRESS "M" KEY REPEATEDLY AND RETURN TO THE "PROGRAM MODE", THEN SELECT THE SECTION TO CHANGE ("1" ACCEPT SECTION, "2" FOR NEXT SECTION), THEN ENTER CORRECT INFORMATION.

STEP 1 The LCD will read: **PROGRAM: CHANNELS**
1(YES) 2(NO)

Press "1" to begin programming the channels.

STEP 2 The LCD will read: **SELECT: 1 OR 2**
0(DONE)

Enter the channel you wish to program (1-2).

Enable/Disable

STEP 3 The LCD will read: **CH X: ENABLE**

1(YES) 2(NO)

("CH X" being the channel selected)

Press "1" to enable the channel. Press "2" to disable the channel.

Exit/Entry Delays

Capable of programming up to a maximum of 3 minutes and 20 seconds each.

STEP 4 The LCD will read: **CH X: EXIT DELAY**
1(YES) 2(NO)

Proceed with A) if you wish to program an exit delay. Proceed with B) if you do not.

A) To program exit delay, press "1".
The LCD will read: **ENTER 0-199 THEN**
PRESS *

Enter the digits corresponding to the number of seconds you wish to install. (For example, press "120" then press "*", if you wish to install a 120-second exit delay).
B) If you do not wish to program an exit delay, press "2".

STEP 5 The LCD will read: **CH X: ENTRY DELAY**
1(YES) 2(NO)

Proceed with A) if you wish to program an entry delay. Proceed with B) if you do not.
A) To program an entry delay, press "1".
The LCD will read: **ENTER 0-199 THEN**
PRESS *

Press "1" to program a delay. Then enter the digits corresponding to the number of seconds you wish to install. (For example, press "90" then press "*", if you wish to install a 90-second delay).
B) If you do not wish to program an entry delay, press "2".

Normally Open/Normally Closed

STEP 6 The LCD will read: **CH X: N.O./N.C.**
1(N.O.) 2(N.C.)

A) Press "1" to select a normally open channel.
B) Press "2" to select a normally closed channel.

Momentary/Continuous Activation

STEP 7 The LCD will read: **CH X: MOM/CONT**
1(MOM) 2(CONT)

A) Press "1" to select a momentary trigger.
B) Press "2" to select continuous activation.

Numbers Dialed/Outgoing Messages

Following these steps allows you to choose which OGM(s) will be delivered and which numbers will be dialed for each channel. NOTE: Dialer LCD will only show programmed numbers and OGM options.

STEP 8 The LCD will read: **CH X: DIAL #X**
1(YES) 2(NO)

("Dial #X" being the number in phone/pager location 1-4)

A) Press "1" to dial phone/pager #X to be dialed when the selected channel is activated. Press "2" if you do not wish this number to be dialed.

B) Continue the above procedure for each of the up to four phone/pager numbers programmed in.

STEP 9 The LCD will read: **CH X: OGM X**
1(YES) 2(NO)

("OGM X" being the OGM recorded in OGM options #2 - #4)

A) Press "1" to deliver OGM X when the channel is activated. Press "2" if you do not wish this OGM to be delivered.
B) Continue the above procedure for each Channel/OGM. If you have programmed in and recorded an ID message as one of your OGM options, this ID will be delivered to all channels. It will not appear in the Channel display.

NOTE: ID AND OGM(S) WILL ONLY BE DELIVERED TO TELEPHONE NUMBERS, CELLULAR NUMBERS, AND VOICE PAGERS.

Completing The Programming
Once you have programmed in all dialing and OGM options for each channel, the LCD will read:

ACCEPT
1(YES) 2(NO)

STEP 10 Press "1" to accept the Channel programming. Press "2" to re-program or to revert to previously programmed setting. You are now ready to review your programming and test the system.

PRESS "M" TO EXIT PROGRAMMING MODE.

TESTING YOUR SYSTEM

Test your system before an emergency occurs.
Do not neglect to review programmed information and verify all elements of your system thoroughly before relying on the dialer to deliver the necessary information to the desired parties accurately and completely.

We strongly recommend testing the system in test mode before connecting to a telephone line. The test mode tests the stored information, not the full functionality of the dialer. To test the full functionality of the dialer, the unit must be tested in the operate mode. In the test mo de, the dialer will not make more than one attempt per number dialed or play any OGM more than once.

NOTE: IF YOU ENTER THE WRONG CHOICE, PRESS "M" KEY REPEATEDLY AND RETURN TO THE "PROGRAM MODE", THEN SELECT THE SECTION TO CHANGE ("1" ACCEPT SECTION, "2" FOR NEXT SECTION), THEN ENTER CORRECT INFORMATION.

STEP 1 Press the "M" Mode key until the LCD reads:

TEST: T-LINE
1(YES) 2(NO)

STEP 2 Press "1" to display the T-Line configuration. The data will scroll through all selections. Press "2" to scroll to the next section.

STEP 3 The LCD will read: **TEST: CHANNEL(S)**
1(YES) 2(NO)

Press "1" to test channels.
Press "2" to scroll to the next section.

STEP 4 The LCD will read: **SELECT: 1-2 3(BOTH) 0(DONE)**

Select the channel you wish to test (1-2). Press "3" to test both. Channels. Once a channel is selected (or "all") the programmed channel information will be displayed on the LCD. Verify data accuracy as the LCD scrolls through by comparing the information displayed with that specified on your Program Planner. Listen to your recorded message(s) to ensure that the correct OGM (if programmed) is delivered. Press "0" to exit testing.

STEP 5 Now connect your dialer to the telephone line you will be using and test the system again, to determine if it functions correctly in an actual emergency situation. Make sure you notify the receiving pa rty of your intent to call them, and tell them it is just a test.

STEP 6 To test the operation of your entire system, set Mode to OPERATE and proceed as explained in the next section: Operating Your System.

Test your system on a regular basis, at least once a week.

OPERATING YOUR SYSTEM

You are now ready to begin operating your system, relying on the AD-2001 to work in conjunction with your alarm system to provide 24-hour security reassurance and peace of mind.

When in the operating mode, the system will monitor both enabled channels, initiating dialing when a valid alarm condition occurs. Upon activation the dialer will begin calling each phone/pager number selected, in sequence, for the pre-selected number of attempts. During each successful attempt, the voice message will be delivered 1, 2, or 3 times, in accordance with the option selected (numeric messages will only be delivered one time). In unsuccessful attempts, the dialer will move on to the next phone/pager number after receiving 8 busy or 8 rings without an answer. The dialer will not allow voice messages to be delivered to programmed numeric pager locations.

If you send a message to a phone attached to an answering machine, it will consider this a successful attempt. Make sure you designate the maximum number of message repeats to be sure that a complete message will be left on the answering machine, because part or all of your emergency message may be "lost" while the answering machine delivers its greeting message.

Placing your system in OPERATE can also be used as a final test of the full functionality of each channel's exit/entry delay, activation, momentary/continuous trigger, phone numbers and OGM. Although serving as a test, this mode reflects actual operation; therefore the OGM(s) will not be heard through your dialer's speaker but only by each party called.

To begin operating your system, simply press the "M" Mode key until the word OPERATE appears on the LCD. To disarm the dialer, switch the mode to OFF by pressing the same key. All programming information will be retained.

System Notations
Here are a few explanations to help you better understand how your AD-2001 dialer operates. For specific information on the AD-2001 unit alone, call United Security Products, Inc.'s Customer Service Department during normal business hours at (858) 597-6677.

Channel Activation
Each of the dialer's two channels can be activated by any of the following: a normally open dry contact, normally closed dry contact or positive 5-28VDC voltage activation. Under a momentary activation, a single violation of a channel will cause the dialer to initiate delivering all preselected OGMs to all programmed numbers associated with that channel. Under continuous activation, the dialer will initiate the process, terminating it if/when the activated channel is restored to a non-alarm state. Once an alarm has occurred and all attempts satisfied, the dialer will continue to monitor any remaining enabled channel. Once the activated channel has been restored to a non-alarm state, it will then be re-armed and ready for the next alarm.

Exit/Entry Delays
If a channel is activated during a pre-selected exit delay, the alarm condition will be ignored until the delay has expired. If an alarm occurs, the entry delay will cause the dialer to wait before starting the dialing process. To de -activate the dialer during the entry wait period, simply press "M" to return to the OFF Mode. Both exit and entry delay times can be pre-selected to range from 1-199 seconds.

Additional Features
The dialer offers three innovative features that enhance the utility of the entire system.

Listen-In
While receiving an OGM on a touch-tone phone, the called party can press "1" to listen in to the activity at the other end of the line for one minute. Pressing "1" again restarts the minute increment period and can be repeated indefinitely. When "1" is pressed the OGM will stop playing and the listen in period will start.

Two-Way
After the called party is listening-in, that party can press "2" to begin a two-way conversation lasting for one minute. This procedure also can be repeated indefinitely by pressing "2" again to restart the minute. Once you are in two-way mode you cannot go back to Listen-In.

Remote Turn-Off
The called party can remotely terminate the activated channel any time during the OGM by pressing "1" then "#" twice within one second. The dialer will continue to monitor the remaining channel. Once the terminated channel is restored to a non-alarm state, it will re-arm. If in listen-in or two-way, simply press "#" twice in one second, for remote turn-off.

SAMPLE PROGRAM PLANNER

Programming Example for Quick Setup
Before programming the dialer, study the example shown on this page. This "quick setup" example programs in one telephone number, two numeric pager numbers, two attempts, two repeats, an ID plus two additional OGMs, and channels 1 and 2.

Once you understand the setup, use the blank **Program Planner** to begin programming your dialer. We recommend making several blank copies of the Planner before beginning the process. It also is advisable to fill in the Planner in pencil initially.

AD2001 PROGRAM PLANNER

PROGRAM: NUMBERS **DATE:**

#	PAGER YES	NO	TELEPHONE # (EXC. PBX DIGIT, INCL. NUMERIC PAGER CODE	NAME OF PARTY TO BE REACHED
1				
2				
3				
4				
5				

PROGRAM: T-LINE

TONE	PULSE	PBX ON	OFF	ATTEMPTS 1 THROUGH 9	MESSAGE REPEAT 1 THROUGH 9

PROGRAM: OGMs

OPTION		STYLE	BRIEFLY DESCRIBE TYPE OF VOICE MESSAG(S)
	1		
	2		
	3		
	4		

PROGRAM: CHANNELS

CH	ENABLE YES	NO	EXIT DELAY (SEC) YES	NO	0-199	ENTRY DELAY (SEC) YES	NO	0-199	ACTIVATION NO	NC	MON	CONT	DIAL NUMBER				PLAY OGM	
1													1	2	3	4	1	2
2																		
3																		
4																		

STEP 1 Press "1".

STEP 2 When the LCD reads SELECT 1-4, press "1" to install the first phone number in location 1 press "2" to indicate no pager; then press, in sequence, (fictitious) phone number "2345678" followed by the "*" sign to store the programming process for that number.

STEP 3 Press "3" to install the second phone number in location 3; press "1" to indicate numeric pager; then press' in sequence, "3456789PP4455#" followed by the "*" sign. The first seven digits represent the pager number dialed; each P stands for a 2-second pause; the next four digits followed b y the # sign represent the pager code and the * stores the programming process for that number. Now press "4" to install the third phone number in location 4; press "1" to indicate numeric pager; then press, in sequence, "3456789PP5544#" followed by the "*" sign.

STEP 4 Press "0" to exit PROGRAM NUMBERS.

STEP 5 At the PROGRAM: T-LINE prompt, press "1" to choose tone; press "2" to indicate no PBX; press "2" to program in two dialing attempts per emergency number called; press "2" to program in two message re peats for each call.

STEP 6 Press "1" to PROGRAM OGM(S). Press "2" three times to Scroll to option #4; press "1" to program in an ID message and two specific outgoing messages (OGMs).

STEP 7 Using a prepared script and speaking six-to-eight inches from the dialer's microphone on the front of the unit, press "R" when you are ready to enunciate your 15-second identification message and your two 18-second messages. Dialer automatically prompts to next OGM. Make OGM1 a message telling the receiving party to call the police department. Make OGM2 a message to call the fire department.

STEP 8 Press "1" to play back all recorded messages; press "1" again to accept. (NOTE: DIALER LCD WILL ONLY SHOW PROGRAMMED NUMBERS AND OGM OPTIONS).

STEP 9 Press "1" to PROGRAM CHANNELS.

STEP 10 Press "1" to program Channel 1. Press "1" to ENABLE. Press "1" then enter "30" then press "*" for a 30-second EXIT delay; press "1" then enter "15" then press "*" for a 15-second entry delay. Now press "2" for NORMALLY CLOSED and then "1" for MOMENTARY activation. Press "1" to select phone/pager number 1 to be dialed. Press "1" again to select phone/pager number 3 to be dialed. Press "2" to not select phone/pager number 4 to be dialed. Press "1" to select OGM1 to be delivered and press "2" to not select OGM2 to be delivered. Press "1" to accept the channel configuration.

STEP 11 Press "2" to program Channel 2. Press "1" to ENABLE. Press "2" twice to indicate no EXIT or ENTRY delay. Now press "1" for NORMALLY OPEN and the "2" for CONTINUOUS activation. Press "1" to select phone/pager number 1 to be dialed. Press "2" to not select phone/pager 3 to be dialed. Press "1" to select phone/pager number 4 to be dialed. Press "2" to not select OGM1 to be delivered and press "1" to select OGM2 to be deliv ered. Press "1" to accept the channel configuration.

STEP 12 Press "0" to exit PROGRAM: **CHANNELS.**

Press "M" to exit programming mode.

After thoroughly testing your system, redo your Program Planner in ink. One copy should be kept in a safe place by the end user; one copy should be retained by the installer.

SPECIFICATIONS

Dimensions

Power source:	9-18VDC
Current (OPERATE mode – standby):	28mA typical.
Current (OPERATE mode – dialing):	100mA max.
Activation: 1) N.C. Activation: dialer activates when an "open" is detected	
2) N.O. Activation: dialer activates when a "close" is detected	
3) Voltage Activation: N.C. (applied voltage: Min. +5VDC, Max. +28VDC)	
N.O. (loss of continuous voltage: Min. 0VDC, Max. 0.25VDC)	
Max. digits for outgoing numbers:	50
Operating temperature range:	-18 to 55 C (0 to 130 F)
Dimensions (inches):	6 x 4 x 1.5 in
Weight (ounces):	10 oz
Mounting:	Wall or Flat Surface
Case Material:	ABS
Color:	White
Warranty:	1 Year

Note: Design and specifications subject to change without notice.

DIALER ACCESSORIES

Power Source

AC-1: AC/DC Adaptor

Plugs into regular 110VAC outlet to provide the dialer with the required primary power.

AC-2: AC/DC Adaptor

12VDC/0.5A for stand alone with siren use.

PP-1: Power (Rechargeable)

Provides 24 (est.) hours of backup standby power.

AC-1P: AC/DC Adaptor For Use With PP-1

Plugs into regular 110VAC outlet to provide the dialer with the required primary power and additional input for PP-1 interface.

IR-1: Isolation Relay

Converts alarm output voltage to N.C. to provide clean input trigger to dialer.

Industrial/Residential Sensors

F20: Temperature Supervisory Switch <40 F
HTS: High Temperature Switch
LTS: Low Temperature Switch
CSS: Cold Storage Switch
WLS: Water Level Sensor
RTS: Adjustable Temperature Controller, N.O., N.C.
PLS: Power Loss Sensor (110VAC)

Sensors
Magnetic Contacts – Door and Window
Glass Break Detectors
Hold Up Buttons/Emergency Switches
Pressure Mats – Sealed and Under Carpet
Motion Detectors

Siren
S-120: 2" Mini Siren, 12VDC @ 120 mA typical

Additional Options
Data logger: AD-2001-DL
Retains in memory log of alarm events for later retrieval and review.

Wireless: AD-2001/W
Wireless version AD-2001 dialer includes wireless pendant transmitter.
24V Application: AD-2001/F
For this option the dialer is configured to operate at 24VDC to 32VDC max. All other specifications apply.
Wireless and 24V Applications: AD-2001/W/F
The AD-2001/W/F incorporates both the wireless feature and 24VDC application. See WIRELESS AND 24V APPLICATION for further details.

NOTE: CALL UNITED SECURITY PRODUCTS FOR ADDITIONAL INFORMATION AND DEVICES NOT LISTED HERE.

Wireless Upgrade:
The standard AD-2001 can be upgraded for wireless link-up with RF-activated mag contacts, motion sensors, pendant, etc., by installing a new back cover containing a pre-tested RF assembly and swivel antenna. The receiver is connected to the main board via a 4-pin interface connector already included in the standard configuration. See WIRELESS for further details.

NOTE: SYSTEMS ALREADY INSTALLED CAN BE UPGRADED WITHOUT REPLACING OR RE-WIRING THE DIALER.

IMPORTANT INFORMATION

Care And Precautions
Location
Place the dialer on a flat level surface or mount the unit on the wall, away from extreme cold or heat, direct sunlight, excessive humidity and away from equipment that generate strong magnetic fields. Avoid placing near large metal objects and areas that produce smoke, dust and mechanical vibrations.

Care
Clean the housing with a soft cloth lightly moistened with water or mild detergent solution. Never use solvents such as alcohol or thinner. Do not allow liquids to spill into the unit.

Optional Backup
To ensure continuous operation during power outages, hookup to a 12VDC backup battery pack is recommended. (PP-1) Available from United Security Products.

Caution
Do not use the dialer if a gas leak is suspected or during lightning.

Problems
If liquid or a foreign object penetrates the unit, disconnect it immediately and contact your installer or other qualified technician. Before calling USP, please make sure...

- You have read this manual and understand how to operate the dialer.
- Your phone line is working.
- You check out the entire system, including external hookup wiring and sensors attached.

If you still have questions or concerns, call our USP Technical Service Department between the hours of 7:30 AM and 4:00 PM, PST, Monday through Friday.

Federal Communications Commission Radio And Television Interference Statement For A Class 'B' Device This equipment generates and uses radio frequency energy and if not installed and used properly, that is, in strict accordance with the manufacturer's instructions, may cause interference to radio and television reception. It has been type tested and found to comply with the limits for a Class 'B' computing device in accordance with the specifications in Subpart B of FCC Rules and Regulations (as outlined in the Code of Federal Regulation, Title 47), which are designed to provide reasonable protection against such interference in a residential installation.

USER INSTRUCTIONS

If this equipment does cause interference to radio or television reception, which can be determined by turning the equipment off, then on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate radio or television.
- Increase the separation between the equipment and receiver.
- Connect the equipment into a different outlet so that the equipment and receiver are on different branch circuits.
- Consult the dealer or an experienced radio/TV technician for help.

Changes or modifications not expressly approved by United security Products, Inc. could void the user's authority to operate the equipment.

United Security Products
Issue date: 4/27/98
For Technical Service And Support: Call (858) 597-6677 * Fax (858) 455-0036
E-mail usp@ix.netcom.com
Monday – Friday * 7:30 AM – 4:00 PM PST

Appendix 3. Glossary of Terms

ADVANCED WASTE TREATMENT Any process of water renovation that upgrades treated wastewater to meet specific reuse requirements. May include general cleanup of water or removal of specific parts of wastes insufficiently removed by conventional processes. Typical processes include chemical treatment and pressure filtration. Also called **TERTIARY TREATMENT**.

AERATION The process of adding air to water. With mixture of wastewater and activated sludge, adding air provides mixing and oxygen for the microorganisms treating the wastewater.

AEROBES Bacteria that must have molecular (dissolved) oxygen (DO) to survive. Aerobes are aerobic bacteria.

AEROBIC A condition in which atmospheric or dissolved molecular oxygen is present in the aquatic (water) environment.

AEROBIC BACTERIA Bacteria which reproduce in an environment containing oxygen which is available for their respiration (breathing), namely atmospheric oxygen or oxygen dissolved in water. Oxygen combined chemically, such as in water molecules (H_2O), or nitrate (NO_3^-), cannot be used for respiration be aerobic bacteria.

AEROBIC DECOMPOSITION The decay or breaking down or organic material in the presence of "free" or dissolved oxygen.

AEROBIC PROCESS A waste treatment process conducted under aerobic (in the presence of "free" or dissolved oxygen) conditions.

ALKALINITY The capacity of water or wastewater to neutralize acids. The capacity is caused by the water's content of carbonate, bicarbonate, hydroxide, and occasionally borate, silicate, and phosphate. Alkalinity is expressed in milligrams per liter of equivalent calcium carbonate. Alkalinity is not the same as pH because water does not have to be strongly basic (high pH) to have a high alkalinity. Alkalinity is a measure of how much acid must be added to a liquid to lower the pH to 4.5.

ANOXIC A condition in which the aquatic (water) environment does not contain enough dissolved molecular oxygen, which is called an oxygen deficient condition. Generally refers to an environment in which chemically bound oxygen, such as in nitrate, is present.

ANOXIC DENITRIFICATION A biological nitrogen removal process in which nitrate nitrogen is converted by microorganisms to nitrogen gas in the absence of dissolved oxygen.

ATTACHED GROWTH PROCESS Wastewater treatment processes in which the microorganisms and bacteria treating the wastes are attached to the media in the reactor. The wastes being treated flow over the media. Trickling filters and rotating biological contactors are attached growth reactors. These reactors can be used for BOD removal, nitrification and denitrification.

AUTOTROPHIC Describes organisms, plants, and some bacteria that use inorganic materials for energy and growth.

BOD Biochemical Oxygen Demand. The rate at which organisms use the oxygen, in water or wastewater, for oxidation of organic matter. In decomposition, organic matter serves as food for the bacteria and energy results from its oxidation. BOD measurements are used as a measure of the organic strength of wastes in water.

BACTERIA Bacteria are living organisms, microscopic in size, which usually consist of a single cell. Most bacteria use organic matter for their food and produce waste products as a result of their life processes.

BATCH PROCESS A treatment process in which a tank or reactor is filled, the wastewater (or other solution) is treated or a chemical solution is prepared, and the tank is emptied. The tank may then be filled and the process repeated. Batch processes are also used to cleanse, stabilize or condition chemical solutions foe use in industrial manufacturing and treatment processes.

BIOCHEMICAL OXYGEN DEMAND (see BOD)

COD Chemical Oxygen Demand. A measure of the oxygen-consuming capacity of organic matter present in wastewater. COD is expressed as the amount of oxygen consumed from a chemical oxidant in mg/l during a specific test. Results are not necessarily related to the biochemical oxygen demand (BOD) because the chemical oxidant may react with substances that bacteria do not stabilize.

CARBONACEOUS A stage of decomposition that occurs in biological treatment processes when aerobic bacteria, using dissolved oxygen, change carbon compounds to carbon dioxide. Sometimes referred to as "first-stage BOD" because the microorganisms attack organic or carbon compounds first and nitrogen compounds later.

CHEMICAL OXYGEN DEMAND (see COD)

DO Abbreviation of Dissolved Oxygen. DO is the molecular (atmospheric) oxygen dissolved in water and wastewater.

DENITRIFICATION (1) The anoxic biological reduction of nitrate nitrogen to nitrogen gas. (2) Te removal of some nitrogen from a system. (3) An anoxic process that occurs when nitrite or nitrate ions are reduced to nitrogen gas and nitrogen bubbles are formed as a result of this process. The bubbles attach to the biological floc in the activated sludge process and float the floc to the surface of the secondary clarifiers. This condition is often the cause of rising sludge observed in secondary clarifiers or gravity thickeners.

DISSOLVED OXYGEN (see DO)

EFFLUENT Wastewater or other liquid – raw (untreated), partially or completely treated – flowing FROM a reservoir, basin, treatment process, or treatment plant.

F/M RATIO Food to microorganism ratio. A measure of food provided to bacteria in an aeration tank or reactor in relation to the microorganism population expressed as follows:

$$\frac{\text{Food}}{\text{Microorganisms}} = \frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}}$$

FIXED FILM Process in which the bacteria attach to a media from a film. The film is fixed to the media being used.

HEADER A large pipe to which the ends of a series of smaller pipes are connected. Also called manifold.

HETEROTROPHIC Describes organisms that use organic matter for energy and growth. Animals, fungi and most bacteria are heterotrophs.

INFLUENT Wastewater or other liquid – raw (untreated) or partially treated, flowing into a treatment plant.

LOADING Quantity of material applied to a device at one time. Hydraulic loading is a measure of liquid flow into a vessel.

MLSS Mixed Liquor Suspended Solids expressed as mg/l of solids usually measured in an aeration tank.

MANIFOLD A large pipe to which the ends of a series of smaller pipes are connected (see HEADER).

MEDIA The material in a trickling filter or biologically aerated filter on which organisms grow and become attached.

MICROORGANISMS Very small organisms that can be seen only through a microscope. Some microorganisms use the waste in wastewater for food and thus remove or alter much of the undesirable matter.

MILLIGRAMS PER LITER mg/l Measure of the concentration of a substance per unit volume. For practical purposes, one mg/l of a substance in water is equal to one part per million parts (ppm)

MIXED LIQUOR SUSPENDED SOLIDS When the activated sludge in an aeration tank is mixed with primary effluent or the raw wastewater and return sludge, this mixture is then referred to as mixed liquor measured in solids in mg/l or ppm.

MIXED LIQUOR VOLATILE SOLIDS The organic or volatile suspended solids in the mixed liquor of an aeration tank. This volatile portion is used as a measure or indication of the microorganisms present.

MOLECULAR OXYGEN The oxygen molecule, O_2, that is not combined with another element to form a compound.

NITRIFICATION An aerobic process in which bacteria change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate). The second-stage BOD is sometimes referred to as the "nitrogenous BOD" (first-stage BOD is called the "carbonaceous BOD")

NITRIFICATION STAGE A stage of decomposition that occurs in biological treatment processes when aerobic bacteria, using dissolved oxygen, change nitrogen compounds (ammonia and organic nitrogen) into oxidized nitrogen (usually nitrate). The second-stage BOD is sometimes referred to as the "nitrification stage" (first-stage BOD is called the "carbonaceous stage").

NITRIFYING BACTERIA Bacteria that change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate).

NITROGENOUS A term used to describe chemical compounds (usually organic) containing nitrogen in combined forms. Proteins and nitrate are nitrogenous compounds.

NUTRIENT CYCLE The transformation or change of a nutrient from one form to another until the nutrient has returned to the organic form, thus completing the cycle. The cycle may take place under either aerobic or anaerobic conditions.

NUTRIENTS Substances, which are required to support living plants and organisms. Major nutrients are carbon, hydrogen, oxygen, sulfur, nitrogen and phosphorous. Nitrogen and phosphorous are difficult to remove from wastewater by conventional treatment processes because they are water-soluble and tend to recycle.

O & M MANUAL Operation and Maintenance Manual. A manual that describes detailed procedures for operators to follow to operate and maintain a specific wastewater treatment or pretreatment plant and the equipment of that plant.

ORGANIC WASTE Waste material comes mainly from animal or plant sources. Bacteria and other small organisms generally can consume organic wastes. Inorganic wastes are chemical substances of mineral origin.

ORGANISM Any form of animal or plant life.

PROGRAMMABLE LOGIC CONTROLLER (PLC) A small computer that controls process equipment (variables) and can control the sequence of valve operations.

RESPIRATION The process in which an organism uses oxygen for its life processes and gives off carbon dioxide.

RETENTION TIME The time water, or solids are retained or held in a process tank

SCFM Cubic Feet of air per Minute at Standard conditions of temperature, pressure, and humidity (0 degrees C, 14.7 psia, and 50% relative humidity).

SECONDARY TREATMENT A wastewater treatment process used to convert dissolved or suspended materials into a form more readily separated from the water being treated. Usually the process follows primary treatment by sedimentation. The process commonly is a type of biological treatment process followed by secondary clarifiers that allow the solids to settle out from the water being treated.

SENSOR A device that measures (senses) a physical condition or variable of interest. Floats and thermocouples are examples of sensors.

SEPTIC A condition produced by anaerobic bacteria. If severe, the wastewater produces hydrogen sulfide, turns black, gives of foul odors, contains little or no dissolved oxygen, and the wastewater has a high oxygen demand.

SERIES OPERATION Wastewater being treated flows through one treatment unit and then flows through another similar treatment unit.

SET POINT The position at which the control or controller is set. This is the same as the desired value of the process variable.

SEWAGE The used household water and water-carried solids that flow in sewers to a wastewater treatment plant. The preferred term is Wastewater.

SHOCK LOAD The arrival at a plant of a waste which is toxic to organisms in sufficient strength to cause operating problems. Possible problems include odors loss of treatment efficiency with excess solids and BOD discharge.

SLUDGE The settleable solids separated from liquids during processing.

SOLUBLE BOD Soluble BOD is the BOD of water that has been filtered in the standard suspended solids test.

SUSPENDED GROWTH Wastewater treatment processes in which the microorganisms and bacteria treating the wastes are suspended in the wastewater being treated. The wastes flow around and through the suspended growths. The various modes of the activated sludge process make use of the suspended growth reactors. These reactors can be used for BOD removal, nitrification, and denitrification.

SUSPENDED SOLIDS Solids that are suspended in water, wastewater, or other liquids, and which are largely removable by laboratory filtering.

TOC Total organic carbon. Measures the amount of organic carbon in water.

TERTIARY Any process of water renovation that upgrades treated wastewater to meet specific reuse requirements. May include general cleanup of water or removal of specific parts of wastes insufficiently removed by conventional treatment processes. Typical processes include chemical treatment and pressure filtration. Also called **ADVANCED WASTE TREATMENT**.

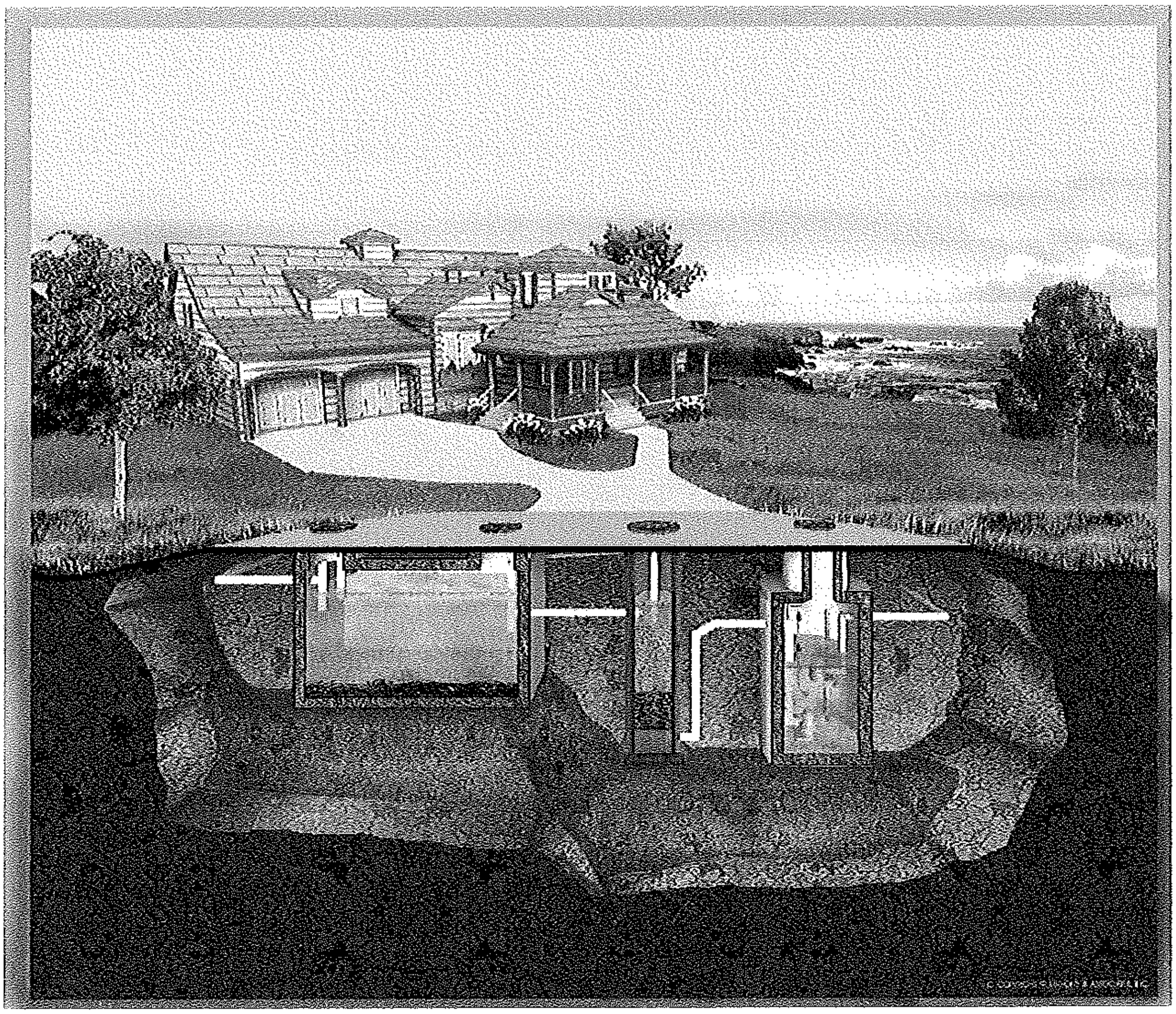
TOTALIZER A device or meter that continuously measures and calculates (adds) as process rate variable in cumulative fashion, such as a flow meter.

TURBIDITY Turbidity units measure of the cloudiness of water. If measured by a nephelometric (deflected light) instrumental procedure, turbidity units are expressed in nephelometric units (NTU) or simply TU.

Amphidrome®

Installation Instructions

The highest level of Nitrogen removal available...



...and at a reasonable cost.

f.r. mahony & associates, inc.
frma

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The Amphidrome® Process

The Amphidrome® system is a submerged attached growth bioreactor process, designed around a deep-bed sand filter. It is specifically designed for the simultaneous removal of soluble organic matter, nitrogen and suspended solids within a single reactor. Since it removes nitrogen, it may also be considered a biological nutrient removal (BNR) process.

To achieve simultaneous oxidation of soluble material, nitrification, and denitrification in a single reactor, the process must provide aerobic and anoxic environments for the two different populations of microorganisms. The Amphidrome® system utilizes two tanks and one submerged attached growth bioreactor, called the Amphidrome® reactor. The first tank, the anoxic/equalization tank, is where the raw wastewater enters the system. The tank has an equalization section, a settling zone, and a sludge storage section. It serves as a primary clarifier before the Amphidrome® reactor.

This Amphidrome® reactor consists of the following three items: under drain, support gravel, filter media. The under drain, constructed of stainless steel, is located at the bottom of the reactor. It provides support for the media and even distribution of air and water into the reactor. The under drain has a manifold and laterals to distribute the air evenly over the entire filter bottom. The design allows for both the air and water to be delivered simultaneously--or separately--via individual pathways to the bottom of the reactor. As the air flows up through the media, the bubbles are sheared by the sand, producing finer bubbles as they rise through the filter. On top of the under drain is 18" (five layers) of four different sizes of gravel. Above the gravel is a deep bed of coarse, round silica sand media. The media functions as filter, significantly reducing suspended solids and provides the surface area for which an attached growth biomass can be maintained.

To achieve the two different environments required for the simultaneous removal of soluble organics and nitrogen, aeration of the reactor is intermittent rather than continuous. Depending on the strength and the volume of the wastewater, a typical aeration scheme may be three to five minutes of air and ten to fifteen minutes without air. Concurrently, return cycles are scheduled every hour, regardless of the aeration sequence. During a return, water from the clear well is pumped back through the filter and overflows into the energy-dissipating TEE. A check valve in the influent line prevents the flow from returning to the anoxic/equalization tank via that route. The energy-dissipating TEE is set at a fixed height above both the media and the influent line, and the flow is by gravity back to the front of the anoxic/equalization tank.

The cyclical forward and reverse flow of the waste stream and the intermittent aeration of the filter achieve the required hydraulic retention time and create the necessary aerobic and anoxic conditions to achieve the required level of treatment.

General

Installers of Amphidrome® systems should be versed in installation of subsurface disposal systems (SSDS). Installers must comply with Local, County and State Health certification requirements for SSDS installers including other applicable safety requirements such as licenses for equipment operators and truck drivers.

Construction of Amphidrome® systems require that the approved plans and instructions be followed. Engineered plans showing elevations of tanks and pipelines and the layout should be on site and referenced by the contractor and their agents. The manufacturer shall be consulted with regard to any conflicts or questions regarding clarification of plans, details, and any omissions or errors that may be encountered.

The Amphidrome® system is designed to use standard construction materials that may be found in any region. Tanks are typically concrete with rubber grommets, boots or gaskets for all pipe penetrations. Piping is standard PVC or cast iron or stainless steel material. The list of materials to be supplied by the contractor to be used in conjunction with the materials supplied by the manufacturer will state the standard sizes, schedules, ratings required.

Contractors will be required to follow the plans and prepare the site in the same manner as would be used with a conventional SSDS. The Amphidrome® system is an advanced wastewater treatment process that performs in much the same way as a conventional SSDS with certain modifications.

The process flow stream will enter an anoxic tank rather than a Septic Tank. The anoxic tank will provide the first function of primary settling and flow equalization. The flow will then proceed to the Amphidrome® Reactor for aerobic treatment and filtration in the forward flow direction. Treated waste will leave the bottom of the reactor and flow through the return pump line and the return pump into the clear well. The clear well will store a batch of treated effluent until a float switch is activated causing the return pump to pump effluent in the return mode back through the reactor and then back to the anoxic tank. Once the return pump stops the flow will then flow by gravity in the forward direction through the reactor and into the clear well. During this cycle the aeration blowers will be off causing an anoxic condition to occur. The process results in denitrification of the wastewater that will be stored in the clear well. The discharge pump will pump to the leach field or absorption field when the process is completed. For a more detailed process description, refer to the Operation and Maintenance Manual.

Contactors will be required to provide and set tanks as called for on the design plans and the associated piping. The contractor shall also complete field wiring of pumps and panels supplied by the manufacturer. All site work and site restoration shall be supplied by the contractor.

Start up services and inspection services of the manufacturer or authorized agents shall include:

1) Inspection of air pattern in the reactor or "Air Pattern Test" prior to installation of media. See media installation instructions below.
2) Process startup including verification of wiring connections, operation of pumps, blowers and process controller.
3) Quarterly inspection of the operation.

Contractor shall perform installation in conformance with all local, county and state inspection requirements for the setting of tanks, pipes, leaching system components, etc. The manufacturer's inspections shall in no way imply approval to backfill components that must be inspected by other authorities without their inspection.

Installation Procedures

Each installation will vary based on individual site conditions and restrictions. The general procedures should be followed for placement of components. These instructions are not intended to instruct contractors on every aspect of an individual installation. It is expected that good construction practices will be followed with regards to excavation, setting of pipes and tanks and placement of bedding and backfill materials with proper grade, slopes, and compaction techniques. Field wiring shall be in accordance with Local and National Wiring Codes and the Manufacturer's wiring diagrams.

Construction will most likely begin with setting of the deepest components first. The anoxic tank, reactor and clear well must be set on level, firm foundation of excavated material or properly compacted and stable fill material. Proper grade or elevations of pipes and tanks is essential to the functioning of this system. Improper grade of pipelines or tanks shall void process warranties.

It is recommended that the contractor verify measurements of each tank and verify the location of pipe penetrations and the size and elevation of these penetrations before placing each tank. It is important to install proper gaskets and seals as provided by the concrete supplier prior to backfilling and water testing the tank.

Refer to Drawing 1. Amphidrome® Process, Single Family Unit

Amphidrome® System Piping

Amphidrome® Reactor Outside Piping

The Amphidrome® Reactor discharge line (2-inch PVC) and associated elbows and fittings should be placed and supported as the backfill material is brought up to the grade of the next lowest horizontal pipe. This fill material must be properly compacted to support all pipes that will be placed in fill material.

Anoxic Tank Outside Piping

Pipelines for inlet and discharge to the anoxic tank and the return and backwash line should be installed to the slope and elevations marked on the plans. The inlet line from the home to the anoxic tank is 4-inch schedule 40 PVC unless otherwise indicated on the plans. The backwash and return line is 4-inch Schedule 40 PVC. The discharge line from the anoxic tank is 2-inch Schedule 40 PVC.

Pipes should penetrate the inside of the tank wall with sufficient length to connect inlet TEE, Discharge TEE and check valve assembly and return & backwash return TEE and energy dissipating drop pipe and diffuser assembly provided by the manufacturer. Pipes shall be properly cleaned and glued with PVC solvent. Pipelines shall be watertight and air tight and tested prior to operation of the system.

Amphidrome® Reactor Interconnecting Piping

The backwash and return line and inlet line may be connected to the Amphidrome® reactor after completion of the installation of air header, support gravel and media as described below. Depending on the reactor depth, the contractor may find it is easier to complete this work before adding the top reactor section that will receive the interconnecting pipes. The discharge line from the reactor (2-inch Schedule 40 PVC) may be continued to the clear well providing sufficient pipe inside the clear well to connect the return pump discharge hose and coupler.

Clear Well Outside Piping

The piping consists of the inlet line referenced above and a discharge line (2-inch Schedule 40 PVC) that will flow to the distribution box or dosing chamber if required. Sufficient pipe must be left inside the clear well to connect the discharge pump discharge hose and coupler.

Air Piping Outside

Air piping from the blower location to the clear well must be properly assembled to provide an airtight assembly from the Amphidrome® Reactor to the blower. The air piping shall be 1-1/2 inch Schedule 80 PVC.

Amphidrome® Reactor Internals

This Amphidrome® reactor consists of the following three (3) items: under drain, support gravel, and filter media that are assembled in a concrete vessel. The under drain, constructed of stainless steel, is located at the bottom of the vessel. It provides support for the media and even distribution of air and water into the reactor. The under drain has a manifold and laterals to distribute the air evenly over the bottom of the reactor. The design allows for both the air and water to be delivered simultaneously, or separately, via individual pathways, to the bottom of the reactor. As the air flows up through the media, the bubbles are sheared by the sand; producing finer bubbles as they continue to rise. On top of the under drain is 18", (five layers), of four different sizes of gravel. Above the gravel is a deep bed of coarse, round, silica sand media. The media functions as a filter; significantly reducing suspended solids, and provides the surface area for which an attached growth biomass can be maintained.

Refer to Drawing 2. 2' Dia. Amphidrome® Reactor, Single Family Home General Arrangement

Amphidrome® Reactor Floats (2)

All conduits from tanks shall be sealed with appropriate material to revent liquid and gas to travel from tank penetrations.

Amphidrome® Reactor High Float

- The float controls the duration of each return after the float is elevated. If the float remains elevated for twenty minutes (20) after either a backwash or a return, a high level alarm is sent.

Amphidrome® Reactor Low Float

- The float initiates a return if liquid level drops to the level of the float. **This function is provided as an option**, which is activated by inputting both a start and stop time into the appropriate V register. Inputting a value of 9999 eliminates the use of the option. The ability to set a start and stop time for this option is provided.

Amphidrome® Reactor Installation Sequence

Pre-Installation Check

- The under drain assembly is a single piece 23.5" in diameter. Measure the inside of the concrete vessel to be sure the under drain assembly will fit.
- Check to see that the pipe penetrations are located properly.

Under Drain Installation

- The influent, dirty backwash, effluent, and backwash air piping are not to be installed until the under drain assembly is installed.
- Place the under drain in the vessel so that it is centered in the vessel and completely level.

Air Pattern Test

- With the under drain assembly in place, fill the basin with water to 2" above the top of the under drain.
- Use either the backwash blower or an air compressor to provide a minimum of 7 CFM of air.
- If the air distribution is visually even across the bottom, proceed to the next step. If not, remove the under drain and check for plugged holes. Repeat the test after clearing the plugged holes.

Piping

- Install the influent, dirty backwash, effluent, and backwash air piping as shown.
- Install the influent check valve at the anoxic tank.

Gravel and Media Installation

Gravel and Sand

- **Gravel and sand are to be installed in the reactor using buckets to drop the material into place. <u>Do not drop gravel and media from the top of the reactor.</u>**
- The bucket should have two (2) ropes attached. One for lowering the bucket into place and a second to tip the bucket to dispense the gravel or media.
- Beginning with the proper size gravel for Layer # 1, carefully lower the bucket into the reactor to within 6" of the under drain, tip the bucket and move the bucket as it is tipped in order to evenly distribute the material.
- Use a rod with a small plate on the end to move mounded material and to gently tamp the material level. Be careful not to tamp too much or too hard as this will cause the gravel to intermix. The top of each layer is to be level across the reactor.
- Repeat this process until the total amount of gravel for each layer has been dispensed.

Media

- Use the same method as the gravel for installation. Be careful not to get sand into the influent pipe nozzle. Use a survey rod to determine the level of the media layer as each layer is added. **NOTE: A SILICA SAND WARNING FOR POTENTIAL LUNG HAZARD IS PRINTED ON THE BACK OF EACH BAG OF MEDIA. PRECAUTION SHOULD BE USED WHEN DISTRIBUTING THIS MATERIAL.**

Layer No. 1 goes into the basin first, then Layer No. 2, and so on through Layer No. 5. A total of 18" of support gravel is placed in the basin. Layer No. 6, Filter Media, is 4'-0" in depth and is put in place last.

LAYER NO.	GRAIN SIZE	DEPTH	VOLUME Cubic Feet	# Bags
1	1 1/2" x 3/4" Gravel	0'-4"	1.0	2
2	3/4" x 1/2" Gravel	0'-2"	0.5	1
3	1/2" x 1/4" Gravel	0'-4"	1.0	2
4	1/4" x 1/8" Gravel	0'-4"	1.0	2
5	1/2" x 1/4" Gravel	0'-4"	1.0	2
6	Filter Media	4'-0"	12.5	25

Reactor Media Flushing

- After installation of gravel and media, the reactor is to be flushed with clean water and air to remove dust and fines. The backwash air blower and pump is used for this purpose. Flushing shall continue for a minimum of 15 minutes or until the backwash water is clear of fines. The reactor is to be filled with water before flushing begins.
- After completion of flushing, drain the reactor as much as possible and cover the media with plastic, or close over the top of the reactor, until the reactor is placed into service. This is to keep foreign contaminants out of the media.

Completion of the top access way cover and interconnecting external piping connections must be completed before backfilling around the top portion of the Reactor. Conduits for float and air piping and Reactor vent piping must be properly bedded and backfilled prior to final grading around the Reactor.

Anoxic Tank Internals

The Anoxic Tank Internals consists of the inlet TEE and vent and discharge line. The inlet line is 4-inch Schedule 40 PVC. The drop pipe or vertical discharge pipe shall be extended to 12-inches below the minimum water level or invert of the tank discharge line. The vent riser pipe shall extend above the maximum water level of the tank.

All Tee's and inside piping must be properly installed with PVC cleaner and solvent and supported with suitable supports as shown or otherwise required to hold the pipe assemblies in place.

The discharge 2-inch Schedule 40 PVC TEE and check valve assembly shall be properly cleaned and PVC solvent shall be used to seal to the 2-inch Schedule 40 PVC discharge line. The vertical inlet pipe shall extend to 10-inches below the minimum water level or invert of the discharge line. The vent riser pipe shall extend above the maximum water level of the tank.

Return & Backwash line shall be 4-inch Schedule 40 PVC. The inlet TEE and energy dissipation header shall be installed with PVC pipe cleaner and solvent. The top of the energy-dissipating header shall be just below the minimum water level of the tank so the header is fully submerged. The vertical drop pipe must be field measured and field cut to the proper length. Proper pipe hangers and supports shall be used to support this assembly.

Refer to Drawing 3. 2,000 Gallon Anoxic Tank

Clear Well Internals

The clear well internals shall consist of the three process control floats, Return and Backwash pump with discharge hose and connector, and discharge pump enclosed in a sump with discharge hose and connector. Conduit penetrations for floats and two pump power supply cables. Each pump shall have polypropylene lifting rope with hanger

Amphidrome® Clear Well Floats (3)

Amphidrome®Clear Well High Float

- The float serves as a high alarm float when it is elevated. The high float shall be set level with the top of the return line.

Amphidrome®Clear Well Middle Float

- The float serves as control to start the return pump when it is elevated. This shall be set near the mid-point of the tank and field adjusted by the manufacturer during start-up.

Amphidrome®Clear Well Low Float

- The float stops the return pump cycle when liquid level drops to the level of the float. The low float shall be set one foot above the bottom of the tank floor.

Refer to Drawing 4. 1,000 Gallon Clear Well Tank

The floats are mini-floats with counterweights. The floats are to be hung in the clear well with sufficient cable slack to permit for level adjustments. Loose cable is to be neatly coiled and fastened with nylon wire tie or suitable non-corrosive strap.

All conduits from tanks shall be sealed with appropriate material to prevent liquid and gas to travel from tank pentrations.

Clear Well Air Bleed

The air bleed for the return pipe in the clear well is required to prevent siphoning of the clear well after the return pump shuts down. A 1/8-inch NPT brass compression by ¼-inch tube connector is supplied by the manufacturer. Inside the clear well at the top of the 2-inch PVC return line drill a 5/16-inch diameter hole. Using a 1/8-27 NPT pipe tap and tap wrench, tap the pipe to receive the compression connector supplied. Use Teflon tape or Teflon paste on the threads and firmly tighten the connector to the newly tapped pipe. **Caution- do not over-tighten into PVC pipe.**

Refer to Drawing 11. Detail G, Return and Discharge Hose Connection Detail

Using the ¼ -inch tube supplied, install retainer nut by removing from connector and sliding back over the tubing. Insert brass insert in end of tubing. Slide tubing through the compression ring and tighten in place. Tubing should be hung and anchored to direct water and airflow down into clear well. Tubing must terminate above the high water level.

Tools Required: Drill and 5/16-inch bit, 1/8-27 NPT tap and tap wrench, ½-inch wrench, 7/16-inch wrench, Teflon past or tape, miscellaneous hangers.

Access Covers Manholes

There shall be a minimum of 4 cast iron bolted and gasketed access covers for the entire system. These are shown on the **Amphidrome® Drawings1, 2, 3, and 4**. One will be located over the discharge of the Anoxic Tank to permit the removal of waste sludge and to permit the inspection of the discharge TEE.

A single access cover shall be installed over the Amphidrome® Reactor to permit access to the reactor for service and inspection.

Two covers shall be placed at each end of the clear well to access each pump for service and to access the discharge end for sample collection.

All access ways and covers shall be securely fastened to each tank and grouted in place to provide watertight seals. Cast Iron manhole covers with a 22-inch clear opening are required.

Access covers may be flush with finished grade to blend into the landscaping. Covers should not be buried.

Blowers And Controls

Blowers will include a process air blower and backwash blower. A single blower will operate to provide process air in the aerobic phase of treatment. During the backwash cycle, the second blower will run to provide additional backwash air. The blowers must be installed in a well-ventilated enclosure that provides shelter from rain and snow. The enclosure may be a separate shed or house constructed to blend into the landscaping and architecture of the property. The blowers will generate some noise during operation. Placement of the blowers should be such that the noise can be reduced.

The blowers must be accessible for service and should not be placed in manholes or otherwise below grade where they may be subject to ground water or surface water accumulations.

In order to reduce the length of power cables and conduits, the blowers should be located within reasonable distance of the Amphidrome® system and the Amphidrome® control panel. Each installation will be different, as homeowners will have different ideas on a suitable location for these components.

Blower Piping

Blower piping shall be assembled with a common header. The header piping and blower placement are designed to reduce the space required. Piping consists of standard iron pipe thread fittings. Assembly should be made with Teflon paste or Teflon tape on all pipe joints. Air piping can be tested for leaks with soapy water. A dilution of dish soap and water in a small squirt bottle works well for this purpose.

Refer to Drawing 13. Blower Detail A, Process Air Piping Assembly and Drawing 14. Blower Detail B, Backwash Blower and Piping Arrangement

The blowers must be anchored to the floor of the enclosure to restrict vibration and stress on the blower piping. Anchors should be used that will permit the easy removal of a blower for service.

Pipe unions will permit removal of a blower with minimal disturbance to the air header.

Refer to Drawing 13. Blower Detail A, Parts 58 and 62

Amphidrome® Control Panel

The Amphidrome® control panel is the central control of all processes in the system. The panel must be mounted in a secure dry place. The panel can be placed in a closet, basement, storage building, garage or any place that can be kept reasonably warm and dry and is in reasonable distance from other system components.

The Amphidrome® control panel is a complete assembly supplied by the manufacturer with field terminal connections and wiring connections to be made by a qualified, licensed electrician. No modification to this panel may be made by anyone other than the manufacturer. Main power supply to the panel must be 30 amp, 120/240 volt.

The panel contains breakers, disconnects, and fuses, alarm lights and indicators for system operations, system program interface connection, programmable logic controller PLC, and process time clock. A main power supply from the household main service panel must be brought to this panel. All wiring from outside conduits must be made gas tight before the system is to be accepted by the owner and warranty begins.

Wiring must be completed in accordance with the manufacturer's wiring diagrams. Cable splices should be avoided when possible. When cable splices are required, proper junction boxes located above ground and average snow cover levels. Splices that are subject to wet conditions shall be sealed with Scotchcast® or equal power cable splice kit. Splices should be made with enough cable slack to permit the disconnection of a pump or float for service repair and replacement with adequate cable length to re-connect and seal the connection.

Refer to Drawing15. Amphidrome® Control System, Electrical Schematic, Drawing 16. Amphidrome® Control System,Control Panel Layout, and Drawing 17. Amphidrome® Control System, Field Wiring

Note: At any time, the manufacturer reserves the right to modify and to improve the Amphidrome® Control System wiring. Modified drawings would supersede drawings included in the Installation Instructions.

Automatic Voice/Pager Alarm Dialer System (Optional)

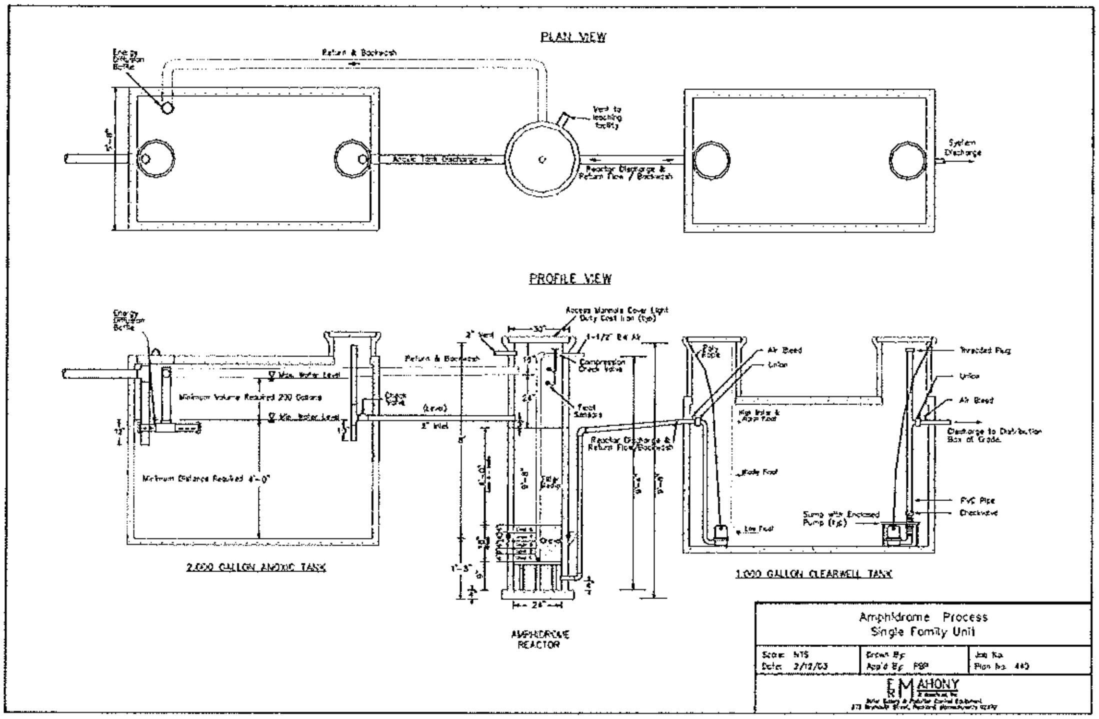
The voice/pager alarm dialer system is used to transmit high clear well or filter high level alarms to one or more remote locations. The dialer features busy line and no answer detection to ensure prompt transmission of a prerecorded message, delivered sequentially to as many as four standard telephones, cellular telephones, voice and/or numeric pagers.

The dialer is fully programmable, offering personalized customization for each individual project. Programming options include but are not limited to:

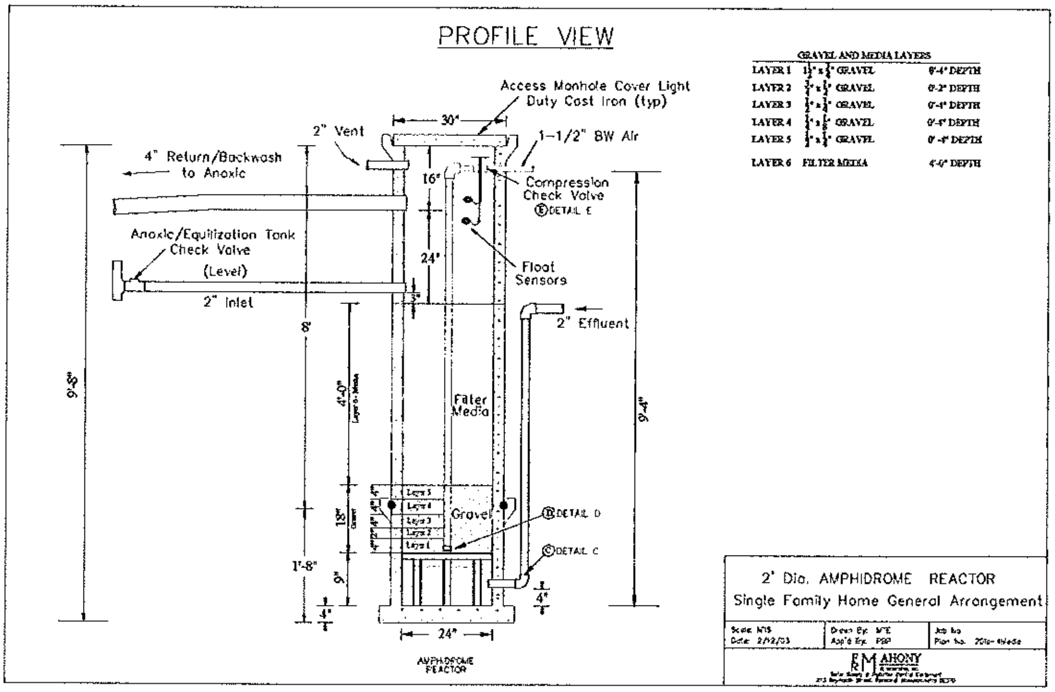
- Store up to four telephone/pager numbers.
- Choose 1 to 9 calling efforts for the numbers dialed.
- Select 1 to 3 message repeats.
- Voice record an outgoing message in any language.
- Program voice messages to telephones and numeric code to pagers.

The voice pager/alarm dialer is a stand alone unit operating 24 hours per day. Monitoring fees are not required.

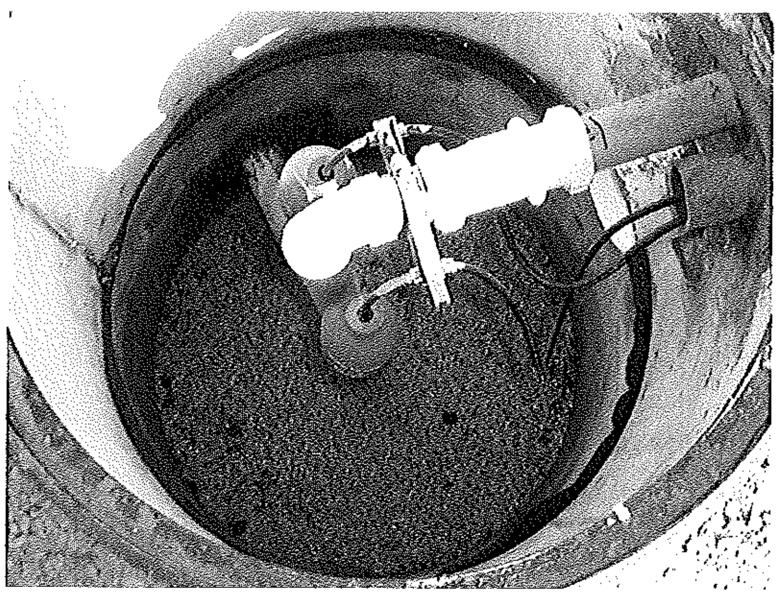
Appendix 1. Drawings



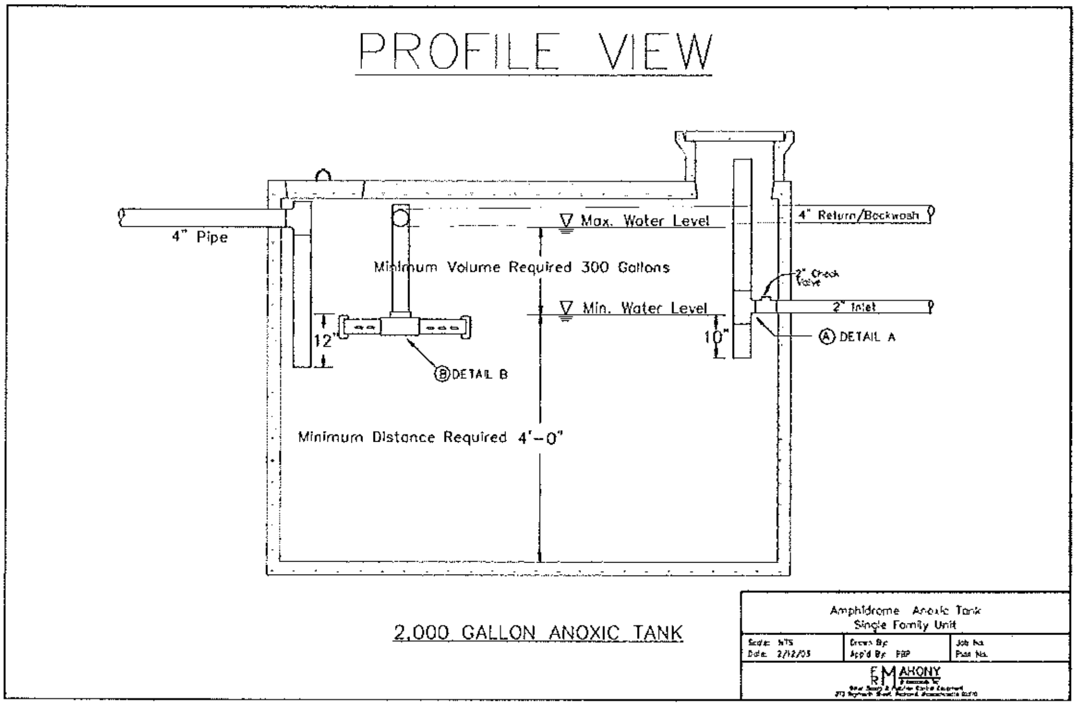
DRAWING 1.
AMPHIDROME® PROCESS
SINGLE FAMILY UNIT



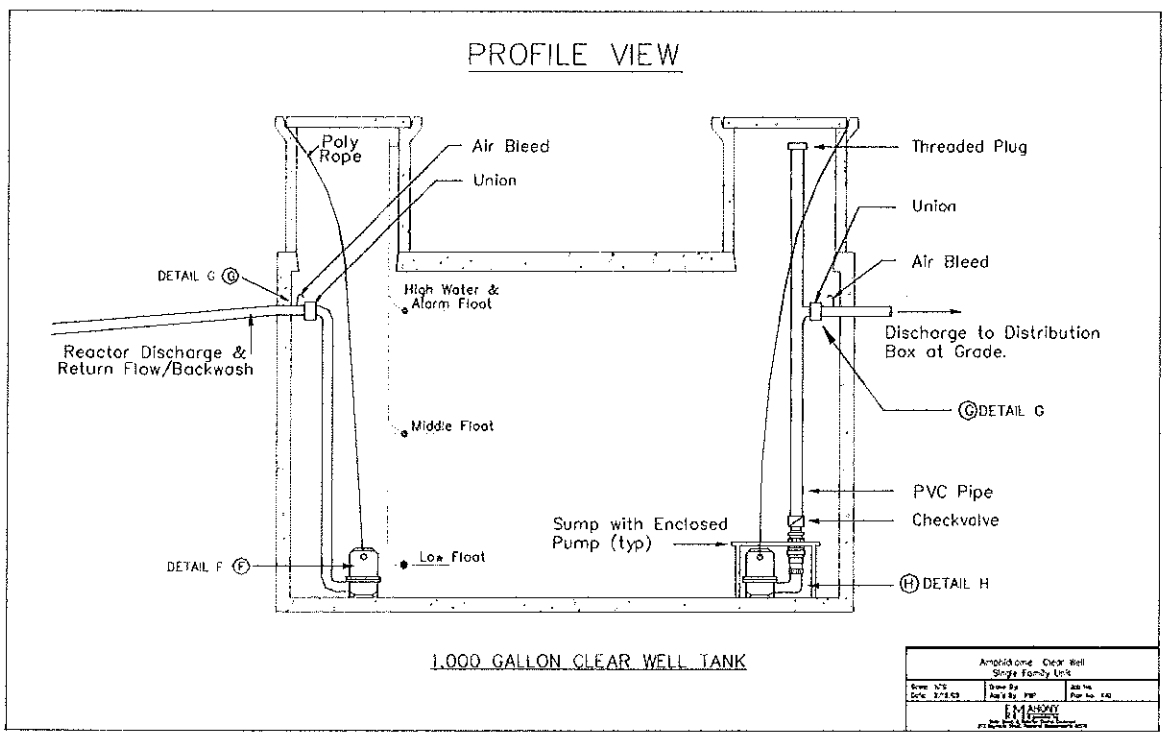
DRAWING 2.
2' DIA. AMPHIDROME® REACTOR, SINGLE FAMILY HOME GENERAL ARRANGEMENT



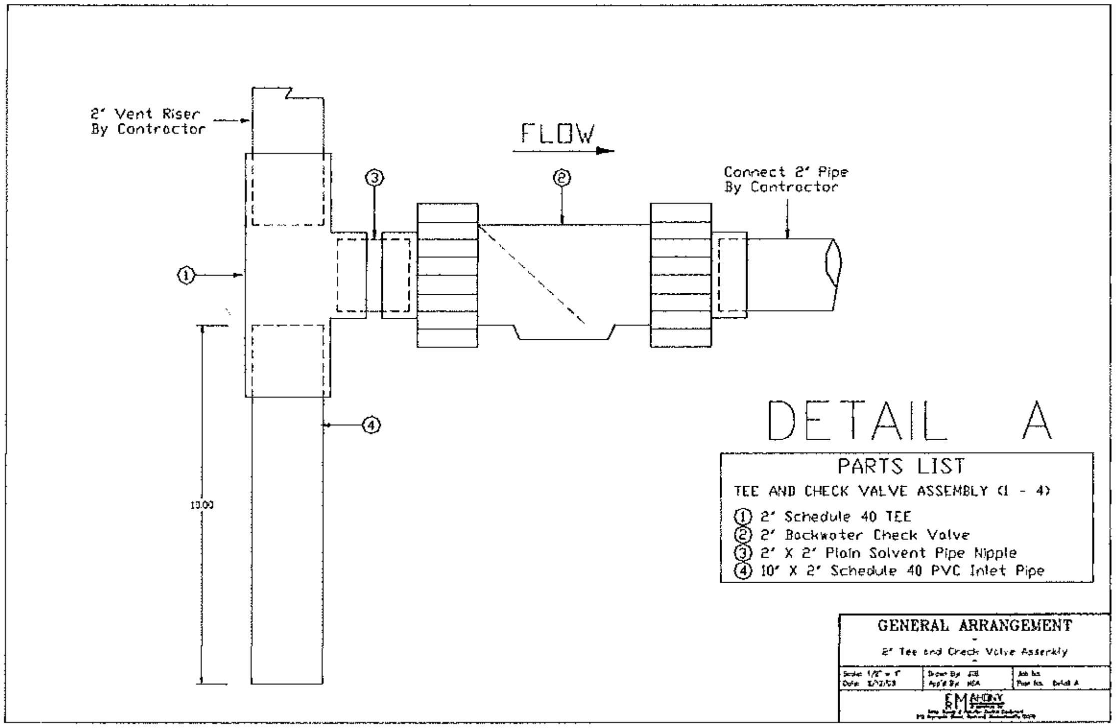
PICTURE 1.
REACTOR FLOATS



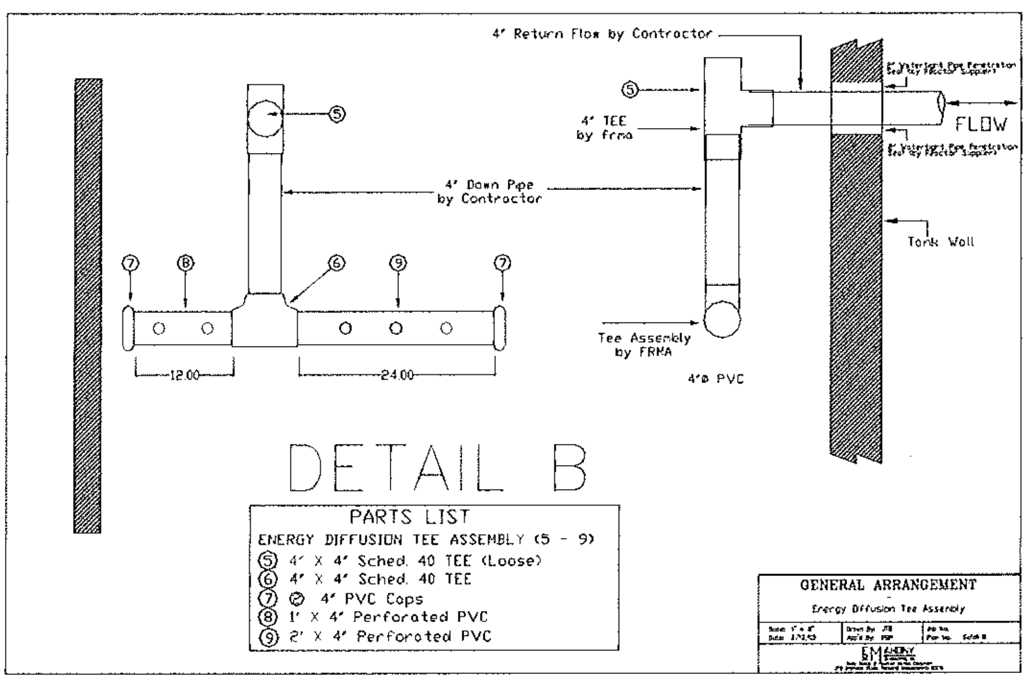
DRAWING 3. 2,000 GALLON ANOXIC TANK



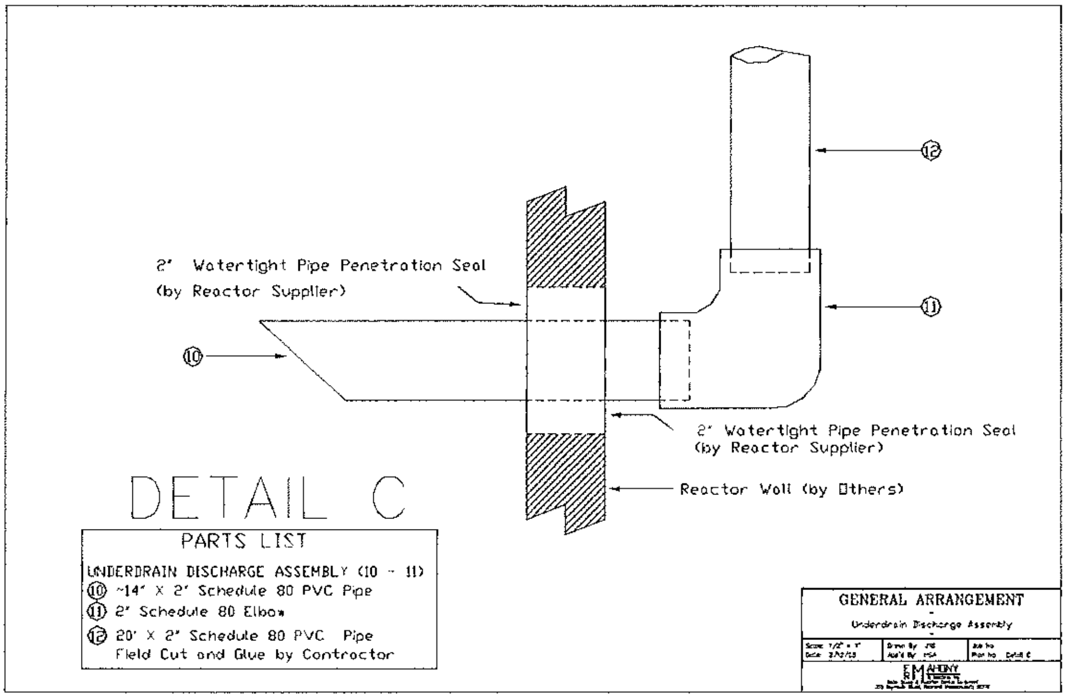
DRAWING 4. 1,000 GALLON CLEAR WELL TANK



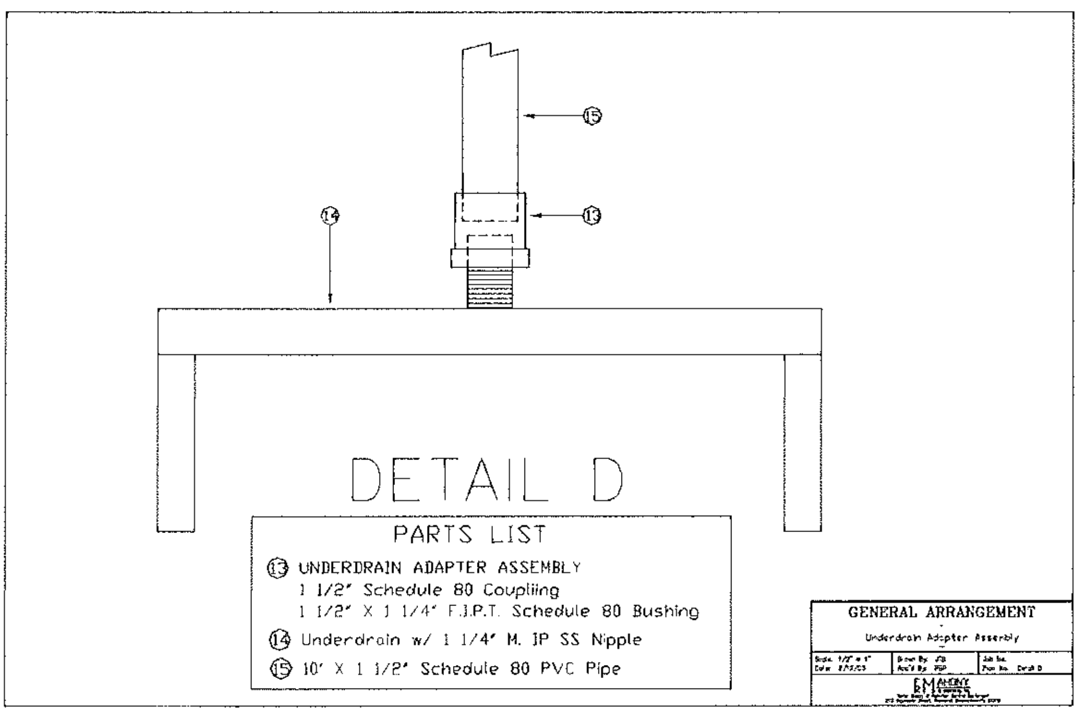
DRAWING 5. DETAIL A, TEE AND CHECK VALVE ASSEMBLY



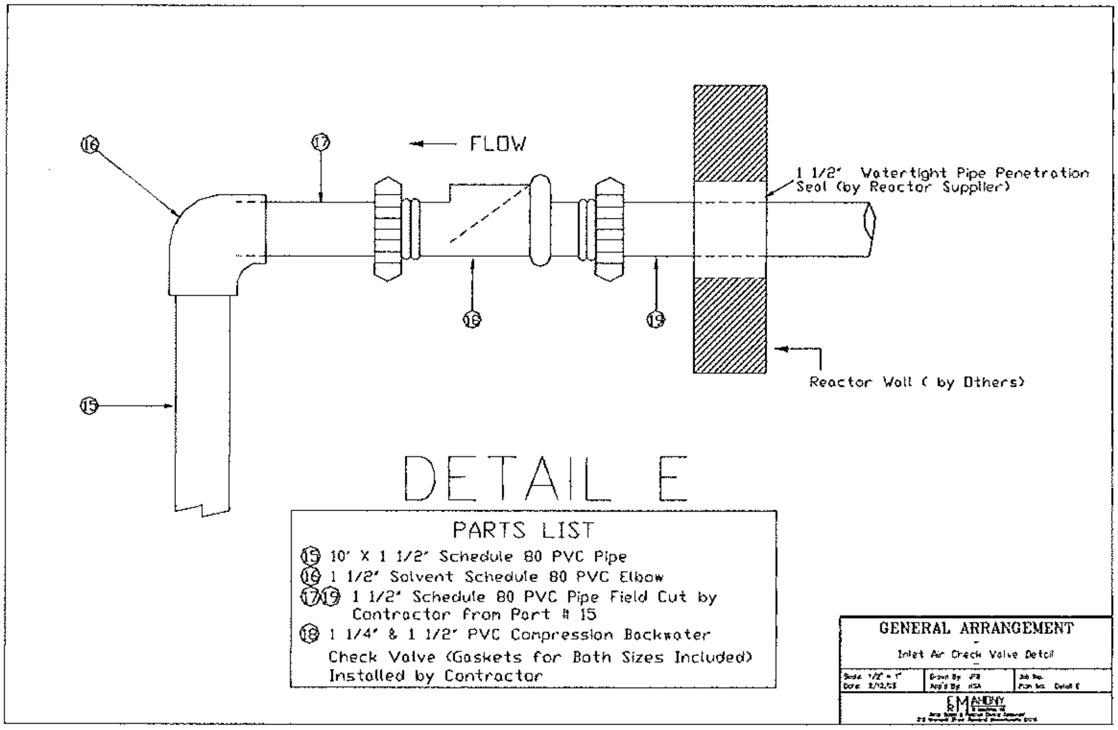
DRAWING 6. DETAIL B, ENERGY DIFFUSION TEE ASSEMBLY



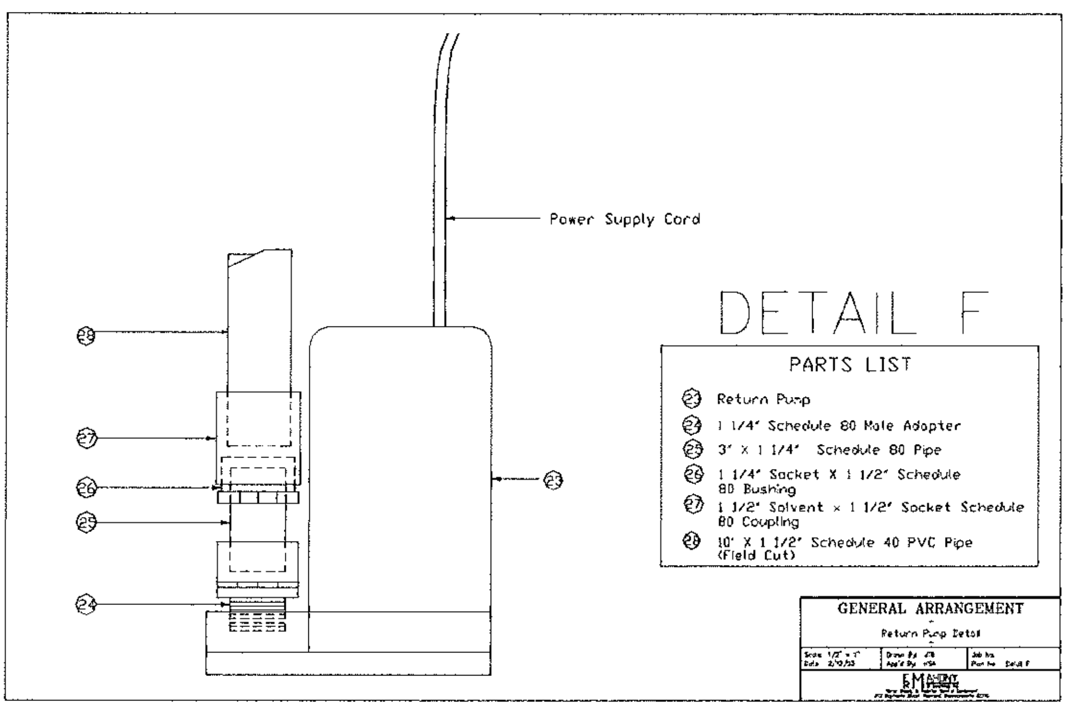
DRAWING 7. DETAIL C, UNDERDRAIN DISCHARGE ASSEMBLY



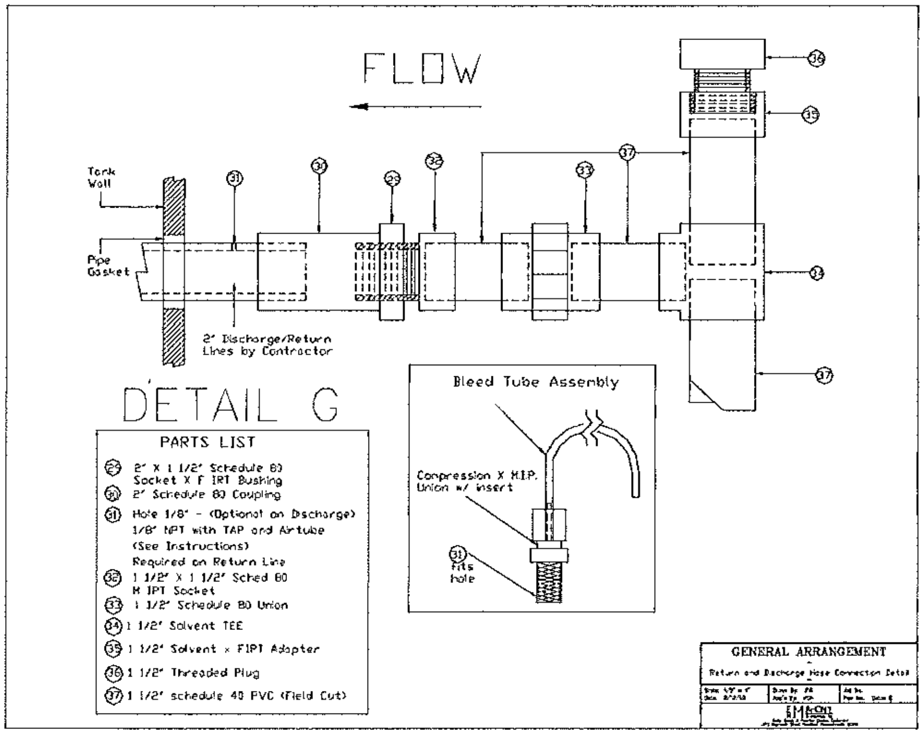
DRAWING 8. DETAIL D, UNDERDRAIN ADAPTER ASSEMBLY



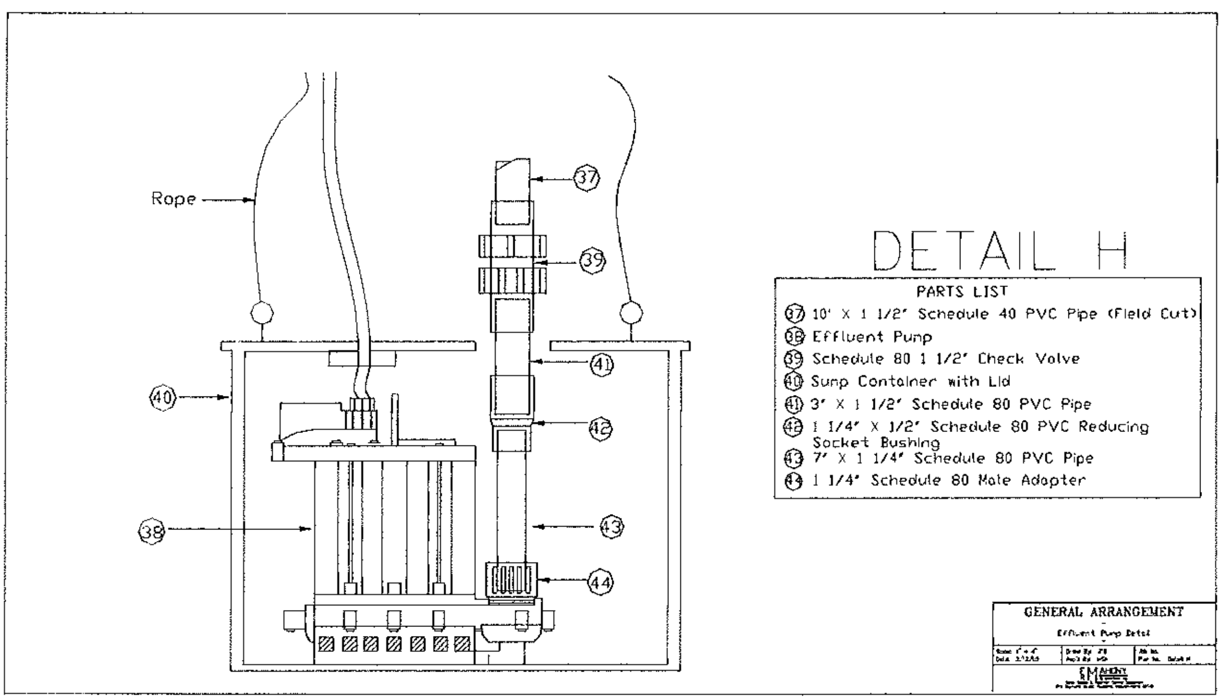
DRAWING 9. DETAIL E, INLET AIR CHECK VALVE DETAIL



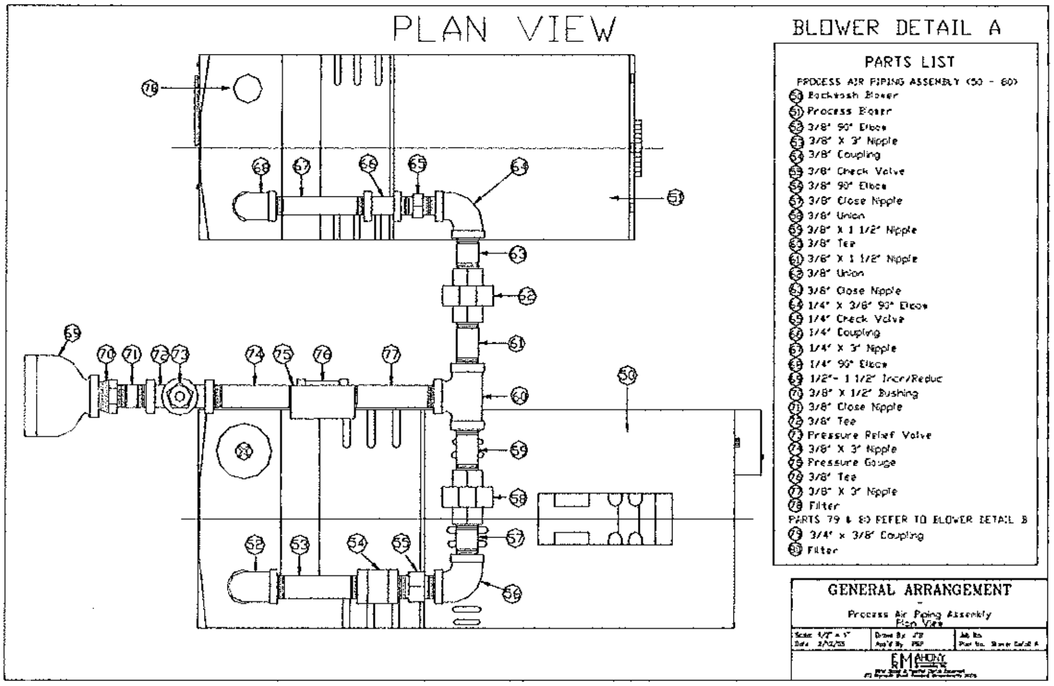
DRAWING 10. DETAIL F, RETURN PUMP DETAIL



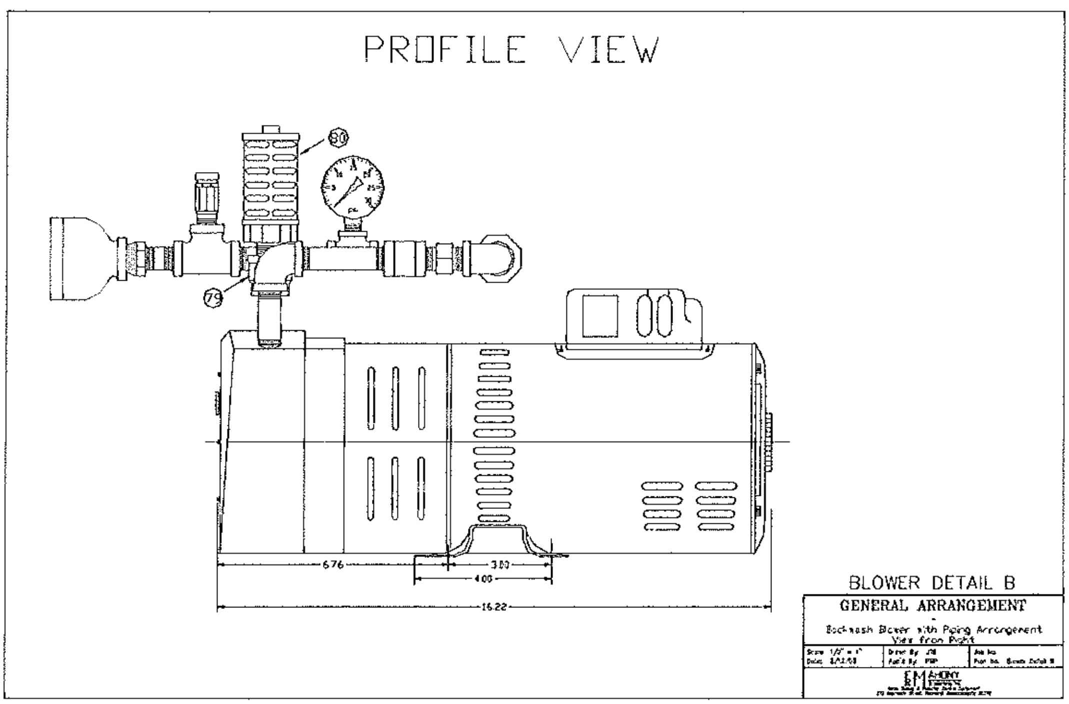
DRAWING 11.
DETAIL G, RETURN AND DISCHARGE HOSE CONNECTION DETAIL



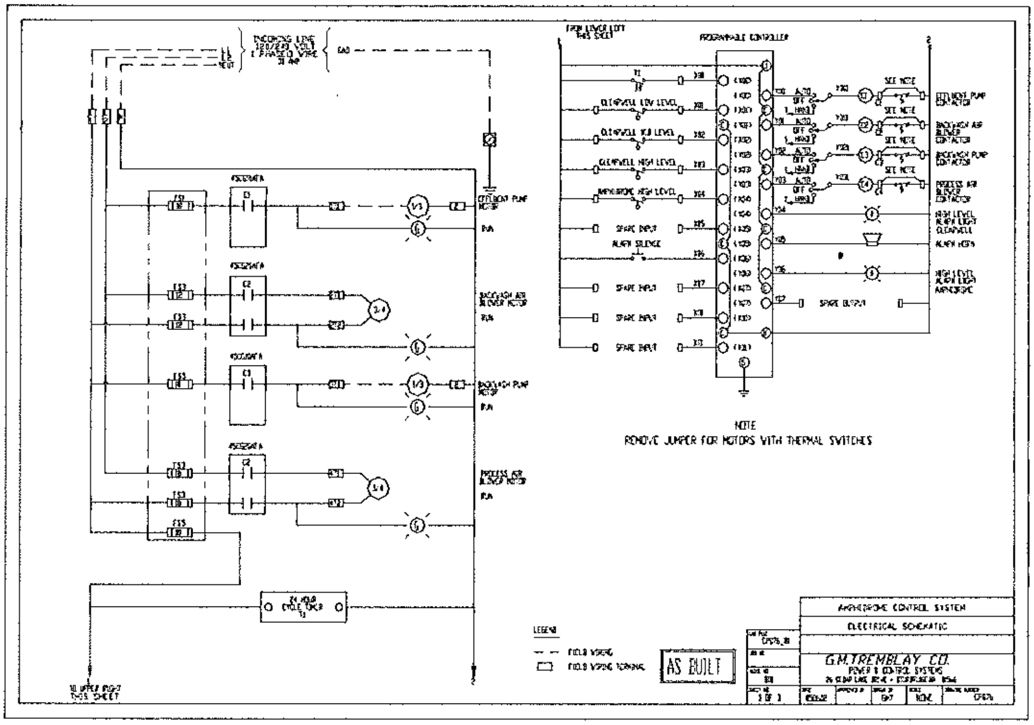
DRAWING 12. DETAIL H, EFFLUENT PUMP DETAIL



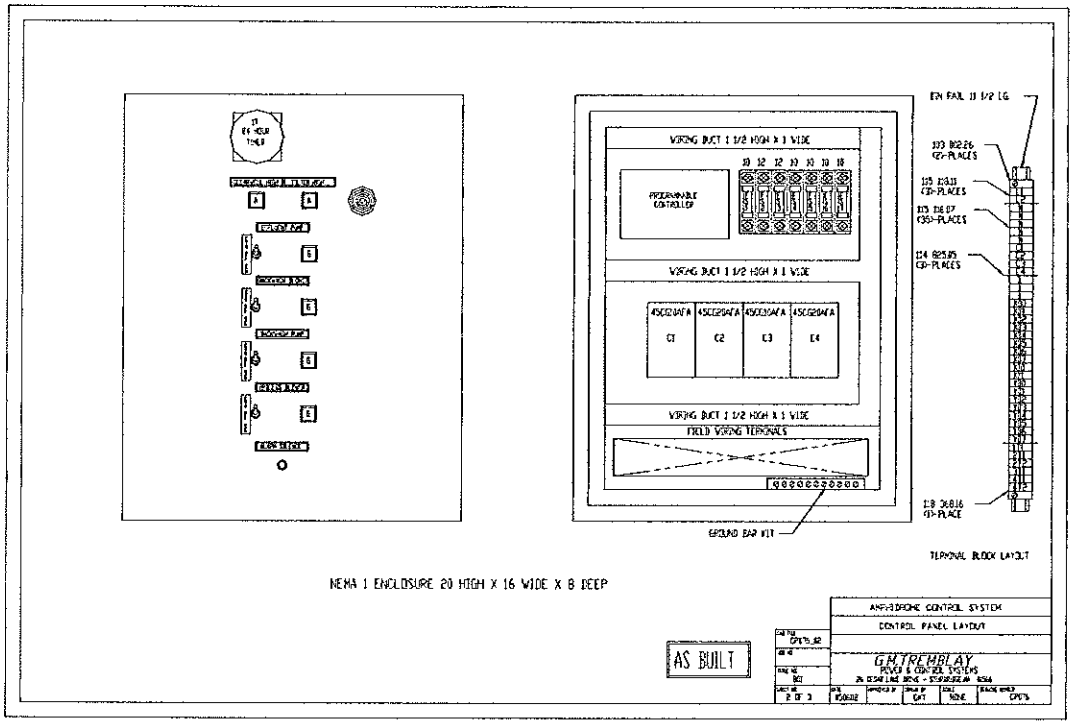
DRAWING 13. BLOWER DETAIL A, PROCESS AIR PIPING ASSEMBLY



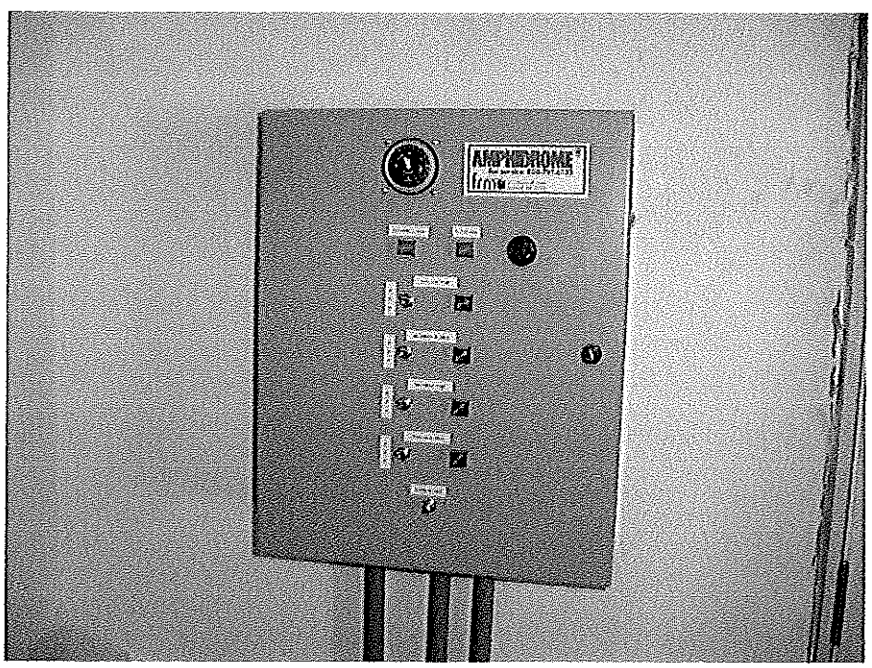
DRAWING 14.
BLOWER DETAIL B, BACKWASH BLOWER AND PIPING ARRANGEMENT



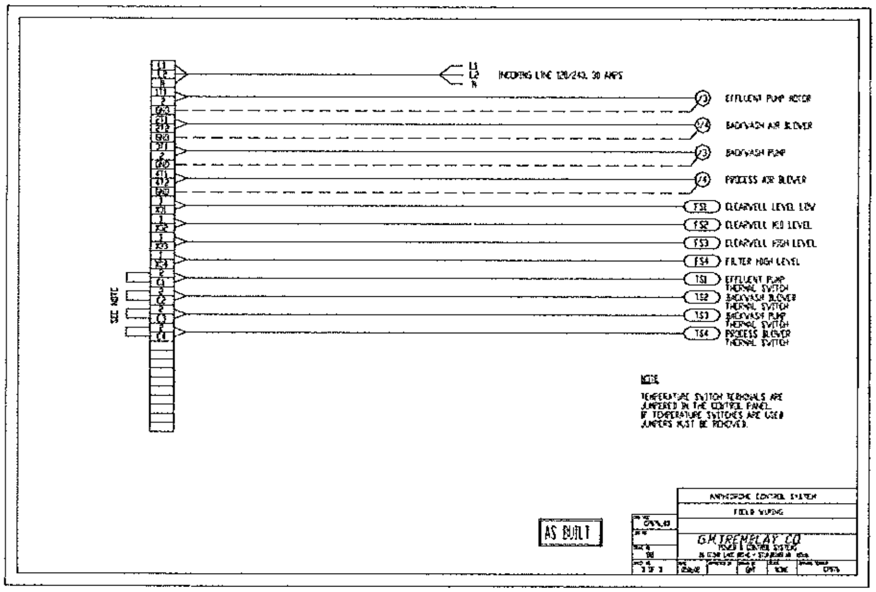
DRAWING 15.
AMPHIDROME® CONTROL SYSTEM
ELECTRICAL SCHEMATIC



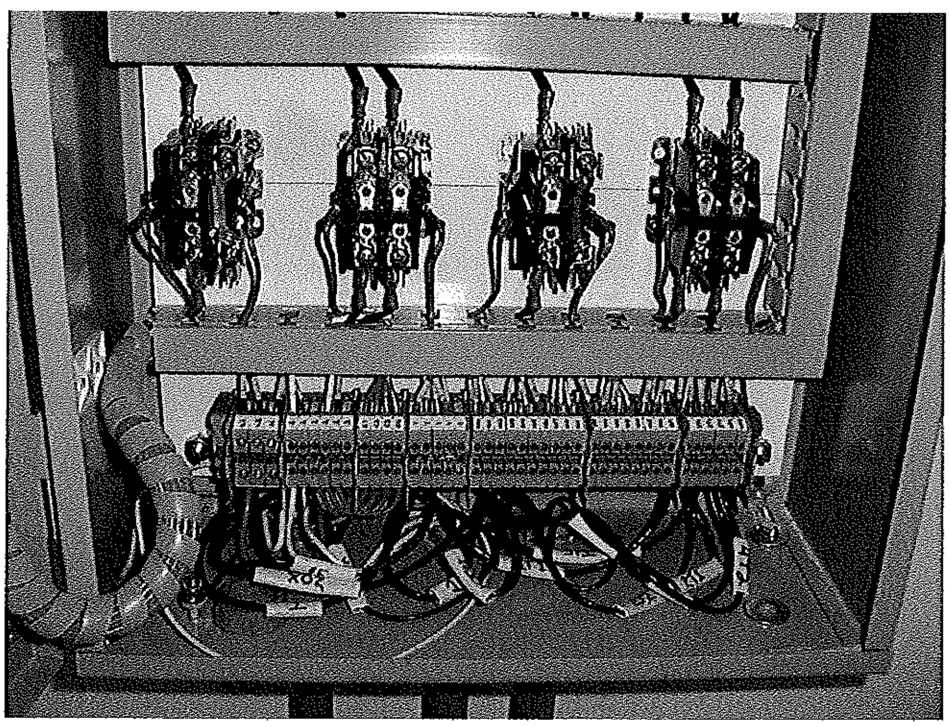
DRAWING 16.
AMPHIDROME® CONTROL SYSTEM, CONTROL PANEL LAYOUT



PICTURE 2. AMPHIDROME® CONTROL PANEL



DRAWING 17. AMPHIDROME® CONTROL SYSTEM, FIELD WIRING



PICTURE 3. CONTROL PANEL TERMINAL STRIP

Appendix 2. Bill of Materials

ANOXIC TANK

CONTRACTOR BILL OF MATERIALS			F.R. MAHONY BILL OF MATERIALS		
#	QUANT	DESCRIPTION	#	QUANT	DESCRIPTION
1	1	2000 GALLON ANOXIC TANK WITH WATER			**ITEMS 1 - 4 REFER TO DETAIL A**
		TIGHT PENETRATION SEALS	1 - 4	1	TEE AND CHECK VALVE ASSEMBLY
2	30'	4" SCHED 40 PVC PIPE PLUS AMOUNT NEEDED			**ITEMS 5 - 9 REFER TO DETAIL B**
		TO GO FROM HOUSE TO ANOXIC TANK	5 - 9	1	4" ENERGY DIFFUSION TEE ASSEMBLY
3	1	4" SCHED 40 PVC TEE			
4	2	4" SCHED 40 PVC ELBOWS			
5	20'	2" SCHED 40 PVC PIPE			
6	1	TANK RISER			
7	1	TANK COVER			

AMPHIDROME® REACTOR

CONTRACTOR BILL OF MATERIALS			F.R. MAHONY BILL OF MATERIALS		
#	QUANT	DESCRIPTION	#	QUANT	DESCRIPTION
8	1	REACTOR BASIN WITH COVER AND			**ITEMS 10 - 12 REFER TO DETAIL C**
		WATER TIGHT PENETRATION SEALS	10 - 11	1	UNDERDRAIN DISCHARGE ASSEMBLY
9	1	2" SCHED 80 PVC PIPE FOR VENT	12	20'	2" SCHED 80 PVC PIPE FOR DISCHARGE
					ITEMS 13 - 15 REFER TO DETAIL D
			13	1	UNDERDRAIN ADAPTER ASSEMBLY
			14	1	2' UNDERDRAIN
			15	10'	1 1/2 SCHEDULE 80 PVC PIPE
					ITEMS 15 - 19 REFER TO DETAIL E
			15	10'	1 1/2 SCHEDULE 80 PVC PIPE
			16	1	1 1/2 SOLVENT SCHEDULE 80 PVC ELBOW
			17	1	1 1/2 SCHEDULE 80 PVC PIPE FIELD CUT
					BY CONTRACTOR FROM ITEM # 15
			18	1	1 1/4" & 1 1/2" PVC COMPRESSION BACKWATER
					CHECK VALVE
			19	1	1 1/2 SCHEDULE 80 PVC PIPE FIELD CUT
					ITEMS 20 - 22 REFER TO 2' DIA. AMPHIDROME®
					REACTOR DRAWING
			20	2	PIPE MOUNTED MINI FLOATS W/30' CABLE
			21	18"	GRAVEL-ASSORTED SIZES
			22	4'	FILTER MEDIA

Bill of Materials (Cont.)

CLEARWELL

CONTRACTOR BILL OF MATERIALS			F.R. MAHONY BILL OF MATERIALS		
#	QUANT	DESCRIPTION	#	QUANT	DESCRIPTION
13	1	1000 GALLON CLEAR WELL TANK WITH			**ITEMS 23 - 28 REFER TO DETAIL F**
		WATER TIGHT PENETRATION SEALS	23	1	RETURN PUMP
14	2	TANK RISERS	24	1	1 1/4" SCHED 80 MALE ADAPTER
15	2	TANK COVERS	25	1	3" X 1 1/4" SCHED 80 PVC PIPE
			26	1	1 1/4" SOCKET X 1 1/2" SCHED 80 BUSHING
			27	1	1 1/2" SOLVENT SCHED 80 COUPLING
			28	1	10' X 1 1/2" SCHED 40 PVC PIPE
					ITEMS 29 - 37 REFER TO DETAIL G
			29	1	2" X 1 1/2" SCHED 80 SOCKET X MALE BUSHING
			30	1	2" SCHED 80 COUPLING
			31	1	1/8" NPT WITH TAP AND AIRTUBE **(REFER TO**
					BLEED TUBE ASSEMBLY/DETAIL G)
			32	1	1 1/2" X 1 1/2" SCHED 80 MALE BUSHING
			33	1	1 1/2" PVC SCHED 80 UNION
			34	1	1 1/2" SOLVENT TEE
			35	1	1 1/2" SOLVENT X F IPT COUPLING
			36	1	1 1/2" THREADED PLUG
			37	1	10' X 1 1/2" SCHED 40 PVC PIPE (FIELD CUT)
					ITEMS 37-44 REFER TO DETAIL H
			37	1	10' X 1 1/2" SCHED 40 PVC PIPE (FIELD CUT)
			38	1	EFFLUENT PUMP
			39	1	1 1/2" SCHED 80 CHECK VALVE
			40	1	SUMP CONTAINER WITH LID
			41	1	3" X 1 1/2" SCHED 80 PVC PIPE
			42	1	1 1/4" X 1/2" SCHED 80 PVC REDUCING BUSHING
			43	1	7" X 1 1/4" SCHED 80 PVC PIPE
			44	1	1 1/4" SCHED 80 MALE ADAPTER
					ITEMS 45 - 49 REFER TO CLEAR WELL TANK
					DRAWING
			45	3	MINI FLOATS W/30' CABLE
			46	1	FLOAT MOUNTING BRACKET KIT
			47	2	20' POLY ROPE FOR PUMPS
			48	1	ROPE HANGER FOR EFFLUENT PUMP
			49	1	SAMPLING DEVICE (OPTIONAL)

Bill of Materials (Cont.)

BLOWERS AND CONTROL SYSTEM

CONTRACTOR BILL OF MATERIALS			F.R. MAHONY BILL OF MATERIALS		
#	QUANT	DESCRIPTION	#	QUANT	DESCRIPTION
16		CONDUIT FOR CONTROL PANEL			**ITEMS 50-80 REFER TO BLOWER DETAIL A & B**
			50 - 80	1	PROCESS AIR PIPING ASSEMBLY
					ITEMS 81 - 82 CONTROL SYSTEM
			81	1	CONTROL PANEL
			82	1	AUTOMATIC DIALER (OPTIONAL)
			83	1	ABOVE GRADE JUNCTION BOX (OPTIONAL)
			84	1	IRRIGATION/SPRINKLER BOX AND SCOTCH KIT (OPTIONAL)

Appendix 3.
AUTOMATIC VOICE/PAGER DIALER SYSTEM*
MODEL AD2001 OPERATING INSTRUCTIONS

HOW IT WORKS

The AD2001 dialer features busy-line and no-answer detection to ensure prompt transmission of up to 2 prerecorded messages delivered sequentially to as many as 4 standard telephones, cellular phones, voice and/or numeric pagers. Messages to both local and long-distance calls can be transmitted. When activated, the dialer instantly begins calling the numbers in sequence, delivering each message 1 to 3 times in a row, in accordance with the pre-selected number of dialing attempts. The AD-2001 is extensively programmable, offering personalized customization to fulfill virtually any residential or business requirement. Plain-English prompts walk the user through the process in a timely manner. Programming options abound, allowing the user to:

· Store up to 4 telephone/pager numbers.
· Choose 1- 9 calling efforts for the numbers dialed.
· Select 1-3 message repeats.
· Record a variable combination (maximum: 3) of instructional outgoing messages (total elapsed time: 51 seconds).

Program up to 2 separate input channels with individually enable/disable, entry/exit delay and activation options (Normally Open (N.O.), Normally Closed (N.C.) (dry contact or voltage activation) including momentary and continuous activation for each).

Further individualize each channel by selecting the delay times, telephone/pager numbers to be dialed and the specific outgoing messages to be played.

PROGRAMMING THE DIALER

Overview

Please study this section thoroughly before beginning to program the dialer, referring to the Sample Program Planner on page 13. Then, select from among the options for each feature, listing each choice in pencil on the blank Program Planner on page 14. Once the dialer is correctly programmed, list each choice in ink. One copy of the Planner should be kept by the installer; one copy should remain with the end user.

A look At The Keypad

· Callout for Numerals:

Press these keys to enter telephone numbers and other programming information as specified in this manual. A maximum of 50 digits can be input in each phone/pager location.

*The manufacturer's <u>Ower's Manual and Operating Instructions</u> for Model AD-2001, the Automatic Voice/Pager Dialer System, has been modified to fit the format of this manual. An original copy of the manufacturer's <u>Owner's Manual and Operating Instructions</u> will be included with the equipment furnished to each homeowner.

- **Callout for P:**

Press this key to program in a pause. Each "P" provides a 2-second pause.

- **Callout for R:**

Press this key to record the combination of identification and directional outgoing messages (OGMs). The total elapsed OGM time cannot exceed 51 seconds.

- **Callout for M:**

Press this key to change the Mode of the dialer, in sequence: **PROGRAM TEST OPERATE OFF.**

Once the unit has been programmed, removing power or placing the dialer in the OFF mode will not affect the programming.

Programming the Dialer

First Time Installation to Initialize Dialer Follow Steps 1 & 2.

STEP 1 Apply power to the unit. The LCD will read: NOT PROGRAMMED PRESS KEYPAD #1.

STEP 2 Press 1. The LCD will change to read: USP AD2001 X.X.
then: PROGRAM: NUMBERS.
then: SELECT: 1-4, 0(DONE).

Programming Telephone And/Or Pager Numbers

You are now ready to begin programming the dialer. All programming can be input before connecting the dialer to a telephone line. Check the unit's LCD as you program numbers in the dialer to ensure accuracy. Please complete all programming instructions before attempting to operate the unit. Before programming your dialer to call the police, fire department or 9-1-1 directly, you must check with these agencies for their approval.

A maximum of 50 digits (including pauses) can be programmed in at each location.

***PROGRAM: NUMBERS** **1(YES) 2(NO)**	**SELECT: 1-4** **0(DONE)**

*This prompt will appear after a number has been programmed and this section has been exited.

STEP 1 Press location number 1-4 to program the first number. This can be any location 1-4. You do not have to program locations in sequence. For example, you can program numbers in locations 2 and 4. When you are done programming all the desired telephone and/or pager numbers, press "O" to exit this section.

The LCD will read:	**PAGER** **1(YES) 2(NO)**

STEP 2 Press "1" if you wish to program in a numeric pager number (step 3A). Press "2" if you wish to program in a telephone number (step 3B), cellular phone numer (step 3B), or a voice pager (step 3C).

STEP 3A- NUMERIC PAGERS
NOTE: WHEN PROGRAMMING NUMERIC PAGERS, YOU MUST PROGRAM IN ONE OR MORE PAUSES. EACH "P" PROVIDES A 2-SECOND PAUSE. BEFORE PROGRAMMING IN A PAGER, CALL THE NUMBER TO DETERMINE THE NUMBER OF 2-SECOND PAUSES TO BE PROGRAMMED IN.

If you pressed "1" to program in a numeric pager...
Press the digits of the pager to be called. The numbers will appear on the LCD, as will the following key designations. Press "P" one or more times in accordance with the number of seconds needed to accommodate the pager. **(Remember, each "P" provides a 2-second pause).**
Press the digits of the numeric pager code.

NOTE: SOME PAGER SERVICES REQUIRE A "#" SIGN FOR SEPARATION OF THE NUMERIC CODE OR AT THE END OF THE NUMERIC CODE FOR PROPER TRANSMISSION.

Press "*" to store the sequence.
Example: To store numeric pager number 555-1212, a 4-second Pause and code 3456:
Press: 5 5 5 1 2 1 2 P P 3 4 5 6 *

STEP 3B – TELEPHONE NUMBERS
If you pressed "2" and wish to program in a telephone number...
Press the digits of the number to be dialed. For long-distance numbers, first press "1" followed by the area code and then the number. The number will appear on the LCD.
Press "*" to store the sequence.
Example: Store telephone number 1-800-555-1212:
Press: 1 8 0 0 5 5 5 1 2 1 2 *

REMEMBER/NOTE: Before programming your dialer to call the police, fire department 0r 9-1-1 directly, you must check with these agencies for their approval.

STEP 3C – VOICE PAGERS
If you pressed "2" and wish to program in a voice pager...
Press the digits of the pager to be called. Press "P" one or more times in accordance with the number of seconds needed to accommodate the pager.
(Remember each "P" provides a 2-second pause).
Press "*" to store the sequence. The number will appear on the LCD.
Example: To store voice pager 555-1212 and a 4-second pause:
Press: 5 5 5 1 2 1 2 P P *

STEP 4 Repeat steps 1-3 for each number to be programmed in each location. Select any of 4 location numbers in Step 1 (SELECT: 1-4) for each number to be programmed.

STEP 5 When you are done programming all desired telephone and/or pager numbers, press "0" to exit this section.

NOTE: IF YOU ENTER THE WRONG CHOICE, PRESS "M" KEY REPEATEDLY AND RETURN TO THE "PROGRAM MODE", THEN SELECT THE SECTION TO CHANGE ("1" ACCEPT SECTION, "2" FOR NEXT SECTION), THEN ENTER CORRECT INFORMATION.

Programming Auxiliary Information

The dialer is preset at the factory to typical telephone line (TLINE), PBX, Dialing Attempts and Message Repeat options. If you choose to accept the following default prompts, simply press "2" to scroll to the next section. If your phone system requires dialing a digit to get an outside line or dial tone, similar to PBX, then turn PBX on and enter digit to program.

PRESETS

T-LINE...............TONE
PBX....................OFF
ATTEMPTS...............2
MESSAGE................2

To change the presets, follow these steps.

T-LINE

The LCD will display:

PROGRAM: T-LINE
1(YES) 2(NO)

Press "1" to program T-LINE.
Press "2" to scroll to the next section.

The LCD will display:

PROGRAM: T-LINE
1(TONE) 2(PULSE)

Press "1" for TONE. Press "2" for PULSE.

PBX

The LCD will display:

PROGRAM: PBX
1(ON) 2(OFF)

Step 1: Press "1" for ON. Press "2" for OFF.

Step 2: If "1" is entered, the LCD will display:

PROGRAM: PBX
ENTER PBX NUMBER

Enter PBX number (1 digit).

Attempts

Attempts refers to the number of times the dialer will call each designated number. Both successful and unsuccessful (busy or no answer) call are considered attempts.

The LCD will display:

PROGRAM: ATTEMPTS
ENTER 1-9

Step 1: Press the digit (1-9) corresponding to the number of times you wish the dialer to call each number.

Message

Message refers to the number of times each message will be delivered to each designated number.

The LCD will display: **PROGRAM: MESSAGE**
REPEAT ENTER 1-3

Step 1: Press the digits (1-3) corresponding to the number of times you wish the message(s) to be delivered.

After selecting the number of message repeats, the dialer will automatically exit this section.

Structuring Your Outgoing Messages
The AD-2001 dialer was designed with optimum versatility and functionality in mind. Nowhere is this more apparent than in the matrix of outgoing messages (OGMs). The user's ability to "mix and match" OGMs allows complete system customization and provides ultimate efficiency.

Typically, each OGM will have a specific purpose. For instance, OGM 1 can alert the person notified to contact the fire department while OGM 2 can alert the person to contact the police department. Typically the dialer is programmed to notify family, friends or another responsible party. Before programming your dialer to call the police, fire department or 9-1-1 directly, you must check with these agencies for their approval.

OPTION #1 No OGM. Select this option if you do not wish to record any outgoing messages.

OPTION #2 1 OGM. Select this option if you wish to record one OGM, which may be as long as 51 seconds.

OPTION #3 2 OGMs. Select this option if you wish to record two OGMs, each of which may be as long as 25.5 seconds.

OPTION #4 ID plus 2 OGMs. Select this option if you wish to record one ID of up to 15 seconds in length, and two OGMs, each of which may be as long as 18 seconds. *

*If your ID message is less than 15 seconds in length, the remaining time will be evenly divided among the OGMs.

Example: OPTION #4: ID plus 2 OGMs.

If the ID is 10 seconds, then each OGM can be (51 minus 10 equals 41 divided by 2 equals) 20.5 seconds in length.

Programming And Recording Your Outgoing Messages
Follow these steps to program and record your outgoing messages. Skip this portion if you have programmed in only numeric pagers, which rely on coded DTMF messages. As with all AD-2001 programming, the unit need not be connected to a phone line when information is programmed in. Remember that "OPT" on the LCD stands for option; "OGM" stands for outgoing message.

NOTE: IF YOU ENTER THE WRONG CHOICE, PRESS "M" KEY REPEATEDLY AND RETURN TO THE "PROGRAM MODE", THEN SELECT THE SECTION TO CHANGE ("1" ACCEPT SECTION, "2" FOR NEXT SECTION), THEN ENTER CORRECT INFORMATION.

STEP 1 Decide which of the four options you prefer.

STEP 2 Before programming in this option, write down all your messages. Time them carefully, changing them if ecessary to fit the alotted time frame. Practice saying them, clearly enunciating each message for maximum clarity in case of an emergency. Keep a final recording script.

STEP 3 Program your option.
A) The LCD will read: **PROGRAM: OGMS**
1(YES) 2(NO)
B) Press "1" to program your OGMs. Press "2" to scroll to the next section.

C) Press "1" to select the option (#1- #4) displayed or press "2" to scroll to the desired option.

STEP 4 After selecting your option as explained above, record your message.
A) The word RECORD will appear in the upper left corner of the LCD, above the instruction: PRESS R. The option selected will appear in the upper right corner. For instance, if you selected option #2, the LCD will read:

RECORD **OGM1**
PRESS R

B) Speak 6-12 inches away from the microphone. Referring to your script and speaking in a normal voice, press and hold R (the word RECORDING will be displayed), releasing the key after you have completed enunciating your messages.
The word DONE will appear on the LCD when the maximum allotted time has been reached.

C) The LCD will read: **PLAY OGM(S)**
1(YES) 2(NO)
Press "1" to play back your recording.

D) The LCD will read: **ACCEPT**
1(YES) 2(NO)
Press "1" to accept the recorded OGM(s). Press "2" if you wish to re-record the messages, beginning with Step 4.

Changing The OGMs After your system is up and operating, you may change one or more of the recorded OGMs and/or choose a completely different option. To do so, simply scroll to the programming section on your display:

PROGRAM: OGMS
1(YES) 2(NO)

Select the option, then begin again from Step 3 above to record your new message(s).

Programming The Channels
The AD-2001 is designed to be adaptable to a complete range of personalized applications. Each of the two input channels can be programmed individually for full system customization. In addition to setting enable/disable options, entry/exit delays and type of activation (N.O., N.C., & momentary or continuous), each user can specify which emergency messages will be delivered and which numbers will be dialed. The first channel activated will be the priority channel. Numbers programmed to that channel will be completed before the dialer moves on to the next

Listen-In
While receiving an OGM on a touch-tone phone, the called party can press "1" to listen in to the activity at the other end of the line for one minute. Pressing "1" again restarts the minute increment period and can be repeated indefinitely. When "1" is pressed the OGM will stop playing and the listen in period will start.

Two-Way
After the called party is listening-in, that party can press "2" to begin a two-way conversation lasting for one minute. This procedure also can be repeated indefinitely by pressing "2" again to restart the minute. Once you are in two-way mode you cannot go back to Listen-In.

Remote Turn-Off
The called party can remotely terminate the activated channel any time during the OGM by pressing "1" then "#" twice within one second. The dialer will continue to monitor the remaining channel. Once the terminated channel is restored to a non-alarm state, it will re-arm. If in listen-in or two-way, simply press "#" twice in one second, for remote turn-off.

SAMPLE PROGRAM PLANNER

Programming Example for Quick Setup
Before programming the dialer, study the example shown on this page. This "quick setup" example programs in one telephone number, two numeric pager numbers, two attempts, two repeats, an ID plus two additional OGMs, and channels 1 and 2.

Once you understand the setup, use the blank Program Planner on page 14 to begin programming your dialer. We recommend making several blank copies of the Planner before beginning the process. It also is advisable to fill in the Planner in pencil initially.

When in the operating mode, the system will monitor both enabled channels, initiating dialing when a valid alarm condition occurs. Upon activation the dialer will begin calling each phone/pager number selected, in sequence, for the pre-selected number of attempts. During each successful attempt, the voice message will be delivered 1, 2, or 3 times, in accordance with the option selected (numeric messages will only be delivered one time). In unsuccessful attempts, the dialer will move on to the next phone/pager number after receiving 8 busy or 8 rings without an answer. The dialer will not allow voice messages to be delivered to programmed numeric pager locations.

If you send a message to a phone attached to an answering machine, it will consider this a successful attempt. Make sure you designate the maximum number of message repeats to be sure that a complete message will be left on the answering machine, because part or all of your emergency message may be "lost" while the answering machine delivers its greeting message.

Placing your system in OPERATE can also be used as a final test of the full functionality of each channel's exit/entry delay, activation, momentary/continuous trigger, phone numbers and OGM. Although serving as a test, this mode reflects actual operation; therefore the OGM(s) will not be heard through your dialer's speaker but only by each party called.

To begin operating your system, simply press the "M" Mode key until the word OPERATE appears on the LCD. To disarm the dialer, switch the mode to OFF by pressing the same key. All programming information will be retained.

System Notations
Here are a few explanations to help you better understand how your AD-2001 dialer operates. For specific information on the AD-2001 unit alone, call United Security Products, Inc.'s Customer Service Department during normal business hours at (858) 597-6677.

Channel Activation
Each of the dialer's two channels can be activated by any of the following: a normally open dry contact, normally closed dry contact or positive 5-28VDC voltage activation. Under a momentary activation, a single violation of a channel will cause the dialer to initiate delivering all preselected OGMs to all programmed numbers associated with that channel. Under continuous activation, the dialer will initiate the process, terminating it if/when the activated channel is restored to a non-alarm state. Once an alarm has occurred and all attempts satisfied, the dialer will continue to monitor any remaining enabled channel. Once the activated channel has been restored to a non-alarm state, it will then be re-armed and ready for the next alarm.

Exit/Entry Delays
If a channel is activated during a pre-selected exit delay, the alarm condition will be ignored until the delay has expired. If an alarm occurs, the entry delay will cause the dialer to wait before starting the dialing process. To de -activate the dialer during the entry wait period, simply press "M" to return to the OFF Mode. Both exit and entry delay times can be pre-selected to range from 1-199 seconds.

Additional Features
The dialer offers three innovative features that enhance the utility of the entire system.

Test your system before an emergency occurs.

Do not neglect to review programmed information and verify all elements of your system thoroughly before relying on the dialer to deliver the necessary information to the desired parties accurately and completely.

We strongly recommend testing the system in test mode before connecting to a telephone line. The test mode tests the stored information, not the full functionality of the dialer. To test the full functionality of the dialer, the unit must be tested in the operate mode. In the test mo de, the dialer will not make more than one attempt per number dialed or play any OGM more than once.

NOTE: IF YOU ENTER THE WRONG CHOICE, PRESS "M" KEY REPEATEDLY AND RETURN TO THE "PROGRAM MODE", THEN SELECT THE SECTION TO CHANGE ("1" ACCEPT SECTION, "2"
FOR NEXT SECTION), THEN ENTER CORRECT INFORMATION.

STEP 1 Press the "M" Mode key until the LCD reads:
TEST: T-LINE
1(YES) 2(NO)

STEP 2 Press "1" to display the T-Line configuration. The data will scroll through all selections. Press "2" to scroll to the next section.

STEP 3 The LCD will read: **TEST: CHANNEL(S)**
1(YES) 2(NO)

Press "1" to test channels.
Press "2" to scroll to the next section.

STEP 4 The LCD will read: **SELECT: 1-2**
3(BOTH) 0(DONE)

Select the channel you wish to test (1-2). Press "3" to test both. Channels. Once a channel is selected (or "all") the programmed channel information will be displayed on the LCD. Verify data accuracy as the LCD scrolls through by comparing the information displayed with that specified on your Program Planner. Listen to your recorded message(s) to ensure that the correct OGM (if programmed) is delivered. Press "0" to exit testing.

STEP 5 Now connect your dialer to the telephone line you will be using and test the system again, to determine if it functions correctly in an actual emergency situation. Make sure you notify the receiving pa rty of your intent to call them, and tell them it is just a test.

STEP 6 To test the operation of your entire system, set Mode to OPERATE and proceed as explained in the next section: Operating Your System.

Test your system on a regular basis, at least once a week.

OPERATING YOUR SYSTEM

You are now ready to begin operating your system, relying on the AD-2001 to work in conjunction with your alarm system to provide 24-hour security reassurance and peace of mind.

A) Press "1" to select a normally open channel.

B) Press "2" to select a normally closed channel.

Momentary/Continuous Activation

STEP 7 The LCD will read: **CH X: MOM/CONT**
1(MOM) 2(CONT)

A) Press "1" to select a momentary trigger.

B) Press "2" to select continuous activation.

Numbers Dialed/Outgoing Messages
Following these steps allows you to choose which OGM(s) will be delivered and which numbers will be dialed for each channel. NOTE: Dialer LCD will only show programmed numbers and OGM options.

STEP 8 The LCD will read: **CH X: DIAL #X**
1(YES) 2(NO)
("Dial #X" being the number in phone/pager location 1-4)

A) Press "1" to dial phone/pager #X to be dialed when the selected channel is activated. Press "2" if you do not wish this number to be dialed.

B) Continue the above procedure for each of the up to four phone/pager numbers programmed in.

STEP 9 The LCD will read: **CH X: OGM X**
1(YES) 2(NO)
("OGM X" being the OGM recorded in OGM options #2 - #4)

A) Press "1" to deliver OGM X when the channel is activated. Press "2" if you do not wish this OGM to be delivered.

B) Continue the above procedure for each Channel/OGM. If you have programmed in and recorded an ID message as one of your OGM options, this ID will be delivered to all channels. It will not appear in the Channel display.

NOTE: ID AND OGM(S) WILL ONLY BE DELIVERED TO TELEPHONE NUMBERS, CELLULAR NUMBERS, AND VOICE PAGERS.

Completing The Programming
Once you have programmed in all dialing and OGM options for each channel, the LCD will read:
ACCEPT
1(YES) 2(NO)

STEP 10 Press "1" to accept the Channel programming. Press "2" to re-program or to revert to previously programmed setting. You are now ready to review your programming and test the system.

PRESS "M" TO EXIT PROGRAMMING MODE.

TESTING YOUR SYSTEM

channel. Although comprehensive in scope, the system is easy to program. Just follow these simple steps.

NOTE: IF YOU ENTER THE WRONG CHOICE, PRESS "M" KEY REPEATEDLY AND RETURN TO THE "PROGRAM MODE", THEN SELECT THE SECTION TO CHANGE ("1" ACCEPT SECTION, "2" FOR NEXT SECTION), THEN ENTER CORRECT INFORMATION.

STEP 1 The LCD will read: **PROGRAM: CHANNELS 1(YES) 2(NO)**

Press "1" to begin programming the channels.

STEP 2 The LCD will read: **SELECT: 1 OR 2 0(DONE)**

Enter the channel you wish to program (1-2).

Enable/Disable

STEP 3 The LCD will read: **CH X: ENABLE 1(YES) 2(NO)**

("CH X" being the channel selected)

Press "1" to enable the channel. Press "2" to disable the channel.

Exit/Entry Delays

Capable of programming up to a maximum of 3 minutes and 20 seconds each.

STEP 4 The LCD will read: **CH X: EXIT DELAY 1(YES) 2(NO)**

Proceed with A) if you wish to program an exit delay. Proceed with B) if you do not.

A) To program exit delay, press "1".
The LCD will read: **ENTER 0-199 THEN PRESS ***

Enter the digits corresponding to the number of seconds you wish to install. (For example, press "120" then press "*", if you wish to install a 120-second exit delay).

B) If you do not wish to program an exit delay, press "2".

STEP 5 The LCD will read: **CH X: ENTRY DELAY 1(YES) 2(NO)**

Proceed with A) if you wish to program an entry delay. Proceed with B) if you do not.

A) To program an entry delay, press "1".
The LCD will read: **ENTER 0-199 THEN PRESS ***

Press "1" to program a delay. Then enter the digits corresponding to the number of seconds you wish to install. (For example, press "90" then press "*", if you wish to install a 90-second delay).

B) If you do not wish to program an entry delay, press "2".

Normally Open/Normally Closed

STEP 6 The LCD will read: **CH X: N.O./N.C. 1(N.O.) 2(N.C.)**

AD2001 PROGRAM PLANNER

PROGRAM: NUMBERS **DATE:**

#	PAGER YES	NO	TELEPHONE # (EXC. PBX DIGIT, INCL. NUMERIC PAGER CODE	NAME OF PARTY TO BE REACHED
1				
2				
3				
4				
5				

PROGRAM: T-LINE

TONE	PULSE	PBX ON	OFF	ATTEMPTS 1 THROUGH 9	MESSAGE REPEAT 1 THROUGH 9

PROGRAM: OGMs

OPTION		STYLE	BRIEFLY DESCRIBE TYPE OF VOICE MESSAG(S)
	1		
	2		
	3		
	4		

PROGRAM: CHANNELS

CH	ENABLE		EXIT DELAY (SEC)			ENTRY DELAY (SEC)			ACTIVATION				DIAL NUMBER				PLAY OGM	
	YES	NO	YES	NO	0-199	YES	NO	0-199	NO	NC	MON	CONT						
1													1	2	3	4	1	2
2																		
3																		
4																		

STEP 1 Press "1".

STEP 2 When the LCD reads SELECT 1-4, press "1" to install the first phone number in location 1 press "2" to indicate no pager; then press, in sequence, (fictitious) phone number "2345678" followed by the "*" sign to store the programming process for that number.

STEP 3 Press "3" to install the second phone number in location 3; press "1" to indicate numeric pager; then press' in sequence, "3456789PP4455#" followed by the "*" sign. The first seven digits represent the pager number dialed; each P stands for a 2-second pause; the next four digits followed b y the # sign represent the pager code
and the * stores the programming process for that number. Now press "4" to install the third phone number in location 4; press "1" to indicate numeric pager; then press, in sequence, "3456789PP5544#" followed by the "*" sign.

STEP 4 Press "0" to exit PROGRAM NUMBERS.

STEP 5 At the PROGRAM: T-LINE prompt, press "1" to choose tone; press "2" to indicate no PBX; press "2" to program in two dialing attempts per emergency number called; press "2" to program in two message re peats for each call.

STEP 6 Press "1" to PROGRAM OGM(S). Press "2" three times to Scroll to option #4; press "1" to program in an ID message and two specific outgoing messages (OGMs).

STEP 7 Using a prepared script and speaking six-to-eight inches from the dialer's microphone on the front of the unit, press "R" when you are ready to enunciate your 15-second identification message and your two 18-second messages. Dialer automatically prompts to next OGM. Make OGM1 a message telling the receiving party to call the police department. Make OGM2 a message to call the fire department.

STEP 8 Press "1" to play back all recorded messages; press "1" again to accept. (NOTE: DIALER LCD WILL ONLY SHOW PROGRAMMED NUMBERS AND OGM OPTIONS).

STEP 9 Press "1" to PROGRAM CHANNELS.

STEP 10 Press "1" to program Channel 1. Press "1" to ENABLE. Press "1" then enter "30" then press "*" for a 30-second EXIT delay; press "1" then enter "15" then press "*" for a 15-second entry delay. Now press "2" for NORMALLY CLOSED and then "1" for MOMENTARY activation. Press "1" to select phone/pager number 1 to be dialed. Press "1" again to select phone/pager number 3 to be dialed. Press "2" to not select phone/pager number 4 to be dialed. Press "1" to select OGM1 to be delivered and press "2" to not select OGM2 to be delivered. Press "1" to accept the channel configuration.

STEP 11 Press "2" to program Channel 2. Press "1" to ENABLE. Press "2" twice to indicate no EXIT or ENTRY delay. Now press "1" for NORMALLY OPEN and the "2" for CONTINUOUS activation. Press "1" to select phone/pager number 1 to be dialed. Press "2" to not select phone/pager 3 to be dialed. Press "1" to select phone/pager number 4 to be dialed. Press "2" to not select OGM1 to be delivered
and press "1" to select OGM2 to be deliv ered. Press "1" to accept the channel configuration.

STEP 12 Press "0" to exit PROGRAM: **CHANNELS.**
Press "M" to exit programming mode.

After thoroughly testing your system, redo your Program Planner in ink. One copy should be kept in a safe place by the end user; one copy should be retained by the installer.

SPECIFICATIONS

Dimensions

Power source:	9-18VDC
Current (OPERATE mode – standby):	28mA typical.
Current (OPERATE mode – dialing):	100mA max.
Activation:	1) N.C. Activation: dialer activates when an "open" is detected 2) N.O. Activation: dialer activates when a "close" is detected 3) Voltage Activation: N.C. (applied voltage: Min. +5VDC, Max. +28VDC) N.O. (loss of continuous voltage: Min. 0VDC, Max. 0.25VDC)
Max. digits for outgoing numbers:	50
Operating temperature range:	-18 to 55 C (0 to 130 F)
Dimensions (inches):	6 x 4 x 1.5 in
Weight (ounces):	10 oz
Mounting:	Wall or Flat Surface
Case Material:	ABS
Color:	White
Warranty:	1 Year

Note: Design and specifications subject to change without notice.

DIALER ACCESSORIES

Power Source

AC-1: AC/DC Adaptor
Plugs into regular 110VAC outlet to provide the dialer with the required primary power.

AC-2: AC/DC Adaptor
12VDC/0.5A for stand alone with siren use.

PP-1: Power (Rechargeable)
Provides 24 (est.) hours of backup standby power.

AC-1P: AC/DC Adaptor For Use With PP-1
Plugs into regular 110VAC outlet to provide the dialer with the required primary power and additional input for PP-1 interface.

IR-1: Isolation Relay
Converts alarm output voltage to N.C. to provide clean input trigger to dialer.

Industrial/Residential Sensors
F20: Temperature Supervisory Switch <40 F
HTS: High Temperature Switch
LTS: Low Temperature Switch
CSS: Cold Storage Switch
WLS: Water Level Sensor

RTS: Adjustable Temperature Controller, N.O., N.C.
PLS: Power Loss Sensor (110VAC)

Sensors
Magnetic Contacts – Door and Window
Glass Break Detectors
Hold Up Buttons/Emergency Switches
Pressure Mats – Sealed and Under Carpet
Motion Detectors

Siren
S-120: 2" Mini Siren, 12VDC @ 120 mA typical

Additional Options
Data logger: AD-2001-DL
Retains in memory log of alarm events for later retrieval and review.

Wireless: AD-2001/W
Wireless version AD-2001 dialer includes wireless pendant transmitter.
24V Application: AD-2001/F
For this option the dialer is configured to operate at 24VDC to 32VDC max. All other specifications apply.
Wireless and 24V Applications: AD-2001/W/F
The AD-2001/W/F incorporates both the wireless feature and 24VDC application. See WIRELESS AND 24V APPLICATION for further details.

NOTE: CALL UNITED SECURITY PRODUCTS FOR ADDITIONAL INFORMATION AND DEVICES NOT LISTED HERE.

Wireless Upgrade:
The standard AD-2001 can be upgraded for wireless link-up with RF-activated mag contacts, motion sensors, pendant, etc., by installing a new back cover containing a pre-tested RF assembly and swivel antenna. The receiver is connected to the main board via a 4-pin interface connector already included in the standard configuration. See WIRELESS for further details.

NOTE: SYSTEMS ALREADY INSTALLED CAN BE UPGRADED WITHOUT REPLACING OR RE-WIRING THE DIALER.

IMPORTANT INFORMATION

Care And Precautions

Location
Place the dialer on a flat level surface or mount the unit on the wall, away from extreme cold or heat, direct sunlight, excessive humidity and away from equipment that generate strong magnetic fields. Avoid placing near large metal objects and areas that produce smoke, dust and mechanical vibrations.

Care
Clean the housing with a soft cloth lightly moistened with water or mild detergent solution. Never use solvents such as alcohol or thinner. Do not allow liquids to spill into the unit.

Optional Backup
To ensure continuous operation during power outages, hookup to a 12VDC backup battery pack is recommended. (PP-1) Available from United Security Products.

Caution
Do not use the dialer if a gas leak is suspected or during lightning.

Problems
If liquid or a foreign object penetrates the unit, disconnect it immediately and contact your installer or other qualified technician. Before calling USP, please make sure...

- You have read this manual and understand how to operate the dialer.
- Your phone line is working.
- You check out the entire system, including external hookup wiring and sensors attached.

If you still have questions or concerns, call our USP Technical Service Department between the hours of 7:30 AM and 4:00 PM, PST, Monday through Friday.

Federal Communications Commission Radio And Television Interference Statement For A Class 'B' Device This equipment generates and uses radio frequency energy and if not installed and used properly, that is, in strict accordance with the manufacturer's instructions, may cause interference to radio and television reception. It has been type tested and found to comply with the limits for a Class 'B' computing device in accordance with the specifications in Subpart B of FCC Rules and Regulations (as outlined in the Code of Federal Regulation, Title 47), which are designed to provide reasonable protection against such interference in a residential installation.

USER INSTRUCTIONS

If this equipment does cause interference to radio or television reception, which can be determined by turning the equipment off, then on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate radio or television.
- Increase the separation between the equipment and receiver.
- Connect the equipment into a different outlet so that the equipment and receiver are on different branch circuits.
- Consult the dealer or an experienced radio/TV technician for help.

Changes or modifications not expressly approved by United security Products, Inc. could void the user's authority to operate the equipment.

United Security Products
Issue date: 4/27/98

For Technical Service And Support: Call (858) 597-6677 * Fax (858) 455-0036
E-mail usp@ix.netcom.com
Monday – Friday * 7:30 AM – 4:00 PM PST

COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
ONE WINTER STREET, BOSTON, MA 02108 617-292-5500

ARGEO PAUL CELLUCCI
Governor

JANE SWIFT
Lieutenant Governor

BOB DURAND
Secretary

LAUREN A. LISS
Commissioner

Approval for Remedial Use
Pursuant to Title 5, 310 CMR 15.000

Name and Address of Applicant:
F.R. Mahony & Associates, Inc.
273 Weymouth Street
Rockland, MA 02370

Trade name of technology and model: Amphidrome Process (hereinafter the "System").

Date of Application: February 18, 2000
Transmittal Number: 204759
Date of Issuance: 11/28/00
Expiration date: 11/28/2005

Authority for Issuance

Pursuant to Title 5 of the State Environmental Code, 310 CMR 15.000, the Department of Environmental Protection hereby issues this Approval for Remedial Use to F.R. Mahony & Associates, Inc., 273 Weymouth Street, Rockland, MA 02370 (hereinafter "the Company"), approving the System described herein for Remedial Use in the Commonwealth of Massachusetts. Sale and use of the System are conditioned on compliance by the Company and the System owner with the terms and conditions set forth below. Any noncompliance with the terms or conditions of this Approval constitutes a violation of 310 CMR 15.000.

Glenn Haas, Acting Assistant Commissioner
Bureau of Resource Protection
Department of Environmental of Protection

11/28/00
Date

I. Purpose

1. The purpose of this Approval is to allow use of the System in Massachusetts, on a Remedial Use basis.

2. With the necessary permits and approvals required by 310 CMR 15.000, this Approval for Remedial Use authorizes the use and installation of the System in Massachusetts.

3. The System may only be installed on facilities that meet the criteria of 310 CMR 15.284(2).

II. Design Standards

1. The Amphidrome Process is a biological wastewater treatment system that utilizes a fixed film, sequencing batch biofilter. The System consists of a single reactor, which alternates between aerobic and anaerobic conditions. Wastewater passes from an anoxic/equalization tank through a granular biological filter and into a clear well. A pump is then used to reverse the flow back to the anoxic/equalization tank. This cycle is repeated multiple times and the effluent is discharged to the soil absorption system.

2. This Remedial Use Approval authorizes the use of the System where the local approving authority finds that the System is for upgrade of a failed, failing or nonconforming system and the design flow for the facility is 10,000 gallons per day (gpd) or less.

3. The System shall be installed in series between the building sewer and the soil absorption system of a standard Title 5 system constructed in accordance with 310 CMR 15.100 - 15.279, subject to the provisions of this Approval. The use of a septic tank is not required.

4. The System may be used in soils with a percolation rate of up to 90 minutes per inch (MPI). For soils with a percolation rate of 60 to 90 MPI, the effluent loading rate shall be 0.15 gpd / sq.ft.

III. Allowable Soil Absorption System Design

1. <u>Reduction of the Required Soil Absorption System Size</u> – An Applicant is eligible for up to a 50 percent reduction in the area of the soil absorption system required by 310 CMR 15.242, where all of the following conditions are met. Accordingly, in approving design and installation of the System by a particular Applicant, the local approving authority may allow up to a 50 percent reduction in the area of the soil absorption system required by 310 CMR 15.242, provided that all of the following conditions are met:

   A. No reduction in the required separation (four feet in soils with a recorded percolation rate of more than two minutes per inch or five feet in soils with a recorded percolation rate of two minutes or less per inch) between the bottom of the stone underlying the SAS and the high groundwater elevation is allowed unless such a reduction is first approved by the local approving authority and then approved by the Department pursuant to 310 CMR 15.284.

B. No reduction in the required four feet of naturally occurring pervious material is allowed unless the Applicant has demonstrated that the four foot requirement cannot be met anywhere on the site, that easements to adjacent property on which a system in compliance with the four foot requirement could be installed have been requested but cannot be obtained, and that a shared system is not feasible. Any such reduction must first be approved by the local approving authority and then approved by the Department pursuant to 310 CMR 15.284.

C. Where full compliance with all of the minimum set back distances in 310 CMR 15.211 is not feasible, the local approving authority may allow a reduction under a local upgrade approval in accordance with 310 CMR 15.405 (1) (a), (b), (f), (g), and (h).

D. Where full compliance with all of the minimum set back distances in 310 CMR 15.211 is not feasible, even taking into account provisions for local upgrade approval as described above, then pursuant to 310 CMR 15.410, the applicant first must obtain variance(s) from the local approving authority and then approval of the Department.

2. <u>Reduction of the Required Separation Distance to High Groundwater Elevation</u> – An Applicant is eligible for a reduction in the required separation (four feet in soils with a recorded percolation rate of more than two minutes per inch or five feet in soils with a recorded percolation rate of two minutes or less per inch) between the bottom of the stone underlying the SAS and the high groundwater elevation, where all of the following conditions are met. Accordingly, in approving design and installation of the System by a particular Applicant, the local approving authority may allow a reduction in the required separation (four feet in soils with a recorded percolation rate of more than two minutes per inch or five feet in soils with a recorded percolation rate of two minutes or less per inch) between the bottom of the stone underlying the SAS and the high groundwater elevation, provided that all of the following conditions are met:

A. A minimum two foot separation (in soils with a recorded percolation rate of more than two minutes per inch) or a minimum three foot separation (in soils with a recorded percolation rate of two minutes or less per inch) between the bottom of the stone underlying the SAS and the high groundwater elevation is maintained.

B. No reduction in the required SAS size is allowed unless such a reduction is first approved by the local approving authority and then approved by the Department pursuant to 310 CMR 15.284.

C. No reduction in the required four feet of naturally occurring pervious material is allowed unless the Applicant has demonstrated that the four foot requirement cannot be met anywhere on the site, that easements to adjacent property on which a system in compliance with the four foot requirement could be installed have been requested but cannot be obtained, and that a shared system is not feasible. Any such reduction must first be approved by the local approving authority and then approved by the Department pursuant to 310 CMR 15.284.

D. Where full compliance with all of the minimum set back distances in 310 CMR 15.211 is not feasible, the local approving authority may allow a reduction under a local upgrade approval in accordance with 310 CMR 15.405 (1) (a), (b), (f), (g), and (h).

E. Where full compliance with all of the minimum set back distances in 310 CMR 15.211 is not feasible, even taking into account provisions for local upgrade approval as described above, then pursuant to 310 CMR 15.410, the applicant first must obtain variance(s) from the local approving authority and then approval of the Department.

3. <u>Reduction of the Requirement for Four Feet of Naturally Occurring Pervious Material</u> -- An Applicant is eligible for a reduction in the required four feet of naturally occurring pervious material in an area with no less than two feet of naturally occurring pervious material, where all of the following conditions are met. Accordingly, in approving design and installation of the System by a particular Applicant, the local approving authority may allow a reduction in the required four feet of naturally occurring pervious material in an area with no less than two feet of naturally occurring pervious material, provided that all of the following conditions are met:

A. The Applicant has demonstrated that the four foot requirement cannot be met anywhere on the site, and that easements to adjacent property on which a system in compliance with the four foot requirement could be installed have been requested but cannot be obtained, and that a shared system is not feasible.

B. No reduction in the required SAS size is allowed unless such a reduction is first approved by the local approving authority and then approved by the Department pursuant to 310 CMR 15.284.

C. No reduction in the required separation (four feet in soils with a recorded percolation rate of more than two minutes per inch or five feet in soils with a recorded percolation rate of two minutes or less per inch) between the bottom of the stone underlying the SAS and the high groundwater elevation is allowed unless such a reduction is first approved by the local approving authority and then approved by the Department pursuant to 310 CMR 15.284.

D. Where full compliance with all of the minimum set back distances in 310 CMR 15.211 is not feasible, the local approving authority may allow a reduction under a local upgrade approval in accordance with 310 CMR 15.405 (1) (a), (b), (f), (g), and (h).

E. Where full compliance with all of the minimum set back distances in 310 CMR 15.211 is not feasible, even taking into account provisions for local upgrade approval as described above, then pursuant to 310 CMR 15.410, the applicant first must obtain variance(s) from the local approving authority and then approval of the Department.

IV. General Conditions

1. All provisions of 310 CMR 15.000 are applicable to the use of this System, the owner and the Company, except those that specifically have been varied by the terms of this Approval.
2. Any required operation and maintenance, monitoring and testing shall be performed in accordance with a Department approved plan. Any required sample analysis shall be conducted by an independent U.S. EPA or DEP approved testing laboratory, or a DEP approved independent university laboratory, unless otherwise is provided in the Department's written Approval. It shall be a violation of this Approval to falsify any data collected pursuant to an approved testing plan, to omit any required data or to fail to submit any report required by such plan.
3. The facility served by the System and the System itself shall be open to inspection and sampling by the Department and the local approving authority at all reasonable times.
4. In accordance with applicable law, the Department and the local approving authority may require the owner of the System to cease operation of the system and/or to take any other action as it deems necessary to protect public health, safety, welfare and the environment.
5. The Department has not determined that the performance of the System will provide a level of protection to public health and safety and the environment that is at least equivalent to that of a sewer system. Accordingly, no System shall be installed, upgraded or expanded, if it is feasible to connect the facility to a sanitary sewer, unless as allowed by 310 CMR 15.004.
6. Design and installation shall be in strict conformance with the Company's DEP approved plans and specifications, 310 CMR 15.000 and this Approval.
7. Pressure distribution designed in accordance with Department guidance is required for all installations of the System.

V. Special Conditions Applicable to the System Owner

1. The System is approved for the treatment and disposal of sanitary sewage only. Any wastes that are non-sanitary sewage generated or used at the facility served by the System shall not be introduced into the System and shall be lawfully disposed.

2. Effluent discharge concentrations shall meet or exceed secondary treatment standards of 30 mg/L biochemical oxygen demand (BOD_5) and 30 mg/L total suspended solids (TSS). The effluent pH shall not vary more than 0.5 standard units from the influent water supply.

3. Operation and Maintenance agreement:

A. Throughout its life, the System shall be under an operation and maintenance (O&M) agreement. No O&M agreement shall be for less than one year.

B. No System shall be used until an O&M agreement is submitted to the Department and the local approving authority which:

a. provides for the contracting of a person or firm competent in providing services consistent with the System's specifications and the operation and maintenance requirements specified by the designer and those specified by the Department;

b. contains procedures for notification to the local approving authority and the Department within five days of a System failure, malfunction or alarm event and for corrective measures to be taken immediately; and

c. Provides the name of the operator, which must be a Massachusetts certified operator as required by 257 CMR 2.00, that will operate and monitor the System. The operator must operate and maintain the System at least every three months and anytime there is an alarm event.

4. The owner of the System shall at all times have the System properly operated and maintained in accordance with the Company's and the designer's operation and maintenance requirements and this Approval.

5. The owner shall furnish the Department any information, which the Department may request regarding the System, within 21 days of the date of receipt of that request.

6. The owner of the System shall provide a copy of this Approval, prior to the signing of a purchase and sale agreement for the facility served by the System or any portion thereof, to the proposed new owner.

7. Effluent from Systems serving a facility with a design flow less than 2,000 gallons per day (gpd) and both influent and effluent from Systems serving a facility with a design flow of 2,000 gpd to 10,000 gpd shall be monitored quarterly. At a minimum, the following parameters shall be monitored: pH, BOD_5, and TSS. Every time the System is monitored, the water meter reading also shall be recorded. All monitoring and operation and maintenance data shall be submitted to the Department and local approving authority by January 31 of each year for the previous calendar year. After one year of monitoring and reporting and at the written request of the owner, the Department may reduce the monitoring and reporting requirements.

8. When a sanitary sewer connection becomes feasible, within 60 days of such feasibility, the owner of the System shall obtain necessary permits and connect the facility served by the System to the sewer, shall abandon the System in compliance with 310 CMR 15.354, unless a later time is allowed, in writing, by the local approving authority, and shall in writing notify the Department of the abandonment.

VI. Special Conditions Applicable to the Company

1. By January 31st of each year, the Company shall submit to the Department, a report, signed by a corporate officer, general partner or Company owner that contains information on the System for the previous calendar year. The report shall state: the

number of units of the System sold for use in Massachusetts during the previous year; the address of each installed System, the owner's name and address, the type of use (e.g. residential, commercial, school, institutional) and the design flow; and for all Systems installed since the first issuance of an Approval for the System, all known failures, malfunctions, and corrective actions taken and the address of each such event.

2. The Company shall notify the Director of the Watershed Permitting Program at least 30 days in advance of the proposed transfer of ownership of the technology for which this Approval is issued. Said notification shall include the name and address of the proposed new owner and a written agreement between the existing and proposed new owner containing a specific date for transfer of ownership, responsibility, coverage and liability between them. All provisions of this Approval applicable to the Company shall be applicable to successors and assigns of the Company, unless the Department determines otherwise.

3. The Company shall furnish the Department any information that the Department requests regarding the System, within 21 days of the date of receipt of that request.

4. Prior to its sale of the System, the Company shall provide the purchaser with a copy of this Approval. In any contract for distribution or sale of the System, the Company shall require the distributor or seller to provide the purchaser of the System, prior to any sale of the System, with a copy of this Approval.

5. If the Company wishes to continue this Approval after its expiration date, the Company shall apply for and obtain a renewal of this Approval. The Company shall submit a renewal application at least 180 days before the expiration date of this Approval, unless written permission for a later date has been granted in writing by the Department.

VII. Reporting

1. All notices and documents required to be submitted to the Department by this Approval shall be submitted to:

Director
Watershed Permitting Program
Department of Environmental Protection
One Winter Street - 6th floor
Boston, Massachusetts 02108

VIII. Rights of the Department

1. The Department may suspend, modify or revoke this Remedial Use Approval for cause, including, but not limited to, non-compliance with the terms of this Approval, non-payment of the annual compliance assurance fee, for obtaining the Approval by misrepresentation or failure to disclose fully all relevant facts or any change in or discovery of conditions that would constitute grounds for discontinuance of the Approval, or as necessary for the protection of public health, safety, welfare or the environment, and as authorized by applicable law. The Department reserves its rights to take any

enforcement action authorized by law with respect to this Approval and/or the System against the owner, or operator of the System and/or the Company.

IX. Expiration Date

1. Notwithstanding the expiration date of this Approval, any System sold and installed prior to the expiration date of this Approval, and approved, installed and maintained in compliance with this Approval (as it may be modified) and 310 CMR 15.000, may remain in use unless the Department, the local approving authority, or a court requires the System to be modified or removed, or requires discharges to the System to cease.

Amphidrome remedial 204759

COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
ONE WINTER STREET, BOSTON, MA 02108 617-292-5500

JANE SWIFT
Governor

BOB DURAND
Secretary

LAUREN A. LISS
Commissioner

PROVISIONAL USE APPROVAL
Pursuant to Title 5, 310 CMR 15.000

Name and Address of Applicant:

F.R. Mahony & Associates
273 Weymouth Street
Rockland, MA 02370

Trade name of technology: Amphidrome Process (hereinafter the "System")

Transmittal Number:	W013046
Date of Issuance:	June 7, 2002
Expiration date:	June 7, 2007

Authority for Issuance

Pursuant to Title 5 of the State Environmental Code, 310 CMR 15.000, the Department of Environmental Protection hereby issues this Approval to: F.R. Mahony & Associates, 273 Weymouth Street, Rockland, MA 02370 (hereinafter "the Company"), for Provisional Use in the Commonwealth of Massachusetts the System described herein. Sale and use of the System are conditioned on and subject to compliance by the Company and the System owner with the terms and conditions set forth below. Any noncompliance with the terms or conditions of this Approval constitutes a violation of 310 CMR 15.000.

Glenn Haas, Director
Division of Watershed Management
Department of Environmental Protection

6/4/02
Date

JUN 07 2002

I. Purpose

1. The purpose of this Approval is to allow use of the System in Massachusetts, on a Provisional Use basis, so as to evaluate further the capabilities and performance of the System. The specific goals of the further evaluation are to determine:

   i. if the System is capable of consistently reducing the total nitrogen ($TN = TKN+NO_2+NO_3$) concentration in the effluent discharged to the soil absorption system (SAS) so that the Department may allow an increase in the loading rate per acre in areas subject to nitrogen loading limitations, and

   ii. if the System is capable of meeting or exceeding effluent limitations equivalent to those of a Recirculating Sand Filter.

2. With the necessary permits and approvals required by 310 CMR 15.000, this Provisional Use Approval authorizes the use and installation of the System in Massachusetts, and requires testing so that the Department can determine whether the System consistently can or cannot function to effectively reduce total nitrogen in the effluent.

3. The System may only be installed on facilities that meet the criteria of 310 CMR 15.286(4).

II. Design Standards

1. The Amphidrome Process is a biological wastewater treatment system that utilizes a Submerged Attached-Growth Sequencing Bioreactor (SAGSB). The System consists of an anoxic/equalization tank, which must comply with the design criteria set forth below, a single reactor which alternates between aerobic and anaerobic conditions, and a clear well. Wastewater passes from the anoxic/equalization tank, through a granular biological filter and into the clear well. A pump is then used to reverse the flow back to the anoxic/equalization tank. This cycle is repeated multiple times and the effluent is discharged to the soil absorption system. A schematic of the System is attached to and is part of this Approval.

   i. The anoxic/equalization tank shall be designed to have a total working volume equal to one day's design flow plus the volume of one backwash.

   ii. The residual volume (i.e. volume below the effluent invert) shall equal one day's design flow.

   iii. The height of the effluent pipe from the bottom of tank shall be at least 4 ft.

   iv. The effluent tee shall not be more than 1 ft. below the effluent invert.

v. The volume between the influent invert and the effluent invert (i.e. fluctuating volume) must be equal to the volume required for one backwash.

vi. The influent invert shall be placed as close to the top of the tank as possible.

vii. The influent and effluent tees shall be located under the access lids or manholes, and positioned at opposite ends of the tank.

viii. The riser of the tee shall come up into the riser of the tank to ensure that it is above the high water level.

ix. A minimum of a 1500 gallon anoxic/equalization tank is required.

x. The requirements in 310 CMR 15.223(1) and 310 CMR 15.224 do not apply to the System.

2. The System shall be installed in series between the building sewer and the soil absorption system of a standard Title 5 system constructed in accordance with 310 CMR 15.100 – 15.279, subject to the provisions of this Approval.

3. New Construction less than 2,000 gpd: When the System is used in areas subject to the nitrogen loading limitations of 310 CMR 15.214, an increase in calculated allowable nitrogen loading per acre is allowed for facilities *with a design flow of less than 2,000 gallons per day (gpd)* as provided in 310 CMR 15.217(2). When used in such areas:

   i. for residential facilities, the design flow shall not exceed 660 gallons per day per acre (gpda), and the System shall not exceed 19 milligrams per liter (mg/L) total nitrogen (TN) concentration in the effluent measured as the total TKN (total Kjeldhal Nitrogen), NO_3-N (Nitrate nitrogen) and NO_2-N (Nitrite nitrogen).

   ii. for non-residential facilities, the design flow shall not exceed 550 gpda, and the System shall not exceed 25 mg/L TN concentration in the effluent.

4. New Construction 2,000 gpd to less than 10,000 gpd: For all facilities with design flows of 2,000 gpd to less than 10,000 gpd, the design flow shall not exceed 440 gpda and the System shall not exceed 25 mg/L TN concentration in the effluent.

III. General Conditions

1. All provisions of 310 CMR 15.000 are applicable to the use and operation of this System, the System Owner and the Company, except those that specifically have been varied by the terms of this Approval.

2. Any required operation and maintenance, monitoring and testing shall be performed in accordance with a Department approved plan. Any required sample analysis shall be conducted by an independent U.S. EPA or DEP approved testing laboratory, or a DEP approved independent university laboratory, unless otherwise is provided in the Department's written Approval. It shall be a violation of this Approval to falsify any data collected pursuant to an approved testing plan, to omit any required data or to fail to submit any report required by such plan.

3. The facility served by the System and the System itself shall be open to inspection and sampling by the Department and the local approving authority at all reasonable times.

4. In accordance with applicable law, the Department and the local approving authority may require the owner of the System to cease operation of the system and/or to take any other action as it deems necessary to protect public health, safety, welfare and the environment.

5. The Department has not determined that the performance of the System will provide a level of protection to public health and safety and the environment that is at least equivalent to that of a sewer system. Accordingly, no System shall be upgraded or expanded, if it is feasible to connect the facility to a sanitary sewer, unless as allowed by 310 CMR 15.004.

6. Design, installation and operation shall be in strict conformance with the Company's DEP approved plans and specifications, 310 CMR 15.000 and this Approval.

IV. Conditions Applicable to the System Owner

1. The System is approved in connection with the discharge of sanitary wastewater only. Any non-sanitary wastewater generated or used at the facility served by the System shall not be introduced into the System and shall be lawfully disposed of.

2. Prior to installation of the System, the proposed owner shall submit to the Department the written approval of the local approving authority, together with a copy of the complete application submitted to the local approving authority. The application shall be deemed approved by the Department if, within 60 days of receipt of a complete application, the Department fails to either:

   i. request additional information in writing from the proposed owner;

   ii. grant a written approval, which may include any conditions the Department deems appropriate, including but not limited to financial assurances, to protect public health, safety, welfare or the environment; or

   iii. deny the application in writing.

   iv. In the event the Department requests additional information from the proposed owner, the 60 day period for Department review shall commence upon the Department's receipt of such additional information.

3. All samples shall be taken at a flowing discharge point, i.e.- distribution box, pipe entering a pump chamber or other Department approved location from the treatment unit. Any required influent sample shall be taken at a point that will provide a representative sample of the influent. Influent sample locations shall be determined by the system designer, subject to the Department's written approval.

4. Effluent discharge concentrations shall meet or exceed secondary treatment standards of 30 mg/L carbonaceous biochemical oxygen demand ($CBOD_5$) and 30 mg/L total suspended solids (TSS).

5. For residential facilities with design flows less than 2,000 gpd, TN concentration in the System effluent shall not exceed 19 mg/L. For all non-residential facilities and residential facilities with design flows 2,000 gpd or greater, TN concentration in the System effluent shall not exceed 25 mg/L.

6. Operation and Maintenance agreement:

   i. Throughout its life, the System shall be under an operation and maintenance (O&M) agreement. The first O&M contract shall be for at least two (2) years, with the Company or its approved maintenance firm. Each subsequent O&M agreement shall be for at least one year.

   ii. No System shall be used until an O&M agreement is submitted to the Department and the local approving authority which:

      a. provides for the contracting with the Company or its approved management company, trained by the Company as provided in Section V (6), to operate the System consistent with the System's specifications and the operation and maintenance requirements specified by the designer and any specified by the Department;

      b. contains procedures for notification to the Department and the local board of health within five days of a System failure or alarm event and for corrective measures to be taken immediately;

      c. contains a plan to determine the cause of effluent limit violations for total nitrogen, after the first three months, if violations occur on two consecutive sampling events;

      d. provides the name of an operator, which must be a Massachusetts certified operator if one is required by 257 CMR 2.00, that will operate and monitor the System. The operator must operate and maintain the System at least every three months and anytime there is an alarm event for residential facilities with a design flow less than 2,000 gpd and at least monthly for facilities with a design flow 2,000 gpd or greater and all non-residential facilities.

7. The owner of the System shall at all times have the System properly operated and maintained in accordance with this Approval, the designer's operation and maintenance requirements and the Company's approved procedures and sampling protocols.

8. Anytime the operator is changed, within seven days of such change, the owner shall notify the Department and the local approving authority in writing and submit a copy of the new agreement to operate and monitor the System.

9. The owner shall furnish the Department any information, which the Department may request regarding the System, within 21 days of the date of receipt of that request.

10. Prior to transferring any or all interest in the property served by the System, or any portion of the property, including any possessory interest, the owner of the System shall provide written notice of all conditions contained in this Approval to

15. Within fourteen days of the local approving authority's issuance of the Certificate of Compliance for the System, the owner shall submit a copy of the Certificate of Compliance to the Department.

IV. Conditions Applicable to the Company

1. By January 31st of each year, the Company shall submit a report to the Department signed by a corporate officer, general partner or Company owner that contains information on the System for the previous calendar year. The report shall state: the number of units of the System sold for use in Massachusetts during the previous year; the address of each installed System, the owner's name and address, the type of use (e.g. residential, commercial, school, institutional) and the design flow; and for all Systems installed since the first issuance of an Approval for the System, all known failures, malfunctions, and corrective actions taken and the address of each such event.

2. The Company shall notify the Director of the Watershed Permitting Program at least 30 days in advance of the proposed transfer of ownership of the technology for which this Approval is issued. Said notification shall include the name and address of the proposed new owner and a written agreement between the existing and proposed new owner containing a specific date for transfer of ownership, responsibility, coverage and liability between them. All provisions of this Approval applicable to the Company shall be applicable to successors and assigns of the Company, unless the Department determines otherwise.

3. The Company shall develop and submit to the Department within 60 days of the effective date of this Approval: minimum installation requirements; an operating manual, including information on substances that should not be discharged to the System; a maintenance checklist; and a recommended schedule for maintenance of the System essential to consistent successful performance of the installed Systems.

4. The Company shall develop and submit to the Department within 60 days of the effective date of this Approval a standard protocol essential for consistent and accurate measurement of performance of installed Systems, including procedures for sample collection and analysis of the System. The protocol shall be in accordance with the latest edition of Standard Methods for the Examination of Water and Wastewater.

5. The Company shall make available, in printed and electronic format, the referenced procedures and protocol in paragraphs 3 and 4 directly above to owners, operators, designers and installers of the System.

6. The Company shall institute and maintain a program of operator training and continuing education, as approved by the Department. The Company shall update the list of qualified operators and make the list known to users of the technology.

the transferee(s). Any and all instruments of transfer and any leases or rental agreements shall include as an exhibit attached thereto and made a part thereof a copy of this Approval for the System. The System owner shall send a copy of such written notification(s) to the Department within 10 days of such notice being given.

11. For year round residential facilities with design flows less than 2,000 gpd, effluent from the System shall be monitored at least once per calendar quarter. Any sample collected within 60 days or more than 90 days of a previous sample shall not be considered a required quarterly sample. For all non-residential facilities and residential facilities with design flows of 2,000 gpd or greater, both influent and effluent shall be monitored monthly. Subject to the Department's written approval, the system designer shall determine influent sampling locations. The following parameters shall be monitored: pH, $CBOD_5$, TSS, alkalinity and TN. Each time the System is monitored, the water meter, if a water meter is installed, shall be read and the water use recorded. All monitoring data shall be submitted to the Department and local approval authority within 45 days of the sampling date. After two years of monitoring for residential facilities with design flows less than 2,000 gpd and three years for all non-residential facilities and residential facilities with design flows of 2,000 gpd or greater, at the written request of the owner, the Department may reduce the monitoring requirements.

12. For seasonal residential facilities where the residence is occupied fewer than six months per year, effluent from the System shall be monitored twice per season; initially 45 days after occupancy, and if the residence is occupied during an additional calendar quarter, once during that following quarter prior to System shut down. The following parameters shall be monitored: pH, $CBOD_5$, TSS, alkalinity and TN. Each time the System is monitored, the water meter, if a water meter is installed, shall be read and the water use recorded. All monitoring data shall be submitted to the Department and local approval authority within 45 days of the sampling date. After four seasons of monitoring and at the written request of the owner, the Department may reduce the monitoring requirements.

13. The inspection results must be recorded on a DEP approved inspection form and a technology checklist, copies of which are attached to this Approval. The forms must be completed by the System operator and submitted to the Department and local approval authority, along with any required sampling data, within 45 days of the inspection date.

14. Prior to the issuance of a Certificate of Compliance for the System, the System owner shall record and/or register in the appropriate Registry of Deeds and/or Land Registration Office, a Notice disclosing both the existence of the alternative septic system subject to this Approval on the property and the Department's approval of the System. If the property subject to the Notice is unregistered land, the Notice shall be marginally referenced on the owner's deed to the property. Within 30 days of recording and/or registering the Notice, the System owner shall submit the following to the Department and the local approving authority: (i) a certified Registry copy of the Notice bearing the book and page/instrument number and/or document number; and (ii) if the property is unregistered land, a Registry copy of the owner's deed to the property, bearing the marginal reference.

7. The Company or its designee shall conduct an intended use review of the System prior to the sale of any nonresidential unit to ensure that the proposed use of the System is consistent with the unit's capabilities.

8. The Company shall conduct a performance evaluation in accordance with 310 CMR 15.286(6) once every three years. A report shall be submitted to the Department no more than 180 days beyond the three-year anniversary of this Approval.

9. The Company shall furnish the Department any information that the Department requests regarding the System, within 21 days of the date of receipt of that request.

10. The Company shall include copies of this Approval and the procedures and protocol described in Section V (3) and (4) with each System that is sold. In any contract executed by the Company for distribution or re-sale of the System, the Company shall require the distributor or re-seller to provide each purchaser of the System with copies of this Approval and the procedures and protocol described in Sections V (3) and (4).

11. If the Company wishes to continue this Approval beyond its expiration date, the Company shall apply for and obtain a renewal of this Approval. The Company shall submit a renewal application at least 180 days before the expiration date of this Approval, unless written permission for a later date has been granted in writing by the Department. This Approval shall continue in force until the Department has acted on the renewal application.

12. The Department may require the technology proponent to perform evaluations of system performance, conduct tests, and take corrective action when, based upon a preponderance of the available data and information, it is necessary to take such actions to ensure technology performance conforms with this Approval.

VI. Reporting

1. All notices and documents required to be submitted to the Department by this Approval shall be submitted to:

   Director
   Watershed Permitting Program
   Department of Environmental Protection
   One Winter Street - 6th floor
   Boston, Massachusetts 02108

VII. Rights of the Department

1. The Department may suspend, modify or revoke this Provisional Use Approval for cause, including, but not limited to, non-compliance with the terms of this

Approval, non-payment of the annual compliance assurance fee, for obtaining the Approval by misrepresentation or failure to disclose fully all relevant facts or any change in or discovery of conditions that would constitute grounds for discontinuance of the Approval, or as necessary for the protection of public health, safety, welfare or the environment, and as authorized by applicable law. The Department reserves its rights to take any enforcement action authorized by law with respect to this Approval and/or the System against the owner, or operator of the System and/or the Company.

VIII. Expiration date

1. Notwithstanding the expiration date of this Approval, any System sold and installed prior to the expiration date of this Approval or any continuation of this Approval, that is approved, installed and maintained in compliance with this Approval (as it may be modified) and 310 CMR 15.000, may remain in use unless the Department, the local approving authority, or a court requires the System to be modified or removed, or requires discharges to the System to cease.

COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
ONE WINTER STREET, BOSTON, MA 02108 617-292-5500

MITT ROMNEY
Governor

KERRY HEALEY
Lieutenant Governor

ELLEN ROY HERZFELDER
Secretary

EDWARD P. KUNCE
Acting Commissioner

April 8, 2003

F.R.Mahony & Associates
273 Weymouth Street
Rockland, MA 02370

Re: Application for BRP WP 61b
Certification for General Use
Alternative Treatment Technology Approval-Amphidrome Process
Transmittal No. W031728

Dear Mr. Dobie:

The Department has completed its review of your application for Certification for General Use for the above referenced technologies and has drafted the enclosed Proposed Certification for General Use. The Department is providing a comment period in order to allow you an opportunity to comment on the Department's Proposed Approval. The comment period for the proposed Certification for General Use will begin on the date of this letter and will end in thirty days. Please submit any comments you may have to the address below within thirty days:

Director
Watershed Permitting Program
Department of Environmental Protection
One Winter Street
Boston, MA 02108

Following our review of any comments, we will issue a final decision.

Should you have any questions regarding this matter, please do not hesitate to call Jim Murphy, P.E. at (617) 292-5677. Thank you for your interest in seeking approval for the use of your innovative technology in Massachusetts.

Sincerely,

Alan D. Slater, P.E., Acting Director
Watershed Permitting Program

Enclosure: Proposed Certification for General Use

APR 1 1 2003

COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
ONE WINTER STREET, BOSTON, MA 02108 617-292-5500

MITT ROMNEY
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Lieutenant Governor

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Secretary

EDWARD P. KUNCE
Acting Commissioner

DRAFT CERTIFICATION FOR GENERAL USE

Pursuant to Title 5, 310 CMR 15.000

Name and Address of Applicant:

F.R. Mahony & Associates
273 Weymouth Street
Rockland, MA 02370

Trade name of technology: Amphidrome Process (hereinafter the "System"). A Schematic Drawing illustrating the System is attached and is part of this Certification.

Transmittal Number: W 031728
Date of Issuance:
Expiration date:

Authority for Issuance

Pursuant to Title 5 of the State Environmental Code, 310 CMR 15.000, the Department of Environmental Protection hereby issues this Certification for General Use to: F.R. Mahony & Associates, 273 Weymouth Street, Rockland, MA 02370 (hereinafter "the Company"), certifying the System described herein for General Use in the Commonwealth of Massachusetts. Sale and use of the System are conditioned on and subject to compliance by the Company and the System owner with the terms and conditions set forth below. Any noncompliance with the terms or conditions of this Certification constitutes a violation of 310 CMR 15.000.

__________________________________ ________________

Glenn Haas, Director
Division of Watershed Management
Department of Environmental Protection

Date

I. Purpose

1. The purpose of this Certification is to allow the use of the System in Massachusetts on a General use basis.

2. With the necessary permits and approvals required by 310 CMR 15.000, this Certification authorizes the installation and use of the System in Massachusetts.

3. The System may be installed on all facilities where a system in compliance with 310 CMR 15.000 exists on site or could be built and for which a site evaluations in compliance with 310 CMR 15.000 has been approved by the local approving authority or by DEP if DEP approval is required by 310 CMR 15.000.

4. The System is approved for use at facilities with a maximum design flow less than 10,000 gallons per day (GPD).

II. Design Standards

1. The Amphidrome Process is a biological wastewater treatment system that utilizes a Submerged Attached-Growth Sequencing Bioreactor (SAGSB). The System consists of an anoxic/equalization tank, which must comply with the design criteria set forth below, a single reactor which alternates between aerobic and anaerobic conditions, and a clear well. Wastewater passes from the anoxic/equalization tank, through a granular biological filter and into the clear well. A pump is then used to reverse the flow back to the anoxic/equalization tank. This cycle is repeated multiple times and the effluent is discharged to the soil absorption system. A schematic of the System is attached to and is part of this Approval.

   i. The anoxic/equalization tank shall be designed to have a total working volume equal to one day's design flow plus the volume of one backwash.
   ii. The residual volume (i.e. volume below the effluent invert) shall equal one day's design flow.
   iii. The height of the effluent pipe from the bottom of tank shall be at least 4 ft.
   iv. The effluent tee shall not be more than 1 ft. below the effluent invert.
   v. The volume between the influent invert and the effluent invert (i.e. fluctuating volume) must be equal to the volume required for one backwash.
   vi. The influent invert shall be placed as close to the top of the tank as possible.
   vii. The influent and effluent tees shall be located under the access lids or manholes, and positioned at opposite ends of the tank.

viii. The riser of the tee shall come up into the riser of the tank to ensure that it is above the high water level.

ix. A minimum of a 1500 gallon anoxic/equalization tank is required.

x. The requirements in 310 CMR 15.223(1) and 310 CMR 15.224 do not apply to the System.

2. The System shall be installed in series between the building sewer and the soil absorption system of a standard Title 5 system constructed in accordance with 310 CMR 15.100 – 15.279, subject to the provisions of this Approval.

III. General Conditions

1. The provisions of 310 CMR 15.000 are applicable to the use and operation of this System, except those that specifically have been varied by the terms of this Certification.

2. Any required operation and maintenance, monitoring and testing shall be performed in accordance with a Department approved plan. Any required sample analysis shall be conducted by an independent U.S. EPA or DEP approved testing laboratory. It shall be a violation of this Certification to falsify any data collected pursuant to an approved testing plan, to omit any required data or to fail to submit any report required by such plan.

3. The facility served by the System, and the System itself, shall be open to inspection and sampling by the Department and the local approving authority at all reasonable times.

4. In accordance with applicable law, the Department or the local approving authority may require the owner of the System to cease operation of the System and/or to take any other action as it deems necessary to protect public health, safety, welfare or the environment.

5. The Department has not determined that the performance of the System will provide a level of protection to public health and safety and the environment that is at least equivalent to that of a sewer. Accordingly, no System shall be upgraded or expanded, if it is feasible to connect the facility to a sanitary sewer, unless as allowed pursuant to 310 CMR 15.004.

6. Design, installation and operation of the System shall be in strict conformance with the Company's DEP approved plans and specifications and 310 CMR 15.000, subject to this Certification.

IV. Conditions Applicable to the System Owner

1. The System is certified in connection with the discharge of sanitary wastewater only. Any non-sanitary wastewater generated or used at the facility served by the System shall not be introduced into the System and shall be lawfully disposed of.

2. Operation and Maintenance agreement:

   i. Throughout its life, the System shall be under an operation and maintenance (O&M) agreement. No O&M agreement shall be for less than one year.

   ii. No System shall be used until an O&M agreement is submitted to the local approving authority which:

      - provides for the contracting of a person or firm trained by the Company as provided in Section V(5) and competent in providing services consistent with the System's specifications, with the operation and maintenance requirements specified by the Company and the designer and with any specified by the Department;

      - Contains procedures for notification to the Department and to the local board of health within five days of a System failure, malfunction or alarm event and for corrective measures to be taken immediately;

      - Provides the name of an operator, which must be a Massachusetts certified operator as required by 257 CMR 2.00 of an appropriate grade that will operate and monitor the System. The operator must operate and maintain the System at least every three months and anytime there is an alarm event.

3. The owner of the System shall at all times have the System properly operated and maintained in accordance with this Certification, the designer's operation and maintenance requirements and the Company's approved procedures. The owner shall notify the Department and the local approving authority, in writing, within seven days of a change in the operator.

4. The owner of the System shall provide a copy of this Certification, prior to signing of a purchase and sales agreement for the facility served by the System or any portion thereof, to the proposed new owner.

5. The owner shall furnish the Department any information that the Department requests regarding the System, within 21 days of the date of receipt of that request.

6. By September 30th of each year, the System owner shall submit to the Department and the local approving authority an O&M and technology checklist, completed by the System operator for each inspection performed during the previous 12 months. Copies of the checklists are attached to this Certification.

V. Conditions Applicable to the Company

1. By January 31st of each year, the Company shall submit to the Department a report signed by a corporate officer, general partner, or Company owner that contains information on the System for the previous calendar year. The report shall state: the number of units of the System sold for use in Massachusetts during the previous year; the address of each installed System, the owner's name and address, the type of use (e.g. residential, commercial, school, institutional) and the design flow; and for all systems installed since the first issuance of Certification for General Use, all known failures, malfunctions, and corrective actions taken and the address of each such event.

2. The Company shall notify the Director of the Watershed Permitting Program at least thirty days in advance of the proposed transfer of ownership of the technology for which this Certification is issued. Said notification shall include the name and address of the proposed owner containing a specific date of transfer of ownership, responsibility, coverage and liability between them. All provisions of this Certification applicable to the Company shall be applicable to successors and assigns of the Company, unless the Department determines otherwise.

3. The Company shall develop and submit to the Department within 60 days of the effective date of this Certification: minimum installation requirements; an operating manual, including information on substances that should not be discharged to the System; a maintenance checklist; and a recommended schedule for maintenance of the System essential to consistent successful performance of the installed Systems.

4. The Company shall make available, in printed and electronic format, the referenced procedures and protocol in paragraphs 3 directly above to owners, operators, designers and installers of the System.

5. The Company shall institute and maintain a program of operator training and continuing education, as approved by the Department. The Company shall update the list of qualified operators and make the list known to users of the technology.

6. The Company shall furnish the Department any information that the Department requests regarding the System within 21 days of the date of receipt of that request.

7. The Company shall include copies of this Certification and the procedures and described in Section V (3) with each System that is sold. In any contract executed by the Company for distribution or re-sale of the System, the Company shall

require the distributor or re-seller to provide each purchaser of the System with copies of this Certification and the procedures described in Sections V (3).

8. If the Company wishes to continue this Certification beyond its expiration date, the Company shall apply for and obtain a renewal of this Certification. The Company shall submit a renewal application at least 180 days before the expiration date of this Certification, unless written permission for a later date has been granted in writing by the Department. This Certification shall continue in force until the Department has acted on the renewal application.

VI. Reporting

1. All notices and documents required to be submitted to the Department by this Certification shall be submitted to:

   Director
   Watershed Permitting Program
   Department of Environmental Protection
   One Winter Street - 6th floor
   Boston, Massachusetts 02108

VII. Rights of the Department

1. The Department may suspend, modify or revoke this Certification for cause, including, but not limited to, noncompliance with the terms of this Certification, non-payment of any annual compliance assurance fee, for obtaining the Certification by misrepresentation or failure to disclose fully all relevant facts or any change in or discovery of conditions that would constitute grounds for discontinuance of the Certification, or as necessary for the protection of public health, safety, welfare, or the environment, and as authorized by applicable law. The Department reserves its rights to take any enforcement action authorized by law with respect to this Certification and/or the System against the owner, or operator of the System, and/or the Company.

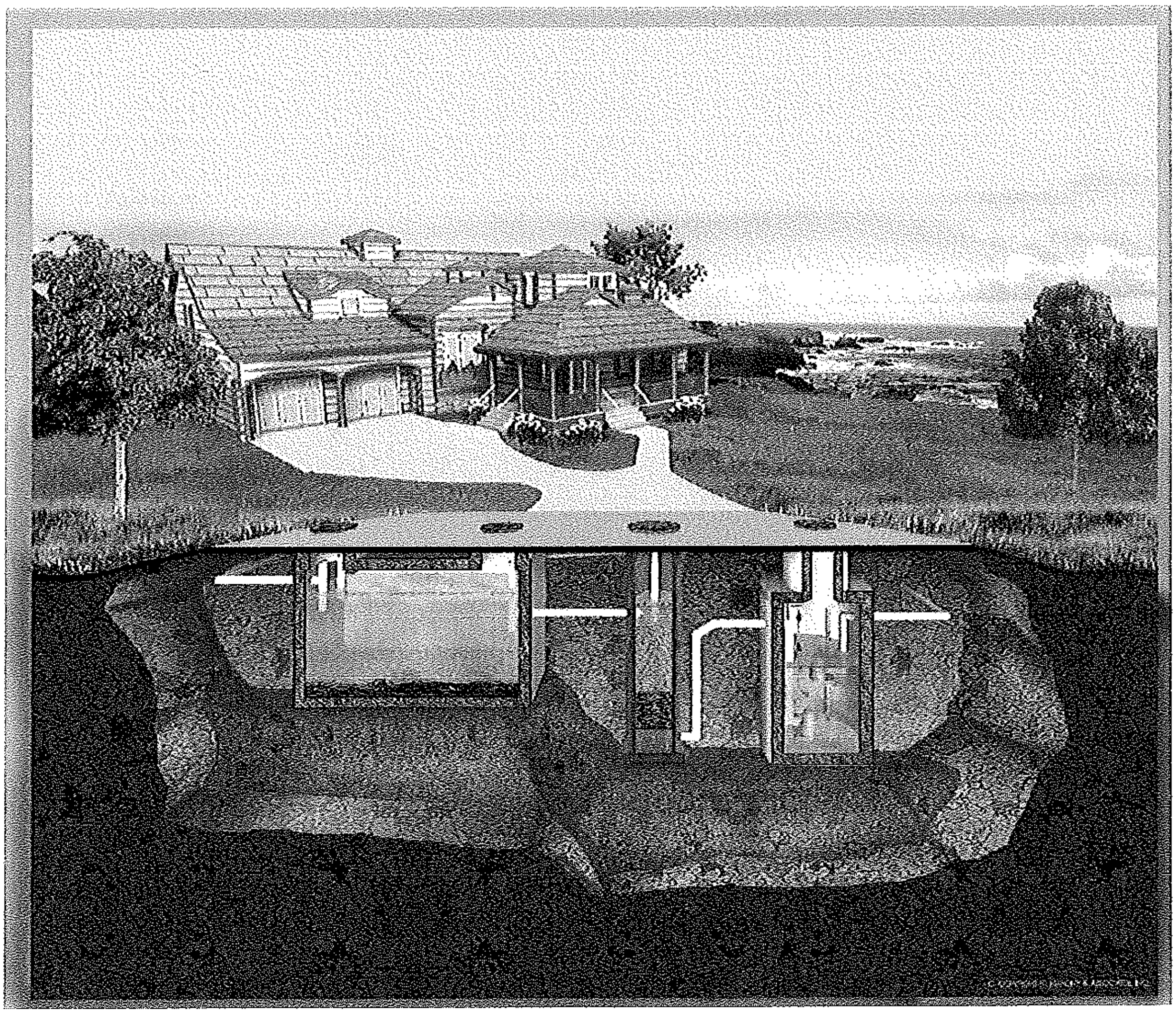
VIII. Expiration date

1. Notwithstanding the expiration date of this Certification, any System sold and installed prior to the expiration date of this Certification, and approved, installed and maintained in compliance with this Certification (as it may be modified) and 310 CMR 15.000, may remain in use unless the Department, the local approval authority, or a court requires the System to be modified or removed, or requires discharges to the System to cease.

Amphidrome®

User Instructions

The highest level of Nitrogen removal available...



...and at a reasonable cost.

f.r. mahony & associates, inc.
frma

USER INSTRUCTIONS

Congratulations on your Amphidrome® investment. With proper care and following some basic precautions, your system should provide years of reliable service.

Basic Principals of Operation

This system is an advanced biological treatment process designed to reduce sanitary waste from your home to a desired permit level for discharge to the ground. This advanced treatment process is used to further treat wastewater beyond the normal levels typically achieved in a conventional septic system. The process requires a waste stream from your home free from hazardous materials or toxic cleaners. The process is designed to work with added air supplied by the process blower(s). At times the process will also operate without the addition of air.

An environment conducive to the biological consumption or reduction of the household waste is maintained in the system. The effectiveness of this process is directly related to the continued support of this environment. Should the system fall into disrepair, the result will be a loss of performance and possible violation of discharge permits.

Caring For Your System

Care should be made with this or any other waste treatment system to not dispose of strong chemicals, gasoline, lubricating oils/grease, glass, metal, seafood shells, goldfish stone, kitty litter, plastic objects, explosives, flammable materials, paint, or pharmaceuticals. Please keep in mind this is a biological process that requires the proper environment to perform correctly. Furthermore, you should not dispose of highly concentrated ammonia-based household cleaning products. These materials are high in nitrogen and could jeopardize the systems ability to meet the nitrogen discharge limits.

Proper maintenance of the anoxic tank requires routine pumping of the solids that accumulate in the bottom of the tank. This process is very similar to maintenance of a conventional septic system. Your operator may recommend a pumping frequency specific to your system. In general, the tank should be pumped annually. This tank must not be used to dispose of solid waste products such as disposable or cloth diapers, socks or cloth, sanitary napkins or tampon applicators, condoms, food wrappers, or other such items that are considered solid waste, trash or non-biodegradable material. The disposal of grease and cooking oil is also not recommended as this material will coat plumbing and drain lines and could also effect to operation of the system.

System Components

Many of the system components are located below ground, with only the control center and process and backwash blowers located above ground. All of the system tanks should have access through manhole covers to perform inspection and maintenance services.

The Anoxic Tank is the first tank in the process. This tank receives all of the wastewater flow from the home. Solids are permitted to settle in this tank and the liquid portion flows to the Amphidrome® Reactor. Routine pumping of this tank to maintain proper solids levels is required. The homeowner should schedule this service with an approved, licensed septage hauler unless otherwise scheduled by the provisions of contract agreement or a pilot program.

The Amphidrome® Reactor provides the majority of the biological treatment. In the forward direction, flow is filtered and aerated. In the return direction, flow is used to clean the filter and return waste solids to the Anoxic Tank. The reactor also works in the absence of added air to further treat the waste to remove nitrogen.

Clear Well provides storage of treatment batches from the first two tanks and prior to discharge to the leaching system. Pumps in this tank direct the flow as needed in the process.

The Control Panel is usually located indoors in a closet or utility room. This panel controls and monitors all of the process functions. The homeowner should be aware of this panel and the functions indicated on the cover. Indicator lights will show the status of the process. When calling for service or assistance, it will be helpful to describe what is happening as shown by the panel lights. Homeowner care is very limited to making certain that power is restored to the panel if the home looses electricity due to inclement weather or other event that effects the power supply to the home. A nameplate is located on the cover of the panel providing service contact information.

Process and Backwash Blowers provide added air supply to support the systems biological needs. These blowers are usually above ground in a shed, garage or under some protective cover. There is no homeowner maintenance required for these blowers.

Power Failure

The system is designed to provide storage in the system for normal power failures. Sufficient capacity is available for a conservative continued use of water in the home. When power is restored, high level alarms may sound. These alarms should clear once the system has resumed normal operation.

Alarm Lights

Alarm lights will indicate if a problem exists in the system. The alarm horn may be silenced locally. An automatic dialer will notify the operator of the alarm condition. If you do not hear from the system operator within 12 hours, please call F. R. Mahony & Associates at 800-791-6132.

Supplemental Instructions

Refer to the Installation Instructions and to the Operation and Maintenance Manual for additional information.

Scheduled Maintenance

Maintenance is scheduled based on the specific discharge permit requirements. The Pineland's Commission requires quarterly sampling and annual inspection to monitor the equipment functions and to verify the system's performance. These service calls generally do not require more than 4-hours during each service visit.

Service Contacts

Manufacturer:

F.R. Mahony & Associates, Inc.
273 Weymouth Street
Rockland, MA 02370
800-791-6132
781-982-1056 FAX

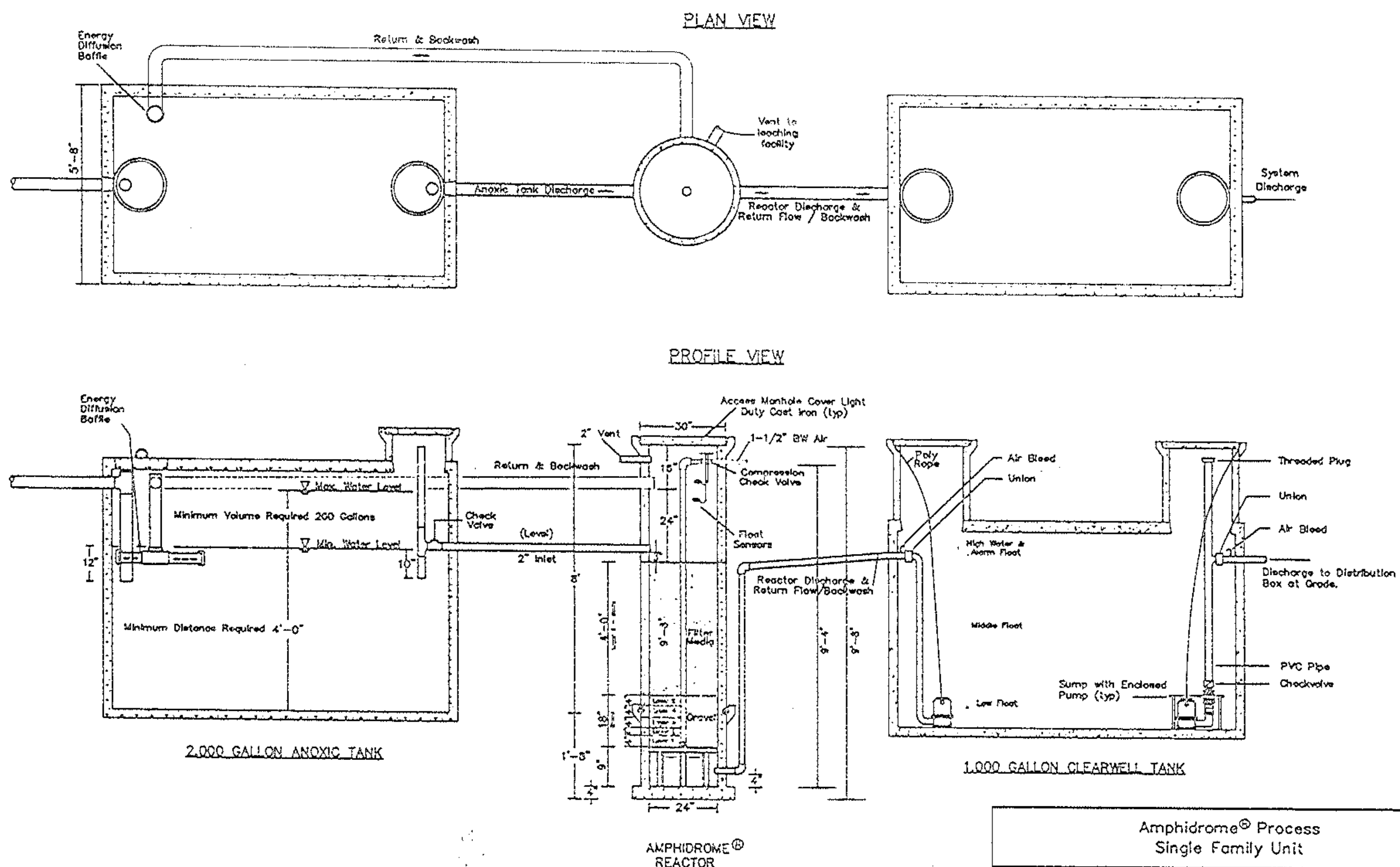
Operator:

APENDIX I

USER PRECAUTIONS

WE STRONGLY RECOMMEND AVOIDING THE INTRODUCTION OF THESE ITEMS INTO THE AMPHIDROME® SYSTEM.

- STRONG CHEMICALS
- GASOLINE
- LUBRICATING OILS/GREASE
- SEAFOOD SHELLS
- GOLDFISH STONE
- PLASTIC OBJECTS
- GLASS
- METAL
- KITTY LITTER
- EXPLOSIVES
- FLAMMABLE MATERIAL
- PAINT
- PHARMACEUTICALS
- HIGH STRENGTH AMMONIA CLEANING PRODUCTS
- DISPOSABLE OR CLOTH DIAPERS
- SOCKS OR CLOTH
- FOOD WRAPPERS
- SANITARY NAPKINS/TAMPON APPLICATORS
- CONDOMS
- COOKING OILS/GREASE
- OR ANY OTHER NON-BIODEGRADABLE MATERIAL



Amphidrome® Process Single Family Unit		
Scale: NTS Date: 2/12/03	Drawn By: App'd By: PBP	Job No. Plan No. 440

RM MAHONY
Water Supply & Pollution Control Equipment
273 Weymouth Street, Rockland, Massachusetts 02370

f.r. mahony & associates inc.
frma water supply and pollution control equipment
73 Weymouth Street • Rockland, MA 02370

EQUIPMENT WARRANTY

F. R. Mahony and Associates, Inc. (FRMA) warrants to the original purchaser and the end user all new equipment manufactured by it to be free from defects in material and workmanship, and at the election of FRMA, Inc. will repair or replace, f.o.b. its factories or other locations designated, and as determined by FRMA any part or parts returned to it, transportation/freight prepaid, which examination shall show to have failed under normal use and service by the original user within one (1) year following start-up or (18) months from shipment, whichever occurs first. Such repair or replacement shall be free of charge except for freight and those parts such as media, chemicals, oil, grease, belts and like that are consumable under normal use. FRMA's obligation under this warranty is conditioned upon it receiving prompt written notice within 30 days of claimed defects during the one year warranty period. Discovery thereof during the one year warranty period is limited to repair or replacement as aforesaid. No allowance will be made for labor, transportation, or other charges incurred in the replacement of repaired defective parts and/or equipment furnished.

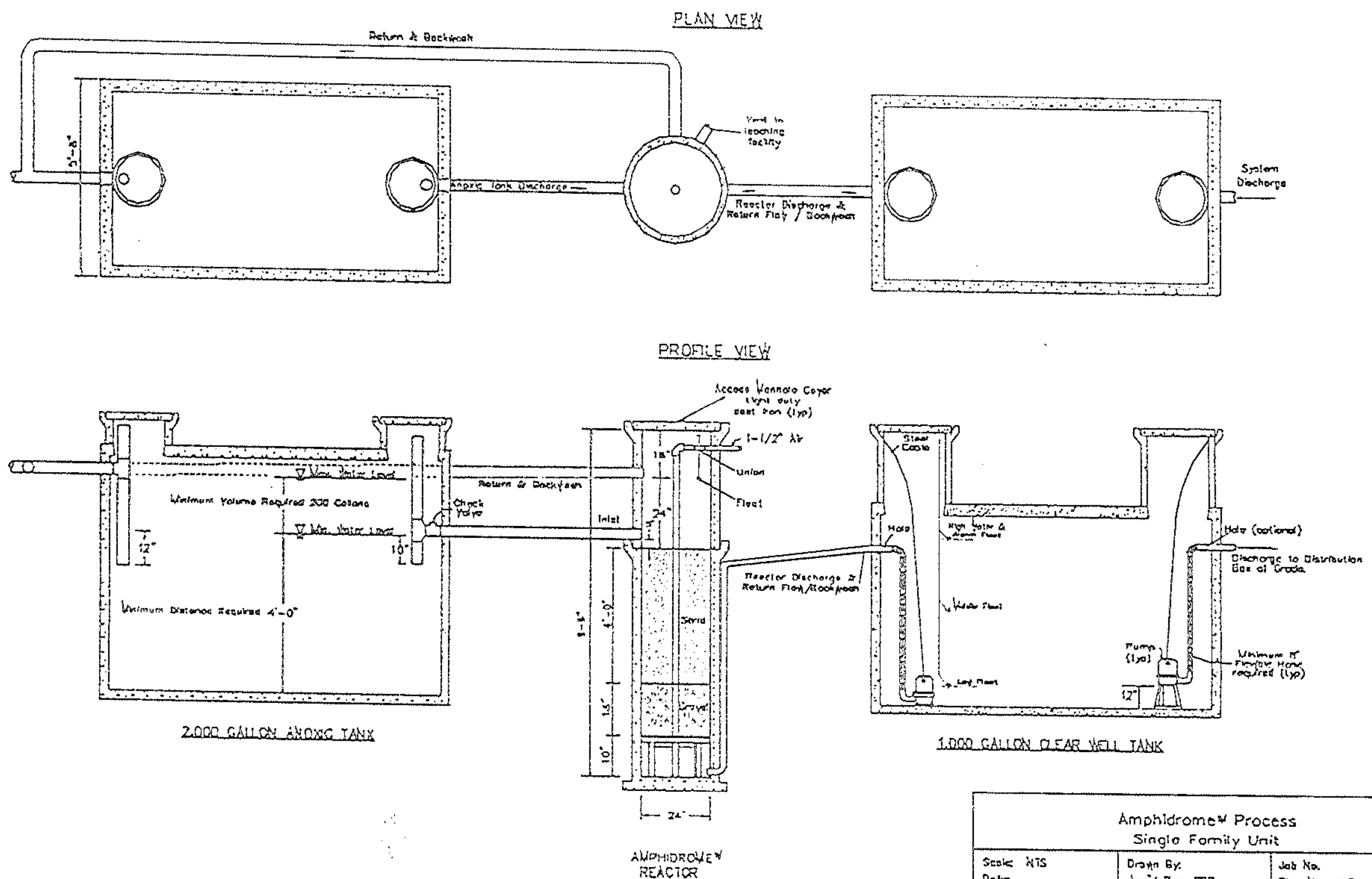
THIS WARRANTY, INCLUDING THE STATED REMEDIES, IS EXPRESSLY MADE BY FRMA AND IS ACCEPTED BY ORIGINAL PURCHASER IN LIEU OF ALL OTHER WARRANTIES, INCLUDING WARRANTIES OF MERCHANTABILITY AND FITNESS FOR PARTICULAR PURPOSE, WHETHER WRITTEN, ORAL, EXPRESS, IMPLIED OR STATUTORY. FRMA NEITHER ASSUMES NOR AUTHORIZES ANY OTHER PERSON TO ASSUME IT FOR ANY OTHER LIABILITIES WITH RESPECT TO ITS EQUIPMENT. FRMA SHALL NOT BE LIABLE FOR NORMAL WEAR AND TEAR, NOR FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGE DUE TO INOPERABILITY OF ITS EQUIPMENT FOR ANY REASON NOR ON ANY CLAIM THAT ITS EQUIPMENT WAS NEGLIGENTLY DESIGNED OR MANUFACTURED.

This warranty shall not apply to equipment or parts thereof which have been altered or repaired outside of FRMA factory or damaged by improper installation, storage, application, erosion, or corrosion of any sort, or subjected to misuse, abuse, neglect, or accident. This warranty is null and void if payment is delayed, not made, or if not in accordance with the terms and conditions of FRMA equipment proposal.

FRMA makes no warranty with respect to parts, accessories, or components manufactured by others. The warranty applicable to such items is that offered by their respective manufacturers.

Rockland, MA F. R. Mahony & Associates, Inc.

tel. 781.982.9300 • fax. 781.982.1056 • frma@compuserve.com • www.frmahony.com



Amphidrome™ Process Single Family Unit		
Scale: NTS	Drawn By:	Job No.
Date:	App'd By: FBP	Plan No. 440

F. R. MAHONY

JUN 0 7 2002

Amphidrome™ Inspection Checklist

Wastewater Facility______________ Location______________________________
Day/Date______________________ Operator/Firm__________________________

Facility Type: Amphidrome______ Plus________ Single________ Dual____________
Design Parameters: Effluent
Flow_______kgpd BOD_____ TSS_____ NH3_____ NO3_____ Total-N_____
Fecal Coliform_____
Actual Data: (latest lab result) *field results ________day avg.
Flow_______kgpd BOD_____ TSS_____ NH3_____ NO3_____ Total-N_____
Fecal Coliform________

No. of Treatment Cycles/24hrs_______ 24 hr Timer Reset______________
Cycle Beginning/End times
Train 1-1______________ 2_____________ 3_____________ 4_____________

Train 2-1______________ 2_____________ 3_____________ 4_____________

Backwash Cycles-TIC
Train 1-1______________ 2_____________ 3_____________ 4_____________
Train-2-1______________ 2_____________ 3_____________ 4_____________
Denite BW Frequency/TIC 1_____________ 2_____________

RETURN CYCLES
Train 1-No. of Return cycles___________ Time after high float______________
Train 2-No. of Return cycles___________ Time after high float______________

Equipment Run Time
TIC_______________
PB1________m/d PB2________m/d BWB1________m/d BWB2________m/d
RP1________m/d RP2________m/d BWP1________m/d BWP2________m/d
DFP1_______m/d DFP2_______m/d DBWP1______m/d DBWP2________m/d
INF Pumps 1__________m/d 2_________m/d 3_________m/d 4_________m/d
EFF Pumps 1__________m/d 2_________m/d 3_________m/d 4_________m/d
Meth.Pump Amph.#1________m/d Amph#2_________m/d Denite_________m/d
Alk Pump/loc. #1________m/d-________ #2_______m/d-_______ #3_____m/d-________

COUNTERS
No. of Discharges off of High float___________
Amp1BW____ Amp1FBW____ Amp2BW____Amp2FBW____ DBW____DFBW____
Equipment OFF-LINE/Reason
1.
2.
3.
4.
Anoxic Tank Sludge DOB/water level_________________/__________________

Amphidrome™ Inspection Checklist

Date________________________ Location__________________________________

Time In______________ Out_____________

Participants:

Review of Site Visit

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Title 5

DEP Approved Inspection and O&M Form for Title 5 I/A Treatment and Disposal Systems

A. Installation

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.

Owner

Facility Street Address

City | Zip

Mailing address of owner, if different:

Street Address/PO Box:

City | State | Zip

( ) - ext.
Telephone Number

B. Authorized Service Provider

O&M Firm

Street Address

City | State | Zip

( ) - ext.
Telephone Number

Certified Operator Name | Certification Number

C. Facility/System Information

DEP ID | Manufacturer's Name & ID | Model Name & Number

Installation Date | Start of Operation

Approval Type: ☐ General ☐ Provisional ☐ Piloting ☐ Remedial

Seasonal Residence – used less than 6 mo./year: ☐Yes ☐No

D. Operating Information

Inspection Date | Previous Inspection Date

Sludge Depth (to be checked yearly) | Pumping Recommended ☐ Yes ☐ No

Effluent Description

E. Sampling Information

Samples Taken: ☐ Influent ☐ Effluent

Parameters sampled: ☐ pH ☐ BOD ☐ TSS ☐ TN ☐ Other (list below)

Other 1 ____________ Other 2 ____________ Other 3 ____________

Description of any maintenance performed since previous inspection & during this inspection:

Notes and Comments:

F. Certification

I certify: I have inspected the sewage treatment and disposal system at the address above, have completed this report and the attached technology operation and maintenance checklist, and the information reported is true, accurate, and complete as of the time of the inspection. I am a Massachusetts certified operator in accordance with 257 CMR 2.00.

Operator Signature ____________ Date ____________

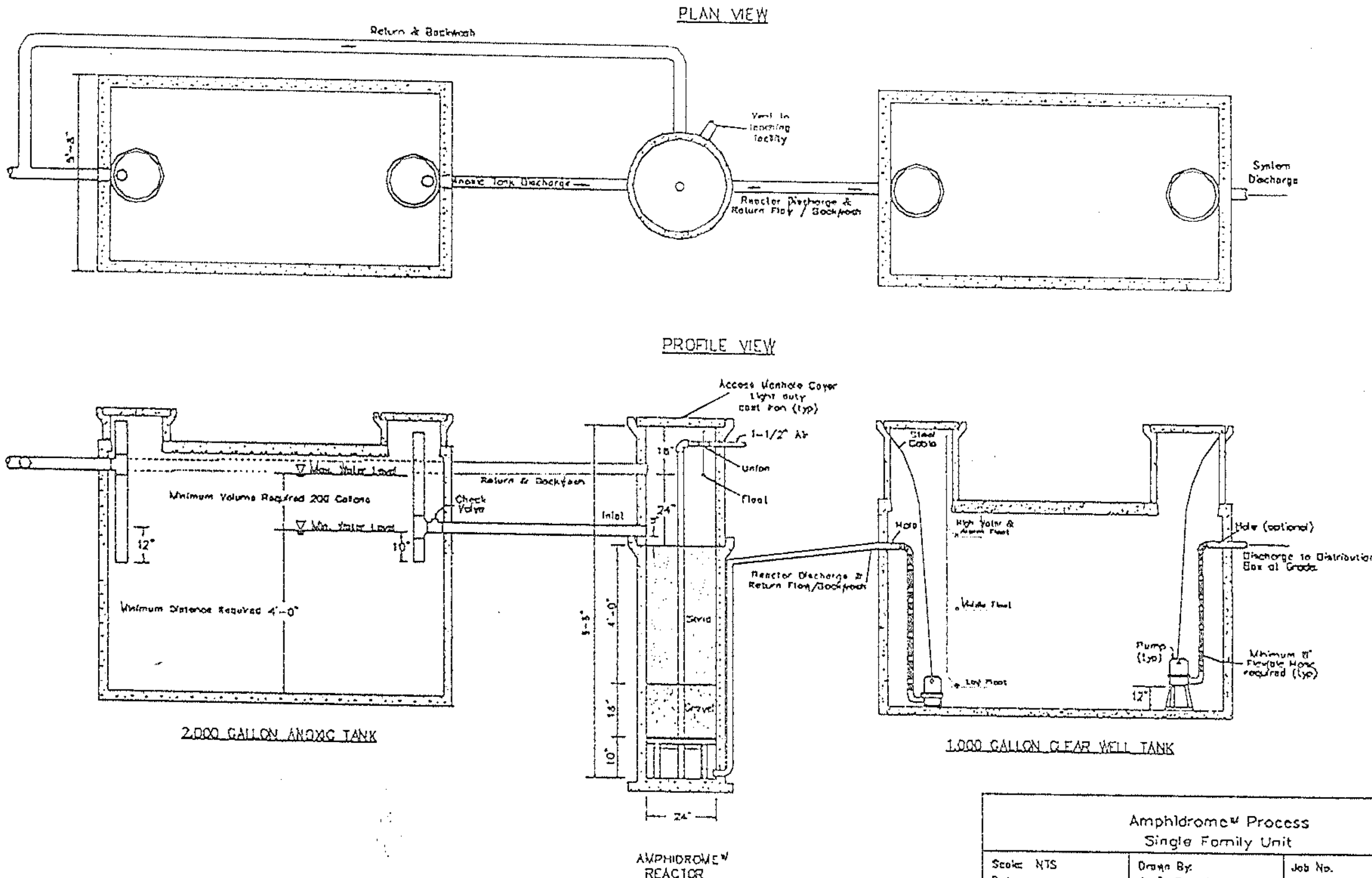
System owner must submit this report, technology O&M checklist, <u>and</u> any required sampling results to the local board of health and DEP as follows for each inspection performed:

Remedial Use– by January 31st of each year for the previous calendar year

Piloting & Provisional Use - within <u>30</u> days of inspection date

General Use – by September 30th of each year for the previous 12 months

Department of Environmental Protection
Attention: Title 5 Program
One Winter Street, 6th Floor
Boston. MA 02108



Amphidrome℠ Process
Single Family Unit

Scale: NTS Date:	Drawn By: App'd By: FDP	Job No. Plan No. 440

F.R. MAHONY & Associates, Inc.

Amphidrome™ Inspection Checklist

Wastewater Facility_____________ Location____________________________
Day/Date______________________ Operator/Firm________________________

Facility Type: Amphidrome______ Plus________ Single________ Dual____________
Design Parameters: Effluent
Flow_______kgpd BOD_____ TSS_____ NH3_____ NO3_____ Total-N_____
Fecal Coliform_____
Actual Data: (latest lab result) *field results ________day avg.
Flow_______kgpd BOD_____ TSS_____ NH3_____ NO3_____ Total-N_____
Fecal Coliform________

No. of Treatment Cycles/24hrs_______ 24 hr Timer Reset______________
Cycle Beginning/End times
Train 1-1______________ 2______________ 3_____________ 4_____________

Train 2-1______________ 2______________ 3_____________ 4_____________

Backwash Cycles-TIC
Train 1-1______________ 2______________ 3_____________ 4_____________
Train-2-1______________ 2______________ 3_____________ 4_____________
Denite BW Frequency/TIC 1_____________ 2_____________

RETURN CYCLES
Train 1-No. of Return cycles___________ Time after high float______________
Train 2-No. of Return cycles___________ Time after high float______________

Equipment Run Time
TIC______________
PB1________m/d PB2________m/d BWB1________m/d BWB2________m/d
RP1________m/d RP2________m/d BWP1________m/d BWP2________m/d
DFP1_______m/d DFP2_______m/d DBWP1______m/d DBWP2________m/d
INF Pumps 1__________m/d 2_________m/d 3_________m/d 4_________m/d
EFF Pumps 1__________m/d 2_________m/d 3_________m/d 4_________m/d
Meth.Pump Amph.#1________m/d Amph#2_________m/d Denite_________m/d
Alk Pump/loc. #1________m/d-_______ #2_______m/d-_______ #3_____m/d-_______

COUNTERS
No. of Discharges off of High float___________
Amp1BW____ Amp1FBW____ Amp2BW____Amp2FBW____ DBW____DFBW____
Equipment OFF-LINE/Reason
1.
2.
3.
4.
Anoxic Tank Sludge DOB/water level_________________/___________________

Date______________________ Location______________________________

Time In_____________ Out___________

Participants:

Review of Site Visit

_______________________________ _______________________________

Environmental Technology Verification Report

DRAFT

Nutrient Reduction in Domestic Wastewater From Individual Residential Homes

F.R. Mahony & Associates, Inc. Amphidrome™ Model Single Family System

Prepared for

NSF International
Ann Arbor, MI 48105

Prepared by

Scherger Associates
In cooperation with
Barnstable County Department of Health and Environment

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

Raymond Frederick, Project Officer
ETV Source Water Protection Pilot
National Risk Management Research Laboratory
Water Supply and Water Resources Division
U.S. Environmental Protection Agency
Edison, New Jersey 08837

January 2003

Notice

The U.S. Environmental Protection Agency (USEPA) through its Office of Research and Development has financially supported and collaborated with NSF International (NSF) under a Cooperative Agreement. The Water Quality Protection Center, Source Water Protection area, operating under the Environmental Technology Verification (ETV) Program, supported this verification effort. This document has been peer reviewed and reviewed by NSF and USEPA and recommended for public release.

Foreword

The following is the final report on an Environmental Technology Verification (ETV) test performed for NSF International (NSF) and the United States Environmental Protection Agency (USEPA) by the Barnstable County Department of Health and Environment (BCDHE). Scherger Associates prepared the Verification Report in cooperation with BCDHE. The verification test for the Amphidrome™ Model Single Family System was conducted from January 2001 through April 2002 at the Massachusetts Alternative Septic System Test Center (MASSTC) test site in Bourne, Massachusetts.

Throughout its history, the USEPA has evaluated the effectiveness of innovative technologies to protect human health and the environment. A new USEPA program, the Environmental Technology Verification Program was developed to verify the performance of innovative technical solutions to environmental pollution or human health threats. ETV was created to substantially accelerate the entrance of new environmental technologies into the domestic and international marketplace. Verifiable, high quality data on the performance of new technologies are made available to end users, regulators, developers, consulting engineers, and those in the public health and environmental protection industries. This encourages rapid availability of approaches to better protect the environment.

The USEPA has partnered with NSF, to verify performance of various treatment systems designed to remove pollutants and protect water used as a source for drinking water and other uses under the Source Water Protection (SWP) area of the Water Quality Protection Center (WQPC). NSF is an independent, not-for-profit testing and certification organization dedicated to public health, safety and protection of the environment. A goal of verification testing is to enhance and facilitate the acceptance of small treatment systems and equipment by state regulatory officials and consulting engineers, while reducing the need for testing of equipment at each location where the its use is contemplated. NSF meets this goal by working with manufacturers and NSF-qualified Testing Organizations (TO) to conduct verification testing under the approved protocols. The Barnstable County Department of Health and Environment is one such TO.

NSF is conducting the WQPC-SWP with participation of manufacturers, under the sponsorship of the USEPA Office of Research and Development, National Risk Management Research Laboratory, Urban Watershed Management Branch, Edison, New Jersey. It is important to note that verification of the equipment does not mean that the equipment is "certified" by NSF or "accepted" by USEPA. Rather, it recognizes that the performance of the equipment has been determined and verified by these organizations for those conditions tested by the TO.

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Appendix A - Installation Manual, and Operation & Maintenance Manual
Appendix B - Verification Test Plan
Appendix C - MASSTC Field SOP's
Appendix D - Lab Data and QA/QC Data
Appendix E - Field Lab Log Book
Appendix F - Spreadsheets with calculation and data summary
Appendix G - Field Operations Logs

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Glossary of Terms

Accuracy - a measure of the closeness of an individual measurement or the average of a number of measurements to the true value and includes random error and systematic error.

Bias - the systematic or persistent distortion of a measurement process that causes errors in one direction.

Commissioning – the installation of the nutrient reduction technology and start-up of the technology using test site wastewater.

Comparability – a qualitative term that expresses confidence that two data sets can contribute to a common analysis and interpolation.

Completeness – a qualitative and quantitative term that expresses confidence that all necessary data have been included.

Precision - a measure of the agreement between replicate measurements of the same property made under similar conditions.

Protocol – a written document that clearly states the objectives, goals, scope and procedures for the study. A protocol shall be used for reference during Vendor participation in the verification testing program.

Quality Assurance Project Plan – a written document that describes the implementation of quality assurance and quality control activities during the life cycle of the project.

Residuals – the waste streams, excluding final effluent, which are retained by or discharged from the technology.

Representativeness - a measure of the degree to which data accurately and precisely represent a characteristic of a population parameter at a sampling point, a process condition, or environmental condition.

Standard Operating Procedure – a written document containing specific procedures and protocols to ensure that quality assurance requirements are maintained.

Technology Panel - a group of individuals established by the Verification Organization with expertise and knowledge in nutrient removal technologies.

Testing Organization – an independent organization qualified by the Verification Organization to conduct studies and testing of nutrient removal technologies in accordance with protocols and test plans.

Vendor – a business that assembles or sells nutrient reduction equipment.

Verification – to establish evidence on the performance of nutrient reduction technologies under specific conditions, following a predetermined study protocol(s) and test plan(s).

Verification Organization – an organization qualified by USEPA to verify environmental technologies and to issue Verification Statements and Verification Reports.

Verification Report – a written document containing all raw and analyzed data, all QA/QC data sheets, descriptions of all collected data, a detailed description of all procedures and methods used in the verification testing, and all QA/QC results. The Verification Test Plan(s) shall be included as part of this document.

Verification Statement – a document that summarizes the Verification Report and is reviewed and approved by USEPA.

Verification Test Plan – A written document prepared to describe the procedures for conducting a test or study according to the verification protocol requirements for the application of nutrient reduction technology at a particular test site. At a minimum, the Verification Test Plan includes detailed instructions for sample and data collection, sample handling and preservation, and quality assurance and quality control requirements relevant to the particular test site.

Abbreviations and Acronyms

Amphidrome™	Amphidrome™ Model Single Family System
ANSI	American National Standards Institute
BDCHE	Barnstable County Department of Health and the Environment
BOD_5	Biochemical Oxygen Demand (five day)
$CBOD_5$	Carbonaceous Biochemical Oxygen Demand (five day)
COC	Chain of Custody
DO	Dissolved Oxygen
DQI	data quality indicators
DQO	data quality objectives
ETV	Environmental Technology Verification
FRMA	F.R. Mahony & Associates, Inc.
GAI	Groundwater Analytical, Inc.
gal	gallons
gpm	gallons per minute
MASSTC	Massachusetts Alternative Septic System Test Center
mg/L	milligrams per liter
mL	milliliters
NIST	National Institute of Standards and Technology
NH_3	Ammonia Nitrogen
NO_2	Nitrite Nitrogen
NO_3	Nitrate Nitrogen
NSF	NSF International
NRMRL	National Risk Management Research Laboratory
O&M	Operation and maintenance
ORD	Office of Research and Development, USEPA
OSHA	Occupational Safety and Health Administration
QA	Quality assurance
QAPP	Quality assurance project plan
QC	Quality control
QMP	Quality management plan
RPD	Relative percent difference
SAG	Stakeholders Advisory Group
SOP	Standard operating procedure
SWP	Source Water Protection Area, Water Quality Protection Center
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TO	Testing Organization
USEPA	United States Environmental Protection Agency
VO	Verification Organization
VR	Verification Report
VTP	Verification Test Plan
WQPC	Water Quality Protection Center

Acknowledgments

The Testing Organization (TO), the Barnstable County Department of Health and the Environment, was responsible for all elements in the testing sequence, including collection of samples, calibration and verification of instruments, data collection and analysis, and data management. Mr. George Heufelder was the Project Manager for the Verification Test.

Barnstable County Department of Health and the Environment
Superior Court House (P.O. Box 427)
Barnstable, MA 02630
(508) 375-6616
Contact: Mr. George Heufelder, Project Manager
Email: gheufeld@capecod.net

The Verification Report was prepared by Scherger Associates.

Scherger Associates
3017 Rumsey Drive
Ann Arbor, MI 48105
(734) 213-8150
Contact: Mr. Dale A. Scherger
Email: Daleres@aol.com

The laboratories that conducted the analytical work for this study were:

Barnstable County Department of Health and the Environment Laboratory
Superior Court House (P.O. Box 427)
Barnstable, MA 02630
(508) 375-6606
Contact: Dr. Thomas Bourne
Email: bcdhelab@cape.com

Groundwater Analytical, Inc. (GAI)
228 Main St.
Buzzards Bay, MA 02532
(508) 759-4441
Contact: Mr. Eric Jensen

The Manufacturer of the Equipment was:

F.R. Mahony & Associates, Inc.
273 Weymouth Street
Rockland, MA 02370
(781) 982-9300
Contact: Mr. Keith Dobie
Email: keithdobie@frmahony.com

The TO wishes to thank NSF International, especially Mr. Thomas Stevens, Project Manager, and Ms. Maren Roush, Project Coordinator, for providing guidance and program management.

1.0 Introduction

1.1 ETV Purpose and Program Operation

The U.S. Environmental Protection Agency (USEPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by substantially accelerating the acceptance and use of innovative, improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

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

NSF International (NSF), in cooperation with the USEPA, operates the Water Quality Protection Center (WQPC), one of six Centers under ETV. Source Water Protection (SWP) is one area within the WQPC. The WQPC-SWP evaluated the performance of the Amphidrome™ Model Single Family System (Amphidrome™ System) for the reduction of nitrogen compounds (TKN, NH_3, NO_2, NO_3), present in residential wastewater. F.R. Mahony & Associates, Inc. (FRMA) sells the Amphidrome™ Model Single Family System to treat wastewater from single-family homes. Other models of the Amphidrome™ System are available for commercial businesses, and similar applications, but this evaluation does not address those models. The Amphidrome™ Reactor is designed to work in conjunction with a FRMA provided anoxic/equalization tank and Clear Well, to provide nitrogen reduction in addition to the removal of organics and solids present in these wastewaters. The Amphidrome™ Reactor is based on a submerged growth bioreactor process, operating in a batch mode. This report provides the verification test results for the Amphidrome™ Model Single Family System, in accordance with the *Protocol for the Verification for Residential Wastewater Treatment Technologies for Nutrient Reduction,* November 2000[1].

1.2 Testing Participants and Responsibilities

The ETV testing of the Amphidrome™ System was a cooperative effort between the following participants:

NSF International

Massachusetts Alternative Septic System Test Center
Barnstable County Department of Health and Environment Laboratory
Groundwater Analytical, Inc.
Scherger Associates
F.R. Mahony & Associates, Inc.
USEPA

1.2.1 NSF International - Verification Organization (VO)

The Water Quality Protection Center of the ETV is administered through a cooperative agreement between USEPA and NSF International (NSF). NSF is the verification partner organization for the WQPC and the Source Water Protection (SWP) area within the center. NSF administers the center, and contracts with the Testing Organization to develop and implement the Verification Test Plan (VTP).

NSF's responsibilities as the Verification Organization included:

- Review and comment on the site specific VTP;
- Coordinate with peer-reviewers to review and comment on the VTP;
- Coordinate with the USEPA Project Manager and the technology vendor to approve the VTP prior to the initiation of verification testing;
- Review the quality systems of all parties involved with the Testing Organization and, subsequently, qualify the companies making up the Testing Organization;
- Oversee the technology evaluation and associated laboratory testing;
- Carry out an on-site audit of test procedures;
- Oversee the development of a verification report and verification statement;
- Coordinate with USEPA to approve the verification report and verification statement; and,
- Provide QA/QC review and support for the TO.

Key contacts at NSF for the Verification Organization are:

Mr. Thomas Stevens, Program Manager
(734) 769-5347 email: stevenst@nsf.org

Ms. Maren Roush, Project Coordinator
(734) 827-6821 email: mroush@nsf.org

NSF International
789 N. Dixboro Road
Ann Arbor, Michigan 48105
(734) 769-8010

1.2.2 U.S. Environmental Protection Agency

The USEPA Office of Research and Development, through the Urban Watershed Management Branch, Water Supply and Water Resources Division, National Risk Management Research Laboratory (NRMRL), provides administrative, technical, and quality assurance guidance and oversight on all ETV Water Quality Protection Center activities. The USEPA reviews and approves each phase of the verification project. The USEPA's responsibilities with respect to verification testing include:

- Verification Test Plan review and approval;
- Verification Report review and approval; and,
- Verification Statement review and approval.

The key USEPA contact for this program is:

Mr. Ray Frederick, Project Officer, ETV Water Quality Protection Center
U.S. EPA, NRMRL
Urban Watershed Management Branch
2890 Woodbridge Ave. (MS-104)
Edison, NJ 08837-3679
(732)-321-6627
email: frederick.ray@epa.gov

1.2.3 Testing Organization

The Testing Organization (TO) for the verification testing was the Barnstable County Department of Health and Environment (BCDHE). Mr. George Heufelder of the BCDHE was the project manager. He had the responsibility for the overall development of the Verification Test Plan (VTP), oversight and coordination of all testing activities, and compiling and submitting all of the test information for development of this final report.

Mr. Dale Scherger of Scherger Associates was contracted by NSF to work with BCDHE to prepare the Verification Report (VR) and Verification Statement (VS).

The BCDHE Laboratory and its subcontractor, Groundwater Analytical, Inc. (GAI), provided laboratory services for the testing program and consultation on analytical issues addressed during the verification test period.

The responsibilities of the TO included:

- Prepare the site specific VTP;
- Conduct Verification Testing, according to the VTP;

- Install, operate, and maintain the Amphidrome™ System in accordance with the Vendor's O&M manual(s);
- Control access to the area where verification testing was carried out;
- Maintain safe conditions at the test site for the health and safety of all personnel involved with verification testing;
- Schedule and coordinate all activities of the verification testing participants, including establishing a communication network and providing logistical and technical support on an "as needed" basis;
- Resolve any quality concerns that may be encountered and report all findings to the Verification Organization;
- Manage, evaluate, interpret and report on data generated by verification testing;
- Evaluate and report on the performance of the technology; and,
- If necessary, document changes in plans for testing and analysis, and notify the Verification Organization of any and all such changes before changes are executed.

The key personnel and contacts for the TO are:

Mr. George Heufelder, Project Manager
Barnstable County Department of Health and the Environment
Superior Court House (P.O. Box 427)
Barnstable, MA 02630
(508) 375-6616
Email: gheufeld@capecod.net

Mr. Sean Foss, Facility Operations Manager
Barnstable County Department of Health and the Environment
Superior Court House (P.O. Box 427)
Barnstable, MA 02630
(508) 563-6757
Email: sfoss@capecod.net.

Dr. Thomas Bourne, Laboratory Manager
Barnstable County Department of Health and the Environment Laboratory
Superior Court House (P.O. Box 427)
Barnstable, MA 02630
(508) 375-6606
Email: bcdhelab@cape.com

Mr. Eric Jensen
Groundwater Analytical, Inc. (GAI)
228 Main St.
Buzzards Bay, MA 02532
(508) 759-4441

Scherger Associates was responsible for:

- Preparation of the Verification Report; and,
- Preparation of the Verification Statement

The key contact at Scherger Associates is:

Mr. Dale A. Scherger
Scherger Associates
3017 Rumsey Drive
Ann Arbor, MI 48105
(734) 213-8150
Email: Daleres@aol.com

1.2.4 Technology Vendor

The nitrogen reduction technology evaluated was the Amphidrome™ System manufactured by F.R. Mahony & Associates, Inc. FRMA was responsible for supplying all of the equipment needed for the test program, and supporting the TO in ensuring that the equipment was properly installed and operated during the verification test. Specific responsibilities of the vendor include:

- Initiate application for ETV testing;
- Provide input regarding the verification testing objectives to be incorporated into the VTP;
- Select the test site;
- Provide complete, field-ready equipment and the operations and maintenance (O&M) manual(s) typically provided with the technology (including instructions on installation, start-up, operation and maintenance) for verification testing;
- Provide any existing relevant performance data for the technology;
- Provide assistance to the Testing Organization on the operation and monitoring of the technology during the verification testing, and logistical and technical support as required;
- Review and approve the site-specific VTP;
- Review and comment on the Verification Report; and,
- Provide funding for verification testing.

The key contact for FRMA is:

Mr. Keith Dobie
F.R. Mahony & Associates, Inc.
273 Weymouth Street
Rockland, MA 02370
(281) 982-9300
Email: keithdobie@frmahony.com

1.2.5 ETV Test Site

The Massachusetts Alternative Septic System Test Center (MASSTC) was the host site for the nitrogen reduction verification test. The MASSTC is located at Otis Air National Guard Base, Bourne, MA. The site was designed as a location to test septic treatment systems and related technologies. MASSTC provided the location to install the technology and all of the infrastructure support requirements to collect domestic wastewater, pump the wastewater to the system, operational support, and maintenance support for the test. Key items provided by the test site were:

- Logistical support and reasonable access to the equipment and facilities for sample collection and equipment maintenance;
- Wastewater that is "typical" domestic, relative to key parameters such as BOD_5, TSS, Total Nitrogen, and phosphorus;
- A location for sampling of raw or screened wastewater and a sampling arrangement to collect representative samples;
- Automatic pump systems capable of controlled dosing to the technology being evaluated to simulate a diurnal flow variation and to allow for stress testing;
- Sufficient flow of wastewater to accomplish the required controlled dosing pattern;
- An accessible but secure site to prevent tampering by outside parties; and,
- Wastewater disposal of both the effluent from the testing operation and for any untreated wastewater generated when testing is not occurring.

1.2.6 Technology Panel

Representatives from the Technology Panel assisted the Verification Organization in reviewing and commenting on the Verification Test Plan.

1.3 Background – Nutrient Reduction

Domestic wastewater contains various physical, chemical and bacteriological constituents, which require treatment prior to release to the environment. Various wastewater treatment processes exist which provide for the reduction of oxygen demanding materials, suspended solids and pathogenic organisms. Reduction of nutrients, principally phosphorus and nitrogen, has been practiced since the 1960's at centralized wastewater treatment plants where there is a specific need for nutrient reduction to protect the water quality and, hence, the uses of the receiving waters, whether ground water or surface water. The primary reasons for nutrient reduction are to protect water quality for drinking water purposes (drinking water standards for nitrite and nitrate have been established), and to reduce the potential for eutrophication in nutrient sensitive surface waters by the reduction of nitrogen and/or phosphorus.

The reduction of nutrients in domestic wastewater discharged from single-family homes, small businesses and similar locations within watersheds is desirable for the same reasons as for large treatment facilities. First, reduction of watershed nitrogen inputs helps meet drinking-water quality standards for nitrate and nitrite; and second, the reduction of both nitrogen and phosphorus helps protect the water quality of receiving surface and ground waters from eutrophication and the consequent loss in ecological, commercial, recreational and aesthetic uses of these waters.

Several technologies and processes can remove nutrients in on-site domestic wastewater. The Amphidrome™ process is based on a submerged growth biological reactor operating in the batch mode. The Amphidrome™ process uses a submerged bioreactor with an attached microbial population for nitrification and denitrification. The process changes the bioreactor conditions between aerobic and anoxic by controlling the aeration period. The anoxic condition in the anoxic/equalization tank also promotes biological denitrification. A brief discussion of basic nitrification and denitrification processes is given below.

1.3.1 Biological Nitrification

Nitrification is a process carried out by bacterial populations (*Nitrosomonas* and *Nitrobacter)* that oxidize ammonium to nitrate with intermediate formation of nitrite. These organisms are considered autotrophic, because they obtain energy from the oxidation of inorganic nitrogen compounds. The two steps in the nitrification process and their equations are as follows:

1) Ammonia is oxidized to nitrite (NO_2^-) by *Nitrosomonas* bacteria.

$$2\ NH_4^+ + 3\ O_2 = 2\ NO_2^- + 4\ H_4^+ + 2\ H_2O$$

2) The nitrite is converted to nitrate (NO_3^-) by *Nitrobacter* bacteria.

$$2\ NO_2^- + O_2 = 2\ NO_3^-$$

Since complete nitrification is a sequential reaction, systems must be designed to provide an environment suitable for the growth of both groups of nitrifying bacteria. These two reactions essentially supply the energy needed by nitrifying bacteria for growth. Several major factors influence the kinetics of nitrification, including organic loading, hydraulic loading, temperature, pH, and dissolved oxygen concentration.

1. Organic loading: The efficiency of the nitrification process is affected by the organic loadings. Although the heterotrophic biomass is not essential for nitrifier attachment, the heterotrophs (organisms that use organic carbon for the formation of cell tissue) form biogrowth to which the nitrifiers adhere. The heterotrophic bacteria grow much faster than nitrifiers do at high BOD_5 concentrations. As a result, the nitrifiers can be over grown by heterotrophic bacteria, which can cause the nitrification process to cease. In order for nitrification to take place, the organic loadings for submerged growth sequencing batch reactors should be less than 1 $kg/m^3/day$.

2. Hydraulic loading: Wastewater is normally introduced at the top of the submerged growth filter systems and flows down through a medium. The total hydraulic flow to the submerged filter can be controlled to some extent by recirculation of the treated effluent. Hydraulic and organic loadings are not independent parameters, because the wastewater concentration entering the plant cannot be controlled. A benefit of recirculation in nitrifying reactors is the reduction of the influent BOD_5 concentration, which makes the nitrifiers more competitive.

3. pH: The nitrification process produces acid. The acid formation lowers the pH and can cause a reduction in the growth rate of the nitrifying bacteria. The optimum pH for *Nitrosomonas* and *Nitrobacter* is between 7.5 and 8.5. At a pH of 6.0 or less nitrification normally will stop. Approximately 7.1 pounds of alkalinity (as $CaCO_3$) are destroyed per pound of ammonia oxidized to nitrate.

4. Dissolved Oxygen (DO): The concentration of dissolved oxygen affects the rate of nitrifier growth and nitrification in biological waste treatment systems. The DO concentration at which nitrification is limited can be 0.5 to 2.5 mg/L in either suspended or attached growth systems under steady state conditions, depending on the degree of mass-transport or diffusional resistance and the solids retention time. The maximum nitrifying growth rate is reached at a DO concentration of 2 to 2.5 mg/L. However, it is not necessary to grow at the maximum growth rate to get effective nitrification if there is adequate contact time in the system. As a result there is a broad range of DO values where DO becomes rate limiting. The intrinsic growth rate of *Nitrosomonas* is not limited at DO concentrations above 1.0 mg/L, but DO concentrations greater than 2.0 mg/L may be required in practice. Nitrification consumes large amounts of oxygen with 4.6 pounds of O_2 being used for every pound of ammonia oxidized.

1.3.2 Biological Denitrification

Denitrification is an anoxic process where nitrate serves as the source of oxygen for bacteria and the nitrate is reduced to nitrogen gas. Denitrifying bacteria are facultative organisms that can use either dissolved oxygen or nitrate as an oxygen source for metabolism and oxidation of organic matter. If both dissolved oxygen and nitrate are present, the bacteria will tend use the dissolved oxygen first. Therefore, it is important to keep dissolved oxygen levels as low as possible.

Another important aspect of the denitrification process is the presence of organic matter to drive the denitrification reaction. Organic matter can be in the form of raw wastewater, methanol, ethanol, or other organic sources. When these sources are not present, the bacteria may depend on internal (endogenous) carbon reserves as organic matter. The endogenous respiration phase can sustain a system for a time, but may not be a consistent enough source of carbon to drive the reaction to completion or to operate at the rates needed to remove the elevated nitrate levels present in nitrified effluent.

The denitrifying reaction using methanol as a carbon source can be represented as follows:

$$6NO_3^- + 5CH_3OH = 5CO_2 + 3N_2 + 7H_2O + 6OH^-$$

Several conditions affect the efficiency of the denitrification process including the anoxic conditions, the temperature, presence of organic matter, and pH.

1. Dissolved oxygen - The level of dissolved oxygen has a direct impact on the denitrifying organisms. As dissolved oxygen increases, denitrification rate decreases. Dissolved oxygen concentrations below 0.3-0.5 mg/L in the anoxic zone are typically needed to achieve efficient denitrification.

2. Organic matter – The denitrification process requires a source of organic matter. Denitrification rate varies greatly depending upon the source of available carbon. The highest rates are achieved with addition of an easily assimilated carbon source such as methanol. Somewhat lower denitrification rates are obtained with raw wastewater or primary effluent as the carbon source. The lowest denitrification rates are observed with endogenous decay as the source of carbon.

3. pH and alkalinity – The optimum pH range for most denitrifying systems is 7.0 to 8.5. The process will normally occur in a wider range, pH 6 – 9, but denitrifying rates may be impacted near the extremes of the range. Acclimation of the population can lower the impact of pH on growth rates. An advantage of the denitrification process is the production of alkalinity that helps buffer the decrease in alkalinity in the nitrification process. Approximately 3.6 pounds of alkalinity is produced for each pound of nitrate nitrogen removed.

2.0 Technology Description and Operating Processes

2.1 Technology Description

The Amphidrome™ Reactor is a submerged growth sequencing batch reactor used in conjunction with an anoxic/equalization tank, and a Clear Well tank for wastewater treatment. The anoxic tank provides solid - liquid separation, and anoxic conditions for denitrification. The bioreactor consists of a deep bed filter, which alternates between aerobic and anoxic treatment. The reactor operates similar to a biological aerated filter[3] (BAF) or recirculating sand filter except that the reactor changes from aerobic to anoxic conditions during the sequential cycling of the unit. According to FRMA, the unique design allows the removal of soluble organics, and for the nitrification and denitrification process to occur in one reactor. The cyclical action of the system is created by allowing a batch of wastewater to pass by gravity flow from the anoxic/equalization tank through the submerged granular biological filter and into the Clear Well. The flow is then reversed using a pump to move water from the Clear Well up through the filter and into a return pipe, which carries the wastewater back to the anoxic tank. These cycles are repeated multiple times, with the conditions changing from aerobic to anoxic within the biofilter. After several cycles, the wastewater is discharged from the Clear Well to the receiving leach field or other receiving environment.

In the submerged biofilter, organic material in the wastewater is degraded by microorganisms present on the media. Organic removal ($CBOD_5$) occurs as the wastewater passes through the media into the Clear Well. Nitrogen compounds, organic nitrogen and ammonia, are converted to nitrite and nitrate as the wastewater passes through the Amphidrome™ Reactor under aerobic conditions. The treated effluent is recycled back through the biofilter (up flow mode) and returns to the anoxic tank. FRMA claims that denitrification occurs in the submerged biofilter unit, as the Reactor changes from aerobic to anoxic conditions, based on PLC control of the air injection system and pump cycle times. According to FRMA, both nitrifying and denitrifying organism are present in the Reactor. Denitrification also occurs in the anoxic tank, where nitrified wastewater, returned from the Clear Well (back through the submerged filter unit), mixes with incoming untreated wastewater.

2.2 Amphidrome™ System Process Description

2.2.1 Overview of the Amphidrome™ Process

The Amphidrome™ System is a somewhat complex and sophisticated system that uses PLC control of aeration and pump cycles to treat wastewater. There are numerous options within the PLC to adjust aeration duration and frequency, in addition to controlling return flow cycle times, frequency and duration of backwash, and discharge frequency and time of day. This section provides a simple overview of the process based on a "typical" setup for the system. Actual settings need to be determined based on site-specific conditions. A more detailed discussion of the process cycles and PLC options is presented in the next section and in Appendix A.

Figure 2-1 gives an overview of the normal cycles used in the Amphidrome™ system. There are normal forward, flow periods with aeration, normal forward, flow periods without aeration, and normal return flow periods with or without aeration. A typical sequence within a one-hour period is as follows:

1. Wastewater enters the anoxic tank from the residence and gravity flow moves the wastewater from the anoxic tank through the submerged filter in a downward mode. The water flows by gravity from the filter unit to the Clear Well. The aeration system is on (one of three 5 minute aeration periods in the hour), adding air (oxygen) to the system. This part of the cycle is called the CalOX™ Cycle in Figure 2-1. During this time, the submerged filter is aerobic and nitrification is occurring, converting ammonia to nitrate. Organic removal is also occurring. Any solids in the anoxic tank effluent are trapped on the top of the sand filter.
2. Forward gravity flow continues after the aeration system shuts down. The submerged filter dissolved oxygen level decreases, as more wastewater flows downward through the unit. When the dissolved oxygen level becomes very low, denitrification begins to occur removing the nitrate in the wastewater. This cycle is shown in Figure 2-1 and is called the Denite® Cycle.
3. After 15 minutes, the aeration system starts again and runs for 5 minutes, repeating the process described in number 1 above. S dissolved oxygen increase the nitrification process increases converting ammonia to nitrate. During cycles described in items 1, 2, and 3, treated wastewater is accumulating in the Clear Well.
4. After one hour, the return pump in the Clear Well is activated by the PLC. The accumulated water in the Clear Well is pumped upward through the filter and enters the return line at the top of the filter. The return wastewater mixes with any incoming wastewater at the front of the anoxic tank. This cycle is shown in Figure 2-1 as the Return CalOX™ Cycle. The return pump shuts down when the low level switch in the Clear Well is activated. Thus, most of the wastewater in the Clear Well is recycled to the front of the system and flows again by gravity back through the filter system, receiving additional treatment.
5. The anoxic tank will have nitrate present from the Clear Well water (after nitrification in the filter unit, see step 1). Denitrification will occur in the anoxic tank.

The hourly cycle of forward gravity flow with/without aeration and the pumped return flow from the Clear Well to the anoxic tank, once per hour, is repeated for approximately 23 hours. At the end of the daily cycle, the treated wastewater in the Clear Well is pumped to the receiving location (leach field or other location). At this time, the system is ready to start another "batch" treatment of wastewater as it is received during the next day.

One additional cycle must occur periodically. The system will require backwashing to remove accumulated solids on the top of the sand filter and some of the solids attached to the submerged filter. Backwash normally occurs from once per day to once per week depending on the system needs. When the PLC activates the backwash cycle, the same pump that was used for the hourly return is used to pump Clear Well water up through the unit. Simultaneously, the backwash blower is activated which provides a vigorous aeration of the filter system. The combined effect of the up flow of water and the aeration is designed to dislodge the accumulate solids. Once a backwash is complete, the system returns to the normal hourly cycle described in items 1 through 5 above.

2.2.2 Detailed Process Amphidrome™ Process Description

The Amphidrome™ System is a submerged attached growth bioreactor process, designed around a deep-bed sand filter. FRMA states that it is specifically designed for the simultaneous removal of soluble organic matter, nitrogen, and suspended solids within a single Reactor. Since it removes nitrogen, it is considered a biological nutrient removal (BNR) process. To achieve simultaneous oxidation of soluble material, nitrification, and denitrification in a single Reactor, the process provides aerobic and anoxic environments for the two different populations of microorganisms. The treatment system utilizes two tanks and one submerged attached growth bioreactor, called the Amphidrome™ Reactor.

The first tank, the anoxic/equalization tank, receives raw wastewater from the home. The tank serves as a primary clarifier before the Amphidrome™ Reactor and is similar to a septic tank. FRMA describes the anoxic/equalization tank as having three zones, the equalization zone, the settling zone and the solids storage zone. The upper part of the tank receives the incoming raw wastewater and receives the return flow from the biofilter. The two flows mix in the tank and flow by gravity to the Amphidrome™ Reactor. Solids settle in the anoxic/equalization tank, moving through the settling zone to the bottom of the tank. Accumulated solids are stored in the bottom of the tank.

The Amphidrome™ Reactor consists of the following three items: under drain, support gravel, and filter media. The under drain, constructed of stainless steel, is located at the bottom of the Reactor. It provides support for the media and even distribution of air and water into the Reactor. The under drain has a manifold and laterals to distribute the air evenly over the entire filter bottom. Air is supplied by a single 1/3 hp blower supplied with the system. The design allows for both the air and water to be delivered simultaneously, or separately, via individual pathways to the bottom of the Reactor. As the air flows up through the media, the bubbles are sheared by the gravel and sand, producing finer bubbles as they rise through the filter. On top of the under drain is 18" (five layers) of five different sizes of gravel (1½ X ¾ inch on the bottom, and progressively smaller to ½ X ¼ inch at the top). Above the gravel is a bed of coarse, round silica sand media. The media functions as a filter, significantly reducing suspended solids, and provides the surface area where attached growth biomass can be maintained.

During normal, gravity flow conditions, wastewater from the anoxic/equalization tank flows into the Reactor, raising the water level (the biofilter is always submerged). The increased water level in the Reactor pushes water from the underdrain through the pipe connected to the backwash/recirculation pump in the Clear Well. The water flows through the pump into the Clear Well chamber. A vent hole in the pipe within the Clear Well provides a vacuum break to prevent siphoning of water from the Reactor into the Clear Well.

To achieve the two different environments (aerobic and anoxic) required for the simultaneous removal of soluble organics and nitrogen, aeration of the Reactor is intermittent rather than continuous. Depending on the strength and the volume of the wastewater, a typical aeration scheme may be three to five minutes of air and ten to fifteen minutes without air. Concurrently, return cycles are scheduled every hour, regardless of the aeration sequence. During a return cycle, water from the Clear Well is pumped to the underdrain of the Reactor, moves up through the filter, and overflows into an energy-dissipating TEE. A check valve in the influent line (located below the return/backwash line) prevents the flow from returning to the anoxic/equalization tank via that route. The energy-dissipating TEE is set at a fixed height above both the media and the influent line, and the flow is by gravity through the return/backwash line to the inlet end of the anoxic/equalization tank. FRMA indicates that the cyclical forward and reverse flow of the waste stream and the intermittent aeration of the filter achieve the required hydraulic retention time, and create the necessary aerobic and anoxic conditions to achieve the required level of treatment.

Figures 2-1 shows the Amphidrome™ Process during each of the operating cycles and Figure 2-2 shows a process flow diagram for the system. Figures 2-3 through 2-5 show the three individual tanks used in the system. FRMA provides a Single Family Installation Instruction Manual, and an Operation and Maintenance Manual for the Amphidrome™ System. These manuals and general literature, providing additional details, are presented in Appendix A.

The Amphidrome™ System is controlled by a programmable logic controller (PLC). The PLC is programmed to operate the blower, all of the pump times/cycles, and respond to high and low level switches and alarms. For this verification test all programming of the PLC was performed by FRMA. The Clear Well of the system being tested had two pumps, a discharge pump and a return/backwash pump (for larger systems there can be four pumps, two discharge, one return, one backwash) installed to handle the various wastewater movements.

The discharge pump is activated once per day (there is an option to discharge twice per day) to discharge treated wastewater from the system. This pump is started by the PLC timer and discharges wastewater until the pump is stopped by a middle level float in the Clear Well. There is also a high level float in the Clear Well, which activates the discharge pump for a short period (5 minutes) to prevent Clear Well overflow.

The second pump in the Clear Well is used to return wastewater from the Clear Well back through the filter (up flow mode) and into the anoxic tank. The PLC controls the number of return cycles by a timer and float system. Under normal operation, the PLC starts the return pump every hour, giving a return flow frequency of 24 times per day. The pump run time is set so that most of the water in the Clear Well is returned to the anoxic tank. The pump duration timer is started when the high float in the Amphidrome™ Reactor is tripped, indicating that water has risen to the level of the gravity return line that carries the wastewater back to the anoxic tank. The return pump cycle, used in conjunction with the middle float in the Clear Well, is also used by the PLC to calculate the influent flow from the residence. The middle float in the Clear Well is used to stop the discharge pump (see discussion above), and thus can be used as an indicator of how much water has entered the system since the last discharge. When the return pump is started, the PLC monitors the time until the middle float drops, thus providing a basis for estimating the amount of influent volume received since the last discharge. This influent volume calculation is important as the PLC uses this estimate to adjust the aeration cycles for the Reactor (see discussion below).

The return pump is also used as the backwash pump in small systems, including the system used for the verification test. The PLC controls the timing and number of backwashes performed each day. When the PLC timer initiates a backwash cycle, the return pump is activated and the process blower is activated to aerate the filter media. Thus, the backwashing of the filter and removal of accumulated solids that could plug the bed is achieved by a combination of hydraulic flow in the up flow mode, supported by vigorous aeration from the process blower. Solids are carried upward with the wastewater to the return pipe at the top of the Reactor, where they flow by gravity back to the anoxic tank.

FRMA stresses that to achieve the two different environments required for removal of organics and nitrogen, aeration of the Reactor is intermittent and must be properly controlled. Control is achieved by four different means within the PLC. First, the length of six potential aeration periods may be adjusted; second, the process blower off time may be adjusted; third, the fixed aeration period may be adjusted; and finally, an aeration multiplier may be adjusted. The normal aeration setup used in the verification system was three to five minutes of aeration and ten to fifteen minutes without aeration. The first three controls are timer and cycle controls set in the PLC. The fourth control is based on the calculated flow in the system (using the return pump and middle float in the Clear Well described above), and mechanism is provided for the PLC to adjust aeration amounts, depending on the flow to the system. As described in the O&M Manual, it takes experience, review of data, and operating time to properly setup the system for a given application. FRMA monitored the verification test unit and made adjustments as needed. A complete description of the aeration PLC control is given in the O&M Manual in Appendix A. The Installation Manual and O&M Manual in Appendix A also give a more detailed explanation of the operations and control of the treatment process.

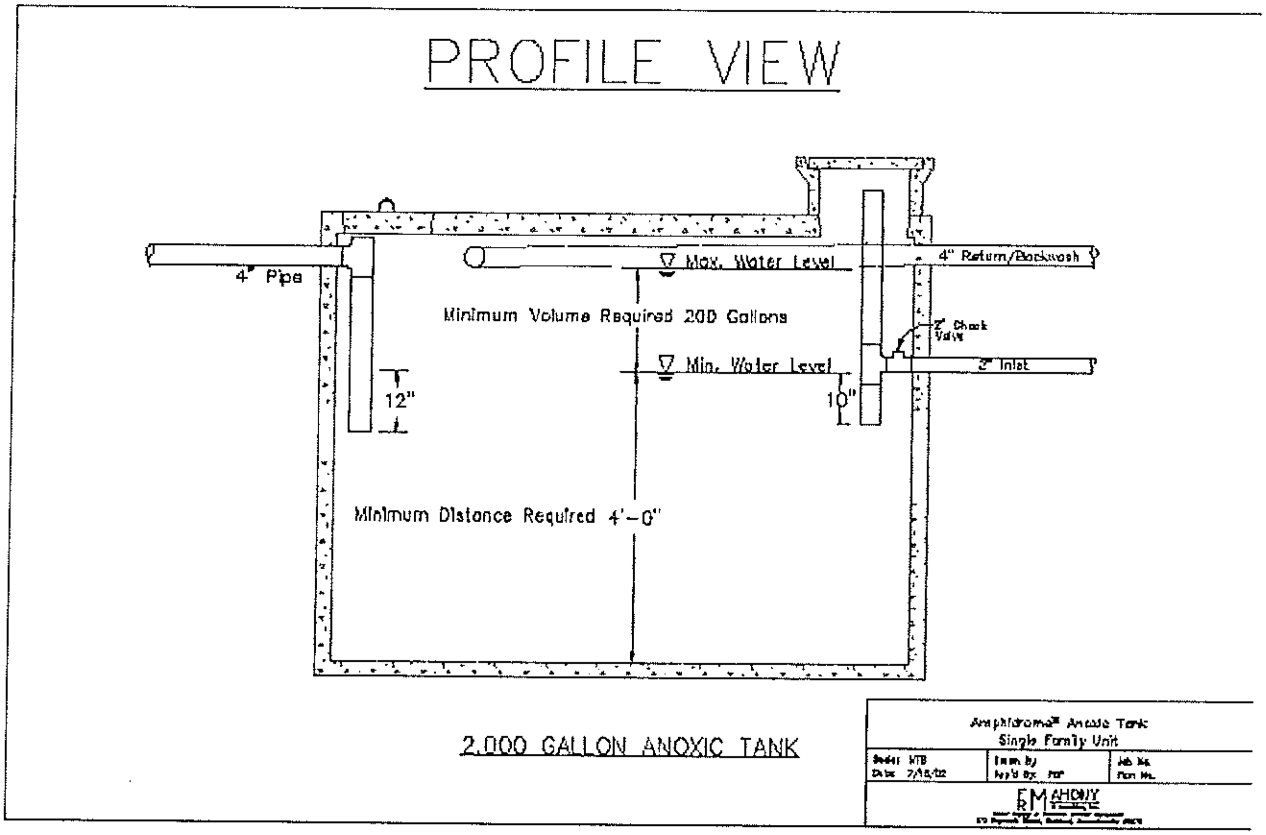
Figure 2-1. Amphidrome™ Process Schematic

This figure is hardcopy only. Will insert with a scanned document.

Figure 2-2. Amphidrome™ Process

This figure is hardcopy only. Will insert with a scanned document

Figure 2-3. Amphidrome™ Anoxic Tank



NOTE: The Return/Backwash line extends to the inlet location, and enters the Anoxic Tank at the same location as the inlet wastewater.

Figure 2-4. Amphidrome™ Reactor

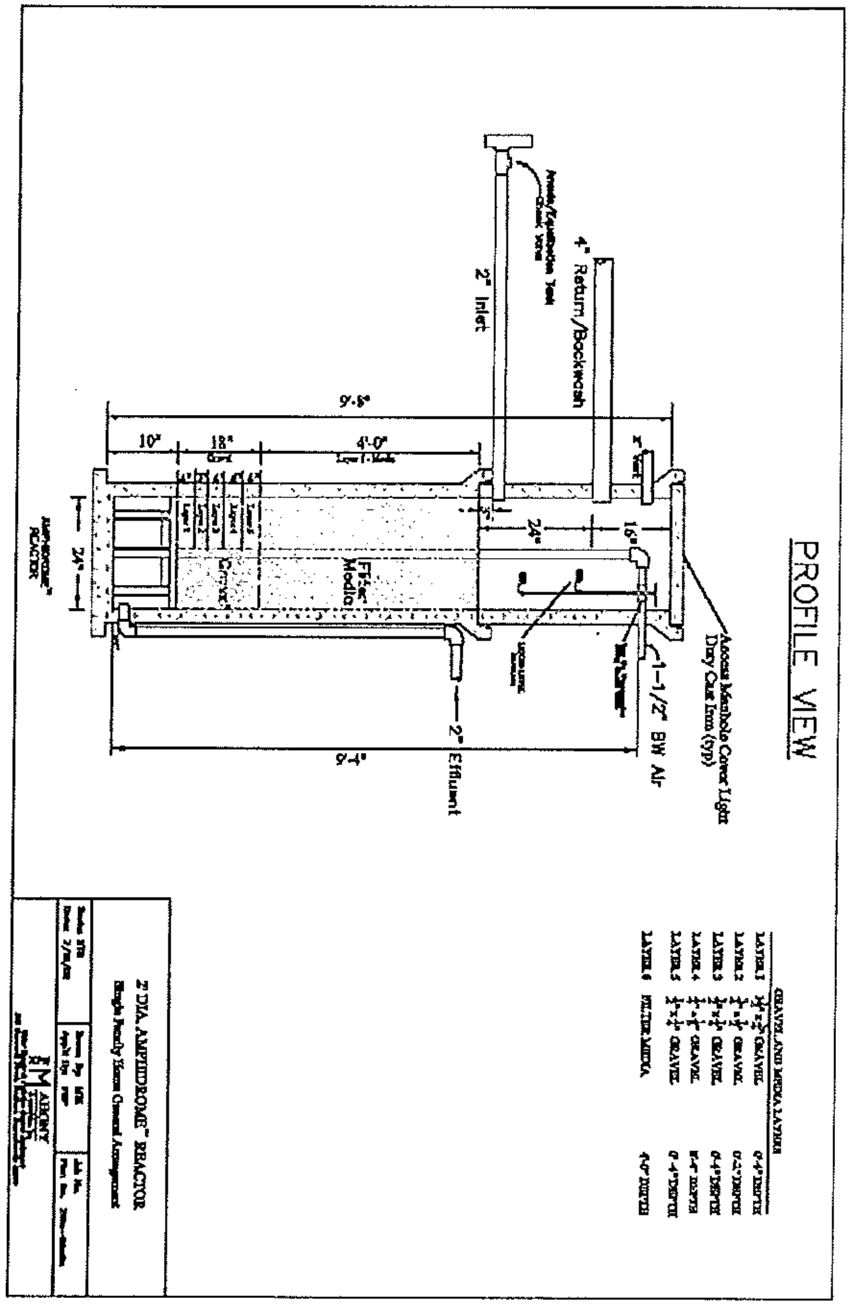
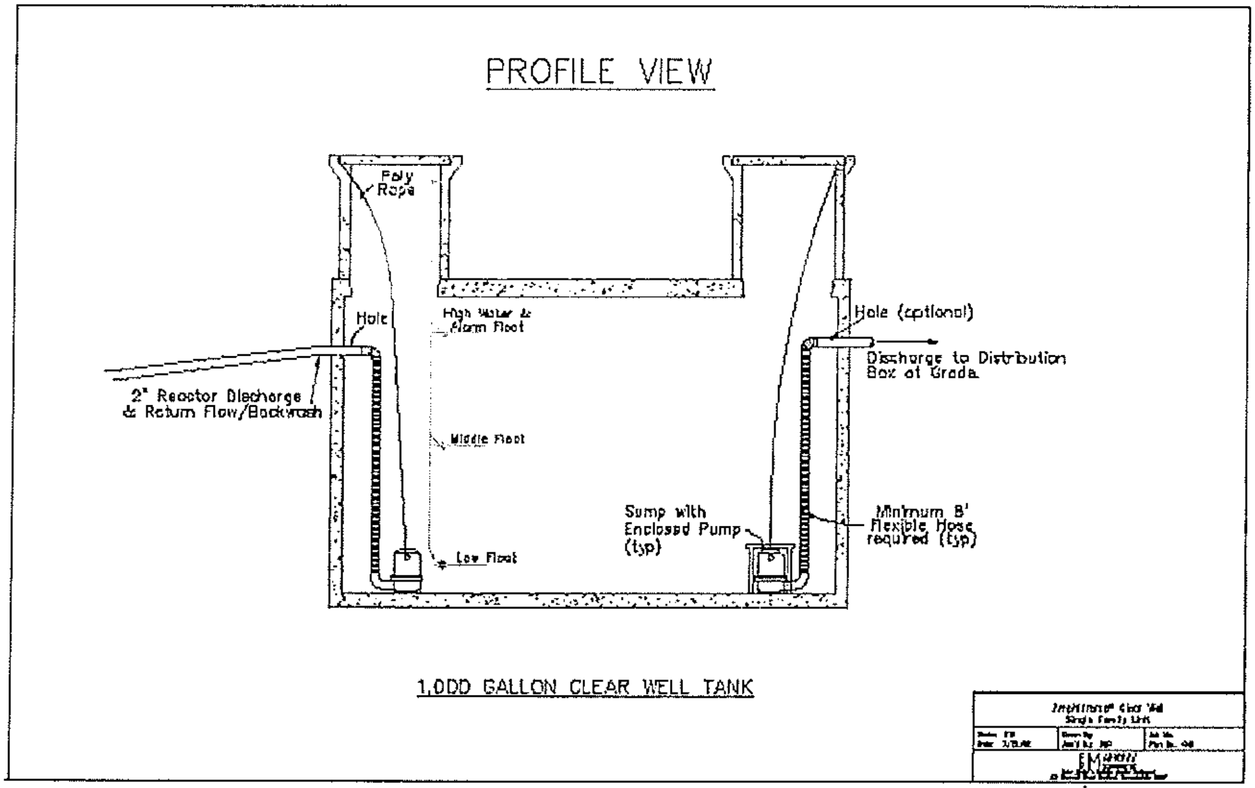


Figure 2-5. Amphidrome™ Clear Well



2.3 Equipment Specifications

The specifications for the Amphidrome™ Model Single Family Unit are summarized in Table 2-1. A full listing of the materials is shown in the Installation Manual in Appendix A. All of the piping used in the systems is either Schedule 40 or 80 PVC pipe.

Table 2-1. Amphidrome™ Unit Specifications

Item	Quantity
Anoxic/Equalization Tank	1
Tank - 2000 gallon (1)	
(1,500 gallon used in verification test)	
Anoxic Tank Cover (1)	
Tank Riser (1)	
Schedule 40 PVC TEE and Swing Check Valve Assembly (1)	
Energy dissipating TEE, 4 inch (1)	
PVC Schedule 40 pipe and fittings	
Amphidrome™ Reactor	1
Reactor Basin with cover (140 gallons)	
Underdrain system (1)	
Gravel - 18 inches	
Sand filter media – 4 feet (12.57 cu. ft.)	
Pipe mounted mini floats (2)	
Schedule 80 PVC pipe and fittings	
Clear Well	1
Tank - 1000 gallons (1)	
(517 gallon tank used in verification test)	
Tank risers and covers (2)	
Discharge pump (1)	
Return/backwash pump (1)	
Process blower with pressure relief (1)	
Pipe mounted mini floats (3)	
Flexible hose and couplings for pumps	
Programmable Logic Controller (PLC)	1
Installation Manual	1
Operations and Maintenance Manual	1

2.4 Operation and Maintenance

FRMA provides a detailed Installation Manual, and an Operational and Maintenance Manual for the Amphidrome™ System. A copy of this information is presented in Appendix A. These manuals provide very important information on installation, startup, and operation of the system. The Amphidrome™ System uses a complex process, and it is important that the PLC settings for pump and aeration control are setup properly for a given application. FRMA requires that a FRMA representative be present to startup the unit after installation is complete.

The Installation Manual provides step-by-step procedures for installing the three tanks and the internal and external piping. Gravel and silica sand media installation procedures are described, as are the methods for checking the air distribution and flushing the system. During and following completion of installation, a representative of FRMA goes to the site to inspect the system and initiate startup procedures. Startup procedures include inspection of the air pattern in the Reactor and "Air Pattern Test" prior to installation of the media, and process startup, which includes verification of wiring connections, operation of the pumps, blower, and process controller (PLC).

The startup procedures include measuring the forward and reverse flow rates through the system, including the gravity flow from the anoxic tank through the Reactor to the Clear Well, and the pumped return and backwash flow rates. The PLC is preset to initiate return flow cycles every hour and backwash cycles once per day. The blower is typically set to operate for 3-5 minutes, followed by an off period of 10-15 minutes. Obtaining the proper aeration cycle is critical to the successful operation of the Reactor. Once the unit is started, FRMA recommends that the unit be operated for a month and then inspected. At the first monthly visit, samples are collected for analyses and all equipment run times (pumps, blowers, etc.) are checked. FRMA recommends that samples be collected frequently during the first 30-90 days after startup. Bimonthly site visits and system checks are recommended after the initial monthly visit. The O&M Manual stresses that maintaining complete and accurate records of the system operating conditions, such as return pump run times, aeration run times, discharge pump run time, etc. are critical to operating the system and troubleshooting, if the needed treatment is not achieved. The PLC records the times for these operations as total time. Therefore, it is important for the service provider to record the times periodically during site visits so that averages can be reviewed and compared from one visit to the next. Meticulous records are the only way to determine if system-operating conditions have changed or to evaluate the impact of changes made to the PLC settings.

The entire Amphidrome™ System is PLC controlled, and therefore all changes to the system are by changing PLC settings. The PLC can be adjusted using the operator interface system that is attached to the control panel. This system allows the operator to make changes to aeration times, and pump start and stop times. There are four methods for controlling aeration cycles in the Reactor. These methods are described in detail in the O&M Manual. Both the return pump and discharge pump start and stop times can be adjusted with the operator interface. Typically, these settings are optimized during the startup period and are not changed after the startup period, unless the system is not meeting discharge requirements. The PLC programming can be changed using a portable computer or a manufacturer's handheld programmer. Changes to the programming logic in the PLC are typically performed only by FRMA or under their supervision.

FRMA recommends bimonthly system inspections once the startup period ends and the system is operating properly. These inspections include checking the system visually (clarity of the effluent, any odor, color, or solids present, etc.), and performing analyses of the effluent using field test kits for ammonia and nitrate. The PLC records for pump and aeration run times are recorded by the service provider to provide a record of the systems operation since the last inspection. Pump operation, particularly return flow (up flow through the Reactor) and backwash flow, is observed to ensure proper operation. The backwash cycle is activated to ensure both the pump and blower work properly. The aeration system is inspected and the bubble pattern above the media observed. The bubble pattern should be evenly distributed over the media.

In additional to the O&M Manual, FRMA provided examples of Inspection and Maintenance Check Lists, Operator Logs, Preventive Maintenance Lists. A narrative description of all of the system components is also provided in the Manual. There are several pages of troubleshooting guidelines that can help an operator evaluate equipment malfunctions and potential causes of poor quality effluent.

2.5 Vendor Claims

F.R. Mahony & Associates, Inc. claims the Amphidrome™ System is designed to consistently remove soluble organics, as measured by $CBOD_5$, total suspended solids (TSS), and nitrogen within a single Reactor. FRMA states that if stringent total nitrogen limits (<10 mg/L) are required, a second smaller polishing reactor is required. The system installed for the verification test did not have a second reactor for denitrification.

3.0 Methods and Test Procedures

3.1 Verification Test Plan and Procedures

A Verification Test Plan (VTP) was prepared and approved for the verification of the F.R. Mahony & Associates, Inc., Amphidrome™ System, and is included in Appendix B. The VTP, *Test Plan for The Massachusetts Alternative Septic System Test Center for the Verification Testing of the F.R. Mahony & Associates, Inc. Amphidrome™ Model Single Family Unit Nutrient Reduction Technology* (4), August 2001, detailed the procedures and analytical methods to be used to perform the verification test. The VTP was prepared in accordance with the SWP protocol, *Protocol for the Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction* (1), November 2000. The VTP included tasks designed to verify the nitrogen reduction capability of the Amphidrome™ System and to obtain information on the operation and maintenance requirements of the Amphidrome™ System. There were two distinct phases of fieldwork to be accomplished as part of the VTP, startup of the unit, and a one-year verification test that included normal dosing and stress conditions. The Protocol requires twelve months of sampling, which was completed between March 2001 and April 2002.

Each of the testing elements, performed during the technology verification, is described in this section. In addition to descriptions of sample collection methods, equipment installation, and equipment operation, this section also describes the analytical protocols. Quality Assurance and Quality Control procedures and data management approach are discussed in detail in the VTP.

3.2 MASSTC Test Site Description

The MASSTC site is located at Otis Air National Guard Base in Bourne, Massachusetts. The site is designed to provide domestic wastewater for use in testing various types of residential wastewater treatment systems. The domestic wastewater source is the sanitary sewerage from the base residential housing and other military buildings. The sewer system for the base flows to an on-base wastewater treatment facility. An interceptor chamber, located in the main sewer line to the base wastewater treatment facility was constructed when the MASSTC was built, and provides a location to obtain untreated wastewater. The raw wastewater passes through a bar screen (grate) located ahead of the transfer pump. This bar screen has one inch spacing between the bars to remove large or stringy materials that could clog the pump or lines. The screened raw wastewater is pumped through an underground two-inch line to the dosing channel at the test site. The design of the interceptor chamber provides mixing of the wastewater just ahead of the transfer pump to ensure a well-mixed raw wastewater is obtained for the influent feed at the test site.

The screened wastewater is pumped to the dosing channel at a rate of approximately 29 gallons per minute (gpm) on a continuous basis for 18 hours per day, yielding at total flow of approximately 31,000 gallons per day (gpd). Wastewater enters the dosing channel, an open concrete channel, sixty-five feet long by two feet wide by three feet deep, via two pipes midway in the channel. Approximately 4,000 to 6,000 gallons per day is withdrawn for test purposes in various treatment units. The excess wastewater flows by gravity to the base sanitary sewer and is treated at the base wastewater treatment plant. The dosing channel is equipped with four recirculation pumps. These pumps, spaced along the channel length, keep the wastewater in the channel constantly moving to ensure the suspension of solids, and to ensure that the wastewater is of similar quality at all locations along the channel.

Dosing of wastewater to the test units is accomplished by individual pumps submerged in-line along the dosing channel. The pumps are connected to the treatment technology being tested by underground PVC pipe. A custom designed, programmable logic controller (PLC) is used to control the pumps and the dosing sequence or cycle. Each technology feed pump can be controlled individually for multiple start and stop times, and for pump run time. For the Amphidrome™ System, the volumetric dosages were set to meet the dosing sequence described in the VTP. The test for the Amphidrome™ System was based on dosing 15 times per day with approximately 26.7 gallons of wastewater per dose. This dosing volume of 400 gallons per day was based on the Amphidrome™ System rated capacity of 400 gpd. The individual dose volume was controlled by adjusting the pump run time for each cycle.

MASSTC maintains a small laboratory at the site to monitor basic wastewater treatment parameters. Temperature, dissolved oxygen, pH, specific conductance, and volumetric measurements are routinely performed to support the test programs at the site. These field parameters were performed at the site during the Amphidrome™ System test.

The MASSTC has been in operation since 1999. Screened wastewater quality has been monitored as part of several previous test programs, and is presented in Table 3-1. Influent wastewater monitoring was part of the startup and verification testing, and is described later in this section. Results of all influent monitoring during the verification test are presented in Chapter 4.

Table 3-1. Historical MASSTC Wastewater Data

Parameter	Average (mg/L)	Standard Deviation
BOD_5	180	61
TSS	160	59
Total Nitrogen	34	4.6
Alkalinity	170	28
pH	7.4	0.13

3.3 Installation and Startup Procedures

3.3.1 Introduction

FRMA provided installation instructions (included in Appendix A) for the Amphidrome™ System and was present at the site during the installation. The system delivered by FRMA consisted of a single compartment, 1,500 gallon anoxic/equalization tank, and a complete Amphidrome™ Reactor, and a 517 gallon Clear Well tank with all associated pumps and float switches. This system was originally installed by a contractor in December 1999 as part of an earlier test program at MASSTC.

3.3.2 Objectives

The objectives of the installation and start-up phase of the VTP were to:

- Install the Amphidrome™ System in accordance with the instructions;
- Start-up and test the Amphidrome™ System to ensure all processes were operating properly, the PLC and pumps are set for proper automatic operation, and any leaks that occurred during the installation are eliminated;
- Make any modifications needed to achieve operation; and,
- Record and document all installation and start-up conditions prior to beginning the verification test.

3.3.3 Installation and Startup Procedures

A contractor, in conjunction with the BCDHE support team and the FRMA staff, performed the installation of the Amphidrome™ System. The installation was completed in December 1999 as part of an earlier test program. In order to prepare for start-up of the Amphidrome™ System for the ETV verification test, the entire system was emptied of wastewater and cleaned in November and December 2000. Solids were removed from the anoxic/equalization tank, and the Clear Well was drained and flushed. All pumps, lines, and associated equipment were cleaned. The filter media was repeatedly flushed to remove solids from the Reactor. Clean water was recirculated in the unit in December to further clean the media and lines. The entire system was then drained and remained off until the beginning of the start-up period in January.

Startup of the Amphidrome™ System began on January 15, 2001. The anoxic tank was filled with raw wastewater from the dosing channel. The dosing sequence was started with a setting of 15 doses of wastewater per day, with a target of 26.67 gallons of wastewater per dose. This dose setting provided a target total daily flow of 400 gallons per day.

The system was monitored during the startup period (January 15 through March 12, 2001) by visual observation of the system, routine calibration of the dosing system, and the collection of influent and effluent samples. Samples for analysis were collected during weeks two, three, five, seven and eight (two sets) of the startup period. Influent samples were analyzed for pH, alkalinity, temperature, BOD_5, TKN, NH_3, and TSS. The effluent was also analyzed for pH, alkalinity, temperature, $CBOD_5$, TKN, NH_3, TSS, NO_2, NO_3, and DO. Procedures for sample collection, analytical methods, and other monitoring procedures were the same procedures used during the one-year verification period. These procedures are described later in this section.

3.4 Verification Testing - Procedures

3.4.1 Introduction

The verification test procedures were designed to verify nitrogen reduction by the Amphidrome™ System. The verification test consisted of a thirteen-month test period, incorporating five stress periods with varying stress conditions simulating real household conditions. Dosing volume was set based on the design capacity of the Amphidrome™ System. Monitoring for nitrogen reduction was accomplished by measurement of nitrogen species (TKN, NH_4, NO_2, NO_3). Carbonaceous biochemical oxygen demand ($CBOD_5$) and other basic parameters (pH, alkalinity, TSS, temperature) were monitored to provide information on overall treatment performance. Operational characteristics such as electric use, residuals generation, noise and odor were also monitored.

Verification results and observations are presented in Section 4 of this Verification Report.

3.4.2 Objectives

The objectives of the verification test were to:

- Determine nitrogen reduction performance of the Amphidrome™ System;
- Monitor removal of other oxygen-using contaminants (BOD_5, $CBOD_5$, TSS);
- Determine operation and maintenance characteristics of the technology; and,
- Assess chemical usage, energy usage, generation of byproducts or residuals, noise and odors.

3.4.3 System Operation- Flow Patterns and Loading Rates

The flow and loading patterns used during the thirteen-month verification test were designed in accordance with the Protocol, as described in the VTP (Appendix B). The flow pattern was designed to simulate the flow from a "normal" household. Several special stress test periods were also incorporated into the test program.

3.4.3.1 Influent Flow Pattern

The influent flow dosed to Amphidrome™ System was controlled by the use of timed pump operation. The dosing pump was set to provide 15 doses of equal volume (target – 26.7 gallons per dose) in accordance with the following schedule:

- 6 a.m. – 9 a.m. Approximately 33 percent of total daily flow in 5 doses
- 11 a.m. – 2 p.m. Approximately 27 percent of total daily flow in 4 doses

- 5 p.m. – 8 p.m. Approximately 40 percent of total daily flow in 6 doses

The influent dosing pump was controlled by a programmable logic controller, which permitted timing of the fifteen individual doses to within one second. The pump flow rate and time setting was calibrated by sequencing the dosing pump for one cycle and collecting the entire volume of flow in a "calibrated" barrel. The barrel was initially calibrated by placing measured volume of water into it. The dosing flow volume was checked by this calibration method at least twice per week. Calibration results were recorded in the field logbook.

The initial total daily flow to the Amphidrome™ System was targeted to be 400 gallons per day (26.7 gallons per dose). After each calibration test, the measured volume was compared to this target rate. If the volume was more than 10 percent above or below the target, the pump run time was increased or decreased to adjust the volume per dose back to the target volume. If the run time was changed, then a second calibration was performed to determine the total volume for the new timer setting. The QC requirement for the dosing volume was 100 ± 10 percent of the target flow (400 gallons per day) based on a thirty (30) day average, with the exception of periods of stress testing. All calibration tests were recorded in the field logbook.

In addition to the twice-weekly direct calibrations, the MASSTC PLC system results were checked on a daily basis. The MASSTC PLC system recorded the number of doses delivered each day for each pump operated by the system. The MASSTC PLC was checked to confirm that 15 doses were delivered each day. The system was also checked to ensure that the start and stop times were set properly. Any changes made to the settings or problems with dose cycles were recorded in the field log.

Flow information was entered into a spreadsheet that showed each day of operation, the pump run time, the gallons pumped per dose, and the number of doses delivered to the System.

3.4.3.2 Stress Testing Procedures

One stress test was performed during the verification test following every two months of operation at the normal design loading. Five stress scenarios were run during the thirteen-month evaluation period. These special tests were designed to test the Amphidrome™ System response to differing load conditions and a power/equipment failure.

Stress testing included the following simulations:

- Washday stress
- Working Parent stress
- Low Load stress
- Power/Equipment Failure stress
- Vacation stress

Washday stress simulation consisted of three (3) washdays in a five (5) day period, with each washday separated by a 24-hour period of dosing at the normal design loading rate. During a washday, the system received the normal flow pattern; however, during the course of the first two (2) dosing periods per day, the hydraulic loading included three (3) wash loads [three (3) wash cycles and six (6) rinse cycles]. The volume of wash load flow was 28 gallons per wash load. The hydraulic loading rate was adjusted so that the loading on washdays did not exceed the design loading rate. Common detergent (Arm and Hammer Fabri-care) and non-chlorine bleach was added to each wash load at the manufacturer recommended amount.

The Working Parent stress simulation consisted of five (5) consecutive days when the Amphidrome™ System was subjected to a flow pattern where approximately 40 percent of the total daily flow was dosed between 6 a.m. and 9 a.m., and approximately 60 percent of the total daily flow was dosed between 5 p.m. and 8 p.m. This simulation also included one (1) wash load [one (1) wash cycle and two (2) rinse cycles] during the evening dose cycle. The hydraulic loading did not exceed the design loading rate during the stress test period.

The Low Load stress simulation consisted of testing the unit at 50 percent of the target flow (200 gallons per day) loading for a period of 21 days. Approximately 35 percent of the total daily flow was dosed between 6 a.m. and 11 a.m., approximately 25 percent of the flow was dosed between 11 a.m. and 4 p.m., and approximately 40 percent of the flow was dosed between 5 p.m. and 8 p.m.

The Power/Equipment Failure stress simulation consisted of a standard daily flow pattern until 8 p.m. on the day when the Power/Equipment Failure stress was initiated. Power to the Amphidrome™ System was turned off at 9 p.m. and the flow pattern was discontinued for 48 hours. After the 48-hour period, power was restored and the system dosed with approximately 60 percent of the total daily flow over a three (3) hour period, which included one (1) wash load [one (1) wash cycle and two (2) rinse cycles].

The Vacation stress simulation consisted of a flow pattern where, on the day that the stress is initiated, approximately 35 percent of the total daily flow was dosed between 6 a.m. and 9 a.m. and approximately 25 percent of the total daily flow was received between 11 a.m. and 2 p.m. The flow pattern was discontinued for eight (8) consecutive days, with power continuing to be supplied to the technology. Between 5 p.m. and 8 p.m. of the ninth day, the technology was dosed with 60 percent of the total daily flow, which included three (3) wash loads [three (3) wash cycles and six (6) rinse cycles].

<u>3.4.3.3 Sampling Locations, Approach, and Frequency</u>

3.4.3.3.1 Influent Sampling Location

Influent wastewater was sampled from the dosing channel at a point near the Amphidrome™ System dosing pump intake, approximately four to six inches from the channel floor to ensure a representative sample of the wastewater was obtained. The influent sampling site selection was based on the layout of the dosing channel at the MASSTC facility. Screened wastewater enters the sixty-five foot long dosing channel via two pipes midway between the channel end and the channel outlet. Dosing pumps for individual systems are located in-line along the dosing channel.

3.4.3.3.2 Amphidrome™ System Effluent Sampling Location

For the Amphidrome™ System effluent, the sampling site was located in the normal effluent pipe from the Clear Well. During installation and setup, a sampling point was constructed in the distribution box where the effluent from the two-inch force main from the system Clear Well discharged to the MASSTC sewer line. The sampling point was installed in the effluent pipe. The sampling point was located so that it could be cleaned of any attached and settled solids. Cleaning of the sampling location, by brushing to remove any accumulated solids, was performed prior to each sampling period. This cleaning was performed to remove biomass that tended to grow in the effluent pipe sampling location during the weeks between sampling events. Cleaning would not be required in normal system, as the sampling location in the discharge pipe was installed for the verification test only and would not be present in a normal installation.

3.4.3.3.3 Sampling Procedures

Both grab and 24-hour flow weighted composite samples were collected at the influent and effluent sampling locations. Grab samples were collected from both locations for the measurement of pH and temperature. Dissolved oxygen was measured at the treated effluent location when flow across the sampling point was occurring. The grab samples were collected by dipping a sample collection bottle into the flow at the same location as the automatic sampler used for composite sample collection. The sample bottle was labeled with the sampling location, time and date. All pH and temperature measurements were performed at the on-site laboratory immediately after sample collection.

Composite samples were collected using automated samplers at each sample collection point. The influent automated sampler was programmed to draw equal volumes of sample from the waste treatment stream at the same frequency and timing as influent wastewater doses. Samples taken in this manner were therefore flow proportional. The effluent sampler timing was set to correspond to the passage of a flow through the Amphidrome™ System discharge line. Since the Amphidrome™ System only discharged once per day, the sampler was set to collect multiple samples during the daily discharge cycle. The automatic samplers were calibrated before each use and the volume of sample collected was checked to ensure that the proper number of individual samples was collected in the composite container. Detailed sampling procedures are described in the MASSTC SOPs (Appendix C).

Table 3-2 shows a summary of the sampling matrix for the verification test.

Table 3-2. Sampling Matrix

		Sample Location		
PARAMETER	**SAMPLE TYPE**	**INFLUENT**	**FINAL EFFLUENT**	**TESTING LOCATION**
BOD_5	24 Hour composite	√		Laboratory
$CBOD_5$	24 Hour composite		√	Laboratory
Suspended Solids	24 Hour composite	√	√	Laboratory
pH	Grab	√	√	Test Site
Temperature (°C)	Grab	√	√	Test Site
Alkalinity (as $CaCO_3$)	24 Hour composite	√	√	Laboratory
Dissolved Oxygen	Grab	√	√	Test Site
TKN (as N)	24 Hour composite	√	√	Laboratory
Ammonia (as N)	24 Hour composite	√	√	Laboratory
Total Nitrate(as N)	24 Hour composite		√	Laboratory
Total Nitrite (as N)	24 Hour composite		√	Laboratory

3.4.3.3.4 Sampling Frequency

Table 3-3 shows a summary of the sampling schedule followed during the test. Sample frequency followed the VTP, and included sampling under design flow conditions on a monthly basis and more frequent sampling during the special stress test periods.

Normal Monthly Frequency

Samples of the influent and effluent were collected at least once per month for the thirteen-month test period (March 2001 – April 2002). The initial VTP was designed for a twelve-month test program; however, the test period was extended for one additional month to provide data for the month of April when temperatures were expected to be higher

Stress Test Frequency

Samples were collected on the day each stress simulation was initiated and when approximately 50 percent of each stress sequence was completed. For the Vacation and Power/Equipment Failure stresses, there is no 50 percent sampling. Beginning twenty-four (24) hours after the completion of Washday, Working Parent, Low Load, and Vacation stress scenarios, samples were collected for six (6) consecutive days. Beginning forty-eight (48) hours after the completion of the Power/Equipment Failure stress, samples were collected for five (5) consecutive days.

Final Week

Samples were also collected for five (5) consecutive days at the end of the yearlong evaluation period.

The decision was made to extend the test period of one additional month to monitor changes in the system that would be influenced by the temperature of the wastewater. Therefore, there was one additional set of samples (April 17, 2002) collected after the five-day sampling of the "final week."

3.4.3.3.5 Sample Handling and Transport

Samples in the automatic samplers were collected with ice surrounding the sample bottle to keep the sample cool. The composite sample container was retrieved at the end of the sampling period, shaken vigorously, and poured into new bottles that were labeled for the various scheduled analysis. Sample bottles used for TKN and ammonia analyses were supplied by the laboratory with preservative. Sample container type, sample volumes, holding times, and sample handling and labeling procedures were detailed in the VTP (Appendix B) and in the MASSTC SOP, Attachment I (Appendix C).

BCDHE personnel transported the samples to the BCDHE laboratory via automobile. The samples were packed in coolers with ice to maintain the temperature of all transported samples at 4 °C. Subsample containers analyzed at the GAI laboratory were transported from BCDHE laboratory to GAI by GAI personnel. Travel time to BCDHE was approximately 40 minutes. Travel time from BCDHE to GAI was approximately 45 minutes.

Table 3-3. Sampling Schedule for Amphidrome™ System

Month/Day	Sampling Event
Jan 23 and 31, 2001	Startup – 2 sampling events
February 14 and 28, 2001	Startup – 2 sampling events
March 7 and 13, 2001	Startup – 2 sampling events
March 21, 2001	Normal monthly sample
April 18, 2001	Normal monthly sample
May 8,10, and 13-18, 2001	Wash day stress - 8 samples
June 6, 2001	Normal monthly sample
July 3, 2001	Normal monthly sample
July 10, 13, and 15-20, 2001	Working Parent stress – 8 samples
August 1, 2001	Normal monthly sample
September 5, 2001	Normal monthly sample
September 18, 27 and October 9-14, 2001	Low Loading stress – 8 Samples
October 31, 2001	Normal monthly sample
November 28, 2001	Normal monthly sample
December 3, and 9-13, 2001	Power Failure stress – 6 samples
December 28, 2001	Normal monthly sample
January 16, 2002	Normal monthly sample
February 4 and 14-19, 2002	Vacation Stress – 7 samples
March 5-8, 2002 and March 11, 2002	Final week sampling – 5 samples
April 17, 2002	Additional monthly sample

3.4.3.4 Residuals Monitoring and Sampling

Solids in the influent wastewater settle in the primary (anoxic) tank and accumulate slowly over time. Byproducts or residuals generated within the Reactor are also returned to the anoxic tank with the return and backwash water pumped from the Clear Well. Measurements of solids depth in the anoxic tank were made on February 4, 2002 and March 8, 2002, after thirteen and fourteen months of operation (includes the startup period). The Clear Well was checked for solids accumulation on March 8, 2002.

A coring solids measurement tool (Core Pro) was used to estimate the depth of solids/, liquid, and scum layers in the 1,500 gallon anoxic/equalization tank. The sampling device is a clear tube with a check valve on the bottom. The tube is pushed through the solids to the bottom of the tank. The valve closes and the entire sample column, water and solids, are removed from the tank. The column height is checked to ensue no sample has leaked from the device. The solids depth is then determined by measuring the height of the solids in the clear tube using a tape measure or ruler. This approach gives a direct measurement of depth of solids. The thickness of any scum layer present is measured by ruler or tape also. Three measurements of the solids depth and scum depth were made at each of the two access manholes.

Samples of solids were recovered from the Core Pro during the final measurement period by emptying the probe contents into a clean container and sending the sample to the BCDHE laboratory for VSS and TSS analysis. This sample included both the solids in the tube and the water present in the column as well. Thus, the concentration measurements for solids represent the concentration as if the entire septic tank were mixed. To estimate the solids concentration in the settled material at the bottom of the tank, the depth of solids and the depth of the water column need to be accounted for and the ratio used to calculate an estimated solids percent.

3.4.4 Analytical Testing and Record Keeping

As shown in Table 3-3, fifty-three (53) samples of the influent and effluent were collected for the Amphidrome™ System over the thirteen-month verification period. Table 3-2 presented the parameter list. Samples included grab and composite samples for each sampling day. Industry standard procedures (USEPA Methods [5,6] or Standard Methods [7]) were used for all sample analysis. The methods used for each constituent are shown in Table 3-4. Temperature, dissolved oxygen and pH were measured onsite. All other analyses were performed by off site laboratories. The Barnstable County Department of Health and Environment Laboratory performed the analyses for alkalinity, total suspended solids, biochemical oxygen demand (BOD_5), carbonaceous biochemical oxygen demand ($CBOD_5$), nitrite, and nitrate. Groundwater Analytical, Inc. (GAI) was responsible for the analyses for Total Kjeldahl Nitrogen and ammonia.

Table 3-4. Summary of Analytical Methods and Precision and Accuracy Requirements

Parameter	Facility	Acceptance Criteria	Acceptance Criteria	Analytical Method
		Duplicates (%)	Spikes (%)	
pH	On-site	N/A	N/A	SM #423
Temperature (°C)	On-site	N/A	N/A	SM #2550
Dissolved Oxygen	On-site	N/A	N/A	SM #4500
Suspended Solids	BCDHE Laboratory	80-120	N/A	SM #2540 D
$CBOD_5$	BCDHE Laboratory	80-120	N/A	SM #5210 B
Alkalinity	BCDHE Laboratory	80-120	N/A	SM #2320
Total Nitrite (as N)	BCDHE Laboratory	90-110	60-140	EPA 353.3
Total Nitrate (as N)	BCDHE Laboratory	90-110	60-140	EPA 353.3
TKN (as N)	GAI Laboratory	80-120	80-120	EPA 351.4
Ammonia (as N)	GAI Laboratory	80-120	80-120	EPA 350.1

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A Quality Assurance Project Plan was developed as part of the VTP, and provided quality control requirements and systems to ensure the integrity of all sampling and analysis. Precision and accuracy limits for the analytical methods are shown in Table 3-4. The QAPP included procedures for sample chain of custody, calibration of equipment, laboratory standard operating procedures, method blanks, corrective action plan, etc. Additional details are proved in the VTP (Appendix B). Three laboratory audits were also performed during the verification test to confirm that the analytical work was being performed in accordance with the methods and the established QC objectives.

The results of all analyses from the off site laboratories were reported to the TO by hardcopy laboratory reports. The laboratory data are presented in Appendix D. The off site laboratories also provided QA/QC data for the data sets. This data is included in Appendix D with the laboratory reports. The on site laboratory maintained a laboratory logbook to record the results of all analyses performed at the site. Copies of the on-site laboratory logbook are presented in Appendix E.

The data received from the laboratories were summarized in an Excel spreadsheet by BCDHE personnel at the test site. The data were checked against the original laboratory reports by the site staff, and were checked by NSF to ensure the data was accurately entered. The spreadsheets are included in Appendix F.

3.4.5 Operation and Maintenance Performance

Both quantitative and qualitative performance of the Amphidrome™ System was evaluated during the verification test. A field log was maintained that included all observations made during the startup of the unit and throughout the verification test. Observations regarding the condition of the system, operation, or any problems that required resolution were recorded in the log by the field personnel.

Observation and measurement of operating parameters included electric use, chemical use, noise, odor, and evaluation of mechanical components, electrical/instrumentation components, and by-product volumes and characteristics.

3.4.5.1 Electric Use

Electrical use was monitored by a dedicated electric meter serving the Amphidrome™ System. The meter reading was recorded twice weekly in the field log by BCDHE personnel. The meter manufacturer, model number, and any claimed accuracy for the meter was recorded in the Field Log. At the end of the testing period, the electric meter was returned to the manufacturer for calibration and the calibration data entered in the Field Log.

3.4.5.2 Chemical Use

For this ETV testing, the Amphidrome™ Unit did not use any process chemicals to achieve treatment.

3.4.5.3 Noise

Noise levels associated with mechanical equipment were measured once during the verification period, using a decibel meter to measure the noise level. Measurements were taken one meter from the unit and one and a half meters above the ground, at 90° intervals in four (4) directions. The meter was calibrated prior to use and the meter readings were recorded in the field log. Duplicate measurements at each quadrant were made to account for variations in ambient sound levels.

3.4.5.4 Odors

Odor observations were made during the verification test, beginning in September 2001 and ending in March 2002. The observation was qualitative based on odor strength (intensity) and type (attribute). Intensity was stated as not discernable; barely detectable; moderate; or strong. Observations were made during periods of low wind velocity (<10 knots). The observer stood upright at a distance of three (3) feet from the treatment unit, at 90° intervals in four (4) directions. All observations were made by the same BCDHE employee.

3.4.5.5 Mechanical Components

Performance and reliability of the mechanical components, such as wastewater pumps, were observed and documented during the test period. These observations included recording in the Field Log of equipment failure rates, replacement rates, and the existence and use of duplicate or standby equipment.

3.4.5.6 Electrical/Instrumentation Components

Electrical components, particularly those that might be adversely affected by the corrosive atmosphere of a wastewater treatment process, and instrumentation and alarm systems were monitored for performance and durability during the course of verification testing. Observations of any physical deterioration were noted in the Field Log. Any electrical equipment failures, replacements, and the existence and use of duplicate or standby equipment were recorded in the Field Log.

4.0 Results and Discussion

4.1 Introduction

Evaluation of the Amphidrome™ System at MASSTC began on January 15, 2001. The system was filled with wastewater, the pumps were activated, and the initial dosing cycles started. The startup period continued until March 12, 2001. Six samples of the influent and effluent were collected during the startup period. Verification testing began on March 13, 2001 and continued for 13 months, until April 17, 2002. The extra month of dosing and sampling (thirteen months versus the planned twelve months) was added to the test to obtain data on the system response as the temperatures began to rise in the spring. During the verification test, 53 sets of influent and effluent samples were collected to determine the system performance.

This chapter presents the results of the sampling and analysis of the influent and effluent to/from the unit, a discussion of the results, and observations on the operation and maintenance of the Amphidrome™ System during startup and normal operation. Summary of results are presented in these sections. Complete copies of all spreadsheets with individual daily, weekly, or monthly results are presented in Appendix F.

4.2 Startup Test Period

The startup period provided time for the Amphidrome™ System to develop a biological growth and acclimate to the site-specific wastewater. The startup also provided an opportunity for the system to be adjusted, as needed, to optimize performance at the site. These first eight weeks of operation also provided site personnel an opportunity to become familiar with the system operation and maintenance requirements. Samples were collected during weeks 2, 3, 5, 7 and 8 (2 sets) of the startup period.

4.2.1 Startup Flow Conditions

The flow conditions for the Amphidrome™ System were established at the target capacity of 400 gallons per day in accordance with the VTP. The dosing pump was set to deliver 15 doses per day at approximately 26.7 gallons per dose. Five (5) doses were delivered between 6 a.m. and 9 a.m., four (4) doses between 11 a.m. and 2 p.m., and six (6) doses between 5 p.m. and 8 p.m. In early September, it was discovered that a MASSTC PLC problem resulted in the actual dosing rate being 14 doses per day, as the first dose in the morning was not occurring. Thus, for the startup period and approximately six months (March 13 to September 4) of the verification test, the unit received 14 doses per day, four (4) in the morning, four (4) mid day, and six (6) in the early evening. The average flow for the startup period was 367 gpd, which was within the $\pm$ 10 percent (360-440 gpd) of the design flow on a monthly basis specified for the test. The volume of wastewater dosed to the system during the startup remained within the monthly average range of 360 to 440 gpd and only minor adjustments to the dosing pump run time were required. Table 4-1 shows a summary of the flow volumes during the startup period. The daily flow records are in Appendix F.

Table 4-1. Flow – Volume Data during the Startup Period

Date	Average		Actual Daily Volume
	Doses/day	Gallons/dose	(Gallons)
Jan 15 – 21	14	26.6	372
Jan 22 - 27	14	26.5	371
Jan 28 - 30	14	26.2	367
Jan 31 – Feb 3	14	26.1	365
Feb 4 - 13	14	26.0	364
Feb 14 – 17	14	26.8	375
Feb 18 - 20	14	25.8	361
Feb 21	14	31.0	434
Feb 22 - 23	14	25.7	360
Feb 24 – 25	14	19.0	266
Feb 26	14	28.0	392
Feb 27	14	27.5	385
Feb 28	14	29.0	406
Mar 1 – 3	14	26.5	371
Mar 4 – 6	14	27.0	378
Mar 7 – 10	14	26.3	368
Mar 11 –12	14	26.0	364

4.2.2 Startup Analytical Results

The results of the influent and effluent monitoring during the startup period are shown Tables 4-2 and 4-3. The first sets of samples were taken eighteen (18) days after the System was started. The initial data showed that the System reduced the $CBOD_5$ and TSS to 15 mg/L and 1 mg/L, respectively, and the Amphidrome™ System was removing some of the total nitrogen (34 mg/L in the influent, 21 mg/L in the effluent). Observations and additional sampling to determine the condition of the System continued for the next six weeks. The only adjustment made to the System during startup was to the clock on the PLC, which was off by a couple of hours and was reset. The treatment performance continued to improve through the end of the startup period.

At the end of the eight weeks allotted for the startup, the verification test period began. The biological growth appeared to be fully established. The $CBOD_5$ of the effluent was 5.0 mg/L and TSS was 4 mg/L on the last sampling day before the start of the verification test. The System was removing some organic and ammonia nitrogen, with TKN of 20 mg/L and ammonia nitrogen of 19 mg/L in effluent, compared to influent levels of 40 mg/L TKN and 25 mg/L ammonia. Denitrification was also starting to occur, as shown by the nitrate, nitrite, and the total nitrogen concentrations in the effluent. On March 13, 2002, nitrate and nitrite (combined) was 4.0 mg/L, and the Total Nitrogen was 24 mg/L in the effluent versus 40 mg/L in the influent (a removal of 40 percent). While there were clear signs that nitrification and denitrification were occurring, the processes did not appear to be firmly established. The pH in the effluent was lower than the influent as is expected when nitrification occurs. However, the overall alkalinity balance showed that less alkalinity was being removed/replaced than would be predicted in a well-established system. The startup began in the middle of winter and influent wastewater temperatures were fairly low (7.1 to 8.2 °C) throughout the period. These low temperatures are most likely a principal cause of the slow startup for the nitrogen removal processes.

Table 4-2. Influent Wastewater Quality - Startup Period

Date	BOD_5 (mg/L)	TSS (mg/L)	Alkalinity (mg/L)	pH (S.U.)	Ammonia (mg/L)	TKN (mg/L)	TN (mg/L)	DO (mg/L)	Influent Temp. (°C)
01/23/01	140	120	180	7.6	26	34	34	0.2	8.2
01/31/01	280	280	170	7.2	24	41	41	1.2	8.0
02/14/01	180	190	190	7.5	26	42	42	NS	NS
02/28/01	200	190	200	7.7	28	46	46	0.8	7.1
03/07/01	180	130	160	7.4	23	34	34	1.4	7.4
03/13/01	160	130	180	7.4	25	40	40	1.1	7.8

N/S – no sample

Table 4-3. Amphidrome™ System Effluent Quality during the Startup Period

Date	$CBOD_5$ (mg/L)	TSS (mg/L)	Alkalinity (mg/L)	pH (S.U.)	Ammonia (mg/L)	TKN (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	TN (mg/L)	DO (mg/L)	Discharge Temp (°C)
01/23/01	15	1	150	7.7	17	20	0.80	<0.05	21	NS	NS
01/31/01	12	5	180	7.3	23	25	0.70	<0.05	26	7.5	NS
02/14/01	13	5	170	7.4	23	27	1.3	0.13	28	NS	NS
02/28/01	7.0	3	170	7.5	21	25	1.7	0.45	27	6.7	NS
03/07/01	4.0	6	160	7.4	20	24	2.2	0.84	27	NS	NS
03/13/01	5.0	4	150	7.2	19	20	2.4	1.6	24	NS	NS

N/S – no sample

4.2.3 Startup Operating Conditions

The Amphidrome™ System was started using the FRMA recommended settings. The PLC controlled all pump times, aeration cycles, and overall system operation. The return pump (pumps treated wastewater from the Clear Well back through the media and into the anoxic tank) was setup to operate in normal mode, activating each hour, 24 hours per day. The aeration system was initially set to add air for seven and one half minutes and be off for fifteen minutes The discharge pump was set to discharge treated wastewater once per day. The backwash cycle was set to backwash the unit every once per week.

No changes were made to the System during the startup period. Regular observations showed that biological growth was being established and the visual effluent quality was good. FRMA staff visited the site periodically during startup to check on the System. There were no mechanical problems during the startup, and overall, the Amphidrome™ System started up without any significant difficulty.

4.3 Verification Test

In accordance with the startup period set forth in the VTP and the Protocol, the verification test was started officially on March 13, 2001. A last startup sample was collected on March 12-13, 2001. All results for the balance of the test were considered part of the verification test period. The data presented for the verification results do not include data from the startup period.

As stated above, there were no changes made to the basic operation of the system during the startup period. All Amphidrome™ System operating parameters (pumps, alarms, etc.) remained the same as during the initial startup period. During the second and third month of the verification test (April and May), FRMA adjusted the airflow cycle and the backwash cycle. On May 15 the backwash cycle was changed from once per week to 5 times per week. The backwash setting remained the same for the duration of the test. On May 24 the timer for the return flow pump was changed from 30 seconds to 60 seconds, and the timer for the backwash pump was changed from 60 seconds to 90 seconds. The time cycle settings were adjusted to try to improve performance. These settings were changed back to the original settings on June 1. The fixed air run time was reduced by 10 percent in October 25, 2001 to 410 seconds per cycle to try to improve denitrification. The reduced aeration time was maintained for the remainder of the test.

4.3.1 Verification Test - Flow Conditions

The dosing sequence (15 doses per day, 26.7 gallons per dose) was performed every day from March 13 through September 3, 2001, except during the stress periods. Volume per dose and total daily volume varied only slightly during this period. In September, it was discovered that while the PLC was set to deliver 15 doses per day and showed 15 doses being delivered, only 14 doses were actually being pumped to the unit. The first dose each morning was being missed because of a timer issue with the start of wastewater flow at the test site. Beginning September 4, 2001, the problem was resolved and daily flow was dosed 15 times per day as originally specified in the VTP. The lower flow being dosed to the unit for the first six months was still within the specification that flow be ± 10 percent of the design flow on a monthly average basis (design flow 400 gpd). Table 4-4 shows the average monthly volumes for the verification period. As this data shows, the actual wastewater volume dosed to the Amphidrome™ was very close to the targeted volume of 400 gallons per day for the last seven months of the test.

Table 4-4. Amphidrome™ System Influent Volume Summary

	Target		Ave Monthly	
Mon/Year	Gallon/dose	Doses/day	Gallon/dose	Gallon/day
Mar-01	26.7	14	26.3	369
Apr-01	26.7	14	26.7	373
May-01	26.7	14	27.1	380
Jun-01	26.7	14	26.8	376
Jul-01	26.7	14	26.9	377
Aug-01	26.7	14	26.4	370
Sep-01	26.7	15(1)	26.8	403(2)
Oct-01	26.7	15	26.1	392(2)
Nov-01	26.7	15	25.2	379
Dec-01	26.7	15	26.7	400(3)
Jan-02	26.7	15	26.3	395
Feb-02	26.7	15	26.2	393(4)
Mar-02	26.7	15	26.2	393
Apr-02	26.7	15	26.3	394
Average			26.4	385
Maximum			27.1	403
Minimum			25.2	369
Std. Dev.			0.47	11.5

(1) The timer and PLC issue was fixed on September 4. Fifteen doses were delivered beginning on September 4, 2001.
(2) September/October – Low Load test run in September and October; average flow data for September and October does not include the low flow days. Only normal flow days are included. During the Low Load test, flow was set at 50 percent of normal flow. Actual average flow during the Low Load test (September 17 to October 7) was 200 gpd.
(3) December – During the Power Failure Stress Test there is one day with no flow and one day with reduced flow. These data point are not included in the monthly average.
(4) February 2002 – Vacation test – 10-day test; no flow for 8 days,
Only nine doses on first and last day; Low or no flow days excluded from the calculation of monthly averages

4.3.2 $BOD_5/CBOD_5$ and Suspended Solids Results

Figures 4-1 and 4-2 show the results for $BOD_5/CBOD_5$ and total suspended solids (TSS) in the influent and effluent for the verification test. Table 4-5 presents same results with a summary of the data (average, median, maximum, minimum, standard deviation). $CBOD_5$ was measured in the effluent as required in the Protocol. The use of the $CBOD_5$ analysis was specified because the effluent from nutrient reduction systems was expected to be low in oxygen demanding organics, and have a large number of nitrifying organisms, which can cause nitrification to occur during the five days of the test. The $CBOD_5$ analysis inhibits nitrification during the analysis, and provides a better measurement of the oxygen demanding organics in the effluent. The BOD_5 test was used for the influent, which had much higher levels of oxygen demanding organics, and was expected to have a very low population of nitrifying organisms. In the standard BOD5 test, it is assumed that little nitrification occurs within the five days of the test, so the oxygen demanding organics are the primary compounds measured in the wastewater influent. Using the BOD5 of the influent and the CBOD5 in the effluent should provide a good comparison of the oxygen demanding organics removal of the system.

The verification test emphasizes sampling during and following the major stress periods. This results in a large number of samples being clustered during five periods, with the remaining samples spread over the remaining months (monthly sampling). Therefore, impacts of the stress test or an upset condition occurring during the concentrated sampling can have an impact on the calculation of average values. Both average and median results are presented in Table 4-5, as the median values compared to average values can help in analyzing these impacts.

The influent wastewater had an average BOD5 of 210 mg/L and a median BOD5 of 200 mg/L. The average influent TSS was 150 mg/L with a median concentration of 130 mg/L. The Amphidrome™ System effluent had an average CBOD5 of 5.0 mg/L and a median CBOD5 of 4.3 mg/L. The average effluent TSS concentration was 5 mg/L, with a median concentration of 3 mg/L. The Amphidrome™ System averaged 96 percent reduction of BOD5/CBOD5 with a median removal of 98 percent. TSS removal averaged 97 percent over the thirteen-month period, with a median removal of 98 percent. Except for two samples, the effluent CBOD5 concentrations typically ranged from 1 to 10 mg/L, and, except for five samples, the effluent TSS ranged from 1 to 10 mg/L.

At the end of the startup period, the Amphidrome™ System was removing TSS and CBOD5 at a high level of efficiency. The data suggests that a well-acclimated microbial population was present and the System was working well. The System came on line quickly and was showing good results for CBOD5 and TSS within a few days.

By the start of the first stress test in May 2001 (Washday stress), the System was producing effluent concentrations of 2.4 mg/L $CBOD_5$ and < 1 mg/L for TSS. After the Washday stress test ended, the effluent $CBOD_5$ increased to 10 mg/L for one day (May 14). The effluent concentration dropped immediately to 1.0 mg/L on the next day (May 15), and remained low for the balance of the stress test monitoring period. This one elevated concentration corresponded to a period when the influent BOD_5 spiked to 340 mg/L. Overall, the Washday stress did not appear to have a significant impact on the $CBOD_5$ and TSS performance. Post stress period monitoring showed good, steady performance through the end of May and June. Effluent $CBOD_5$ was less than 5 mg/L and TSS less than 6 mg/L (typically < 1 to 3 mg/L) during the two-month period.

The Working Parent stress test was started on July 9, 2001 and was completed on July 13, 2001. A July monthly sample taken the week before on July 3 indicated a possible upset condition as $CBOD_5$ increased to 10 mg/L and TSS to 26 mg/L in the effluent. As will be discussed in the nitrogen section below, the nitrogen removal was clearly impacted by some type of upset condition in late June or early July. The impact on BOD_5 and TSS performance was short lived and removal of both $CBOD_5$ and TSS improved immediately. During and following the Working Parent Stress test, the $CBOD_5$ and TSS effluent concentrations varied from 3 to 19 mg/L, with most results being less than 10 mg/L. The System was not as steady as during earlier and later periods, but overall treatment of $CBOD_5$ and TSS was good. Conditions prior to Working Parent stress appeared to cause the instability on the system and not the actual stress test. System recovery may have been slightly slowed by the stress test, but the system did recover.

After the sampling on September 1, the system became very steady with respect to $CBOD_5$ and TSS removal. All results show effluent concentrations below 10 mg/L and in the case of TSS all but one sample was less than 5 mg/L. The Low Load stress test was started on September 18 and had no apparent impact on $CBOD_5$ or TSS performance. The Power/Equipment Failure stress test was initiated on December 3 and, again, removal continued steady. The last stress test, the Vacation stress test was started on February 4. The $CBOD_5$ and TSS results during this period, and through the end of the verification test, remained constant. Once the system had settled down after the late June early July upset condition, performance for organic and suspended solids removal, as measured by $CBOD_5$ and TSS, remained very good.

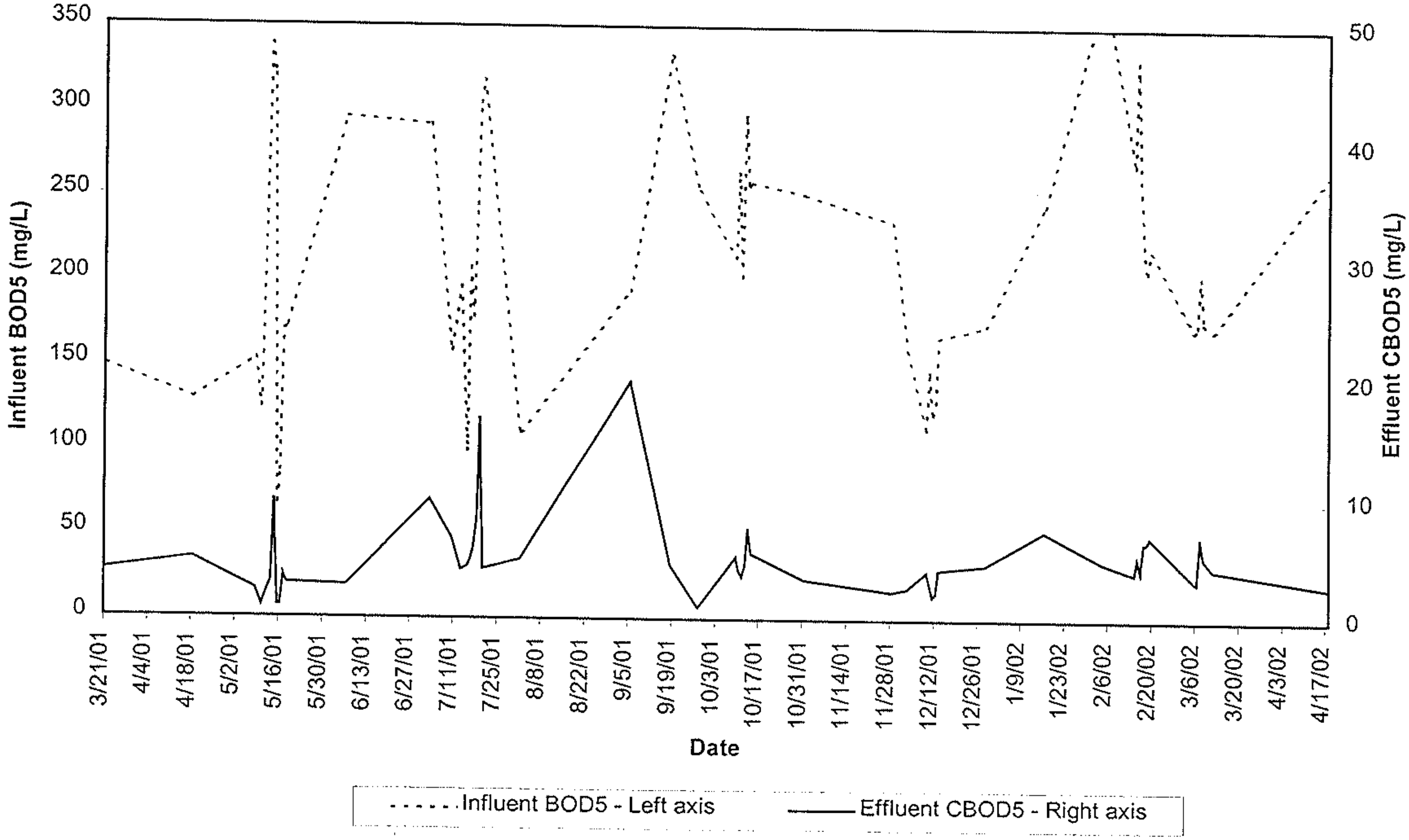

Figure 4-1. Amphidrome™ System BOD_5/$CBOD_5$ Results

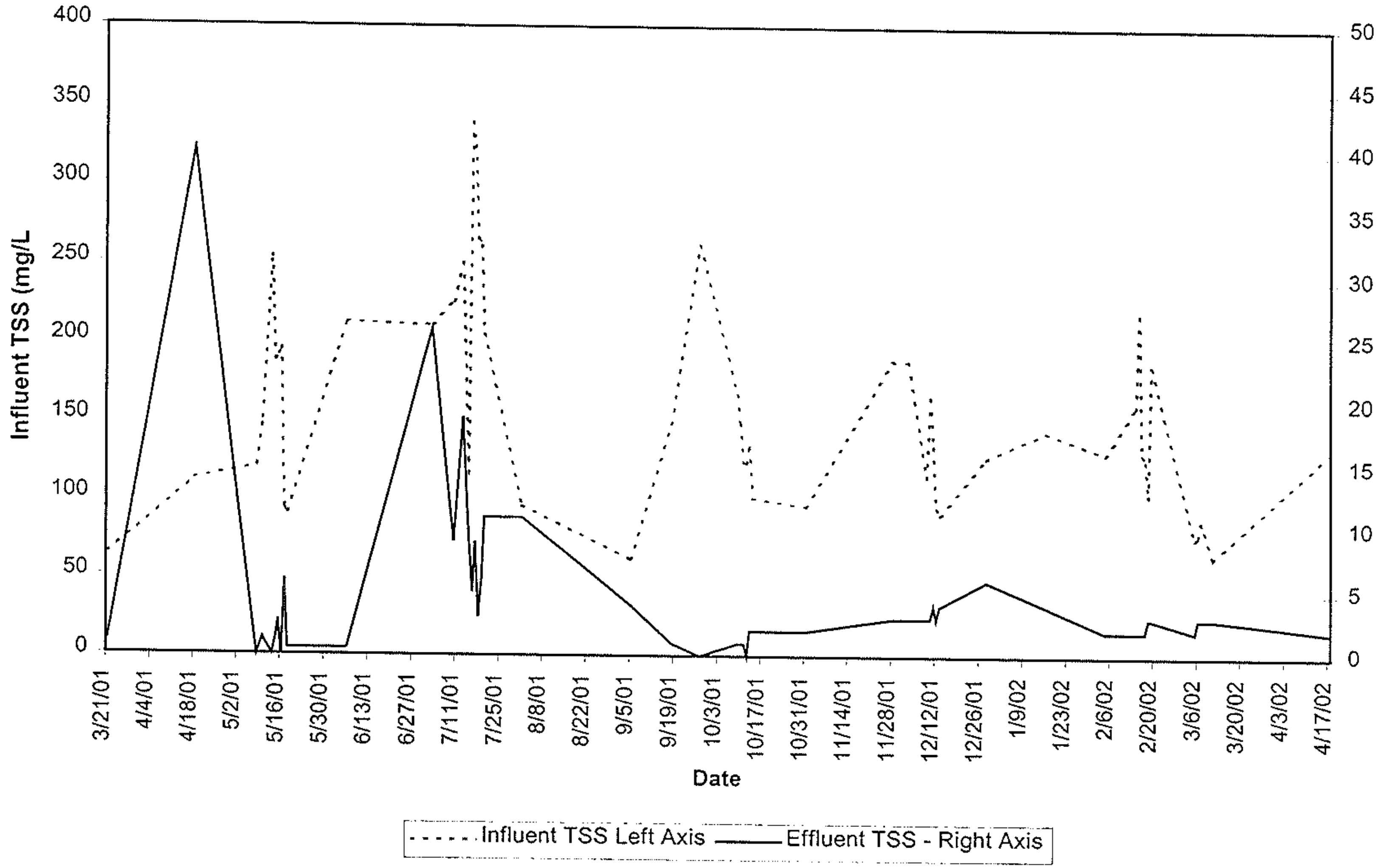

Figure 4-2. Amphidrome™ System Total Suspended Solids Results

Table 4-5. Amphidrome™ System $BOD_5/CBOD_5$ and TSS Results

	BOD_5	$CBOD_5$		TSS		
Date	Influent (mg/L)	Effluent (mg/L)	Removal (Percent)	Influent (mg/L)	Effluent (mg/L)	Removal (Percent)
03/21/01	150	4.0	97	63	1	98
04/18/01	130	5.0	96	110	40	64
05/08/01	150	2.4	98	120	<1.0	>99
05/10/01	120	1.0	99	150	1	99
05/13/01	340	3.1	99	250	<1.0	>99
05/14/01	320	10	97	190	1	99
05/15/01	67	1.0	99	190	3	99
05/16/01	86	1.0	99	200	<1.0	>99
05/17/01	170	3.6	98	92	6	93
05/18/01	170	2.9	98	90	1	99
06/06/01	300	2.8	99	210	1	>99
07/03/01	290	10	97	210	26	88
07/10/01	160	6.8	96	220	9	96
07/13/01	200	4.1	98	250	19	92
07/15/01	99	4.4	96	120	9	92
07/16/01	210	4.9	98	340	5	99
07/17/01	180	6.0	97	320	9	97
07/18/01	240	8.4	97	260	3	99
07/19/01	300	17	94	260	6	98
07/20/01	320	4.2	99	200	11	95
08/01/01	110	5.0	95	96	11	89
09/05/01	190	20	90	61	4	93
09/18/01	330	4.6	99	150	1	99
09/27/01	250	1.0	>99	260	<1.0	>99
10/09/01	210	5.3	98	170	1	99
10/10/01	260	4.2	98	150	1	99
10/11/01	200	3.7	98	120	1	99
10/12/01	300	4.6	98	120	<1.0	>99
10/13/01	260	7.7	97	130	2	99
10/14/01	260	5.6	98	100	2	98

4.3.3 Nitrogen Reduction Performance

4.3.3.1 Results

Figures 4-3 through 4-5 present the results for the TKN, ammonia, and total nitrogen (TN) in the influent and effluent during the verification test. Figure 4-6 shows the results for nitrite and nitrate in the effluent from the Amphidrome™ System. Table 4-6 presents all of the nitrogen results with a summary of the data (average, median, maximum, minimum, standard deviation).

The influent wastewater had an average TKN concentration of 37 mg/L and an average ammonia nitrogen concentration of 23 mg/L, with median concentrations of 37 mg/L and 23 mg/L, respectively. Average TN concentration in the influent was 37 mg/L (median of 37 mg/L), based on the generally accepted assumption that the nitrite and nitrate concentration in the influent was negligible. The Amphidrome™ System effluent had an average TKN concentration of 8.5 mg/L, with a median of 8.3 mg/L. The average ammonia nitrogen concentration in the effluent was 7.0 mg/L, with a median concentration of 6.1 mg/L. The nitrite concentration in the effluent averaged 0.27 mg/L, with a median concentration 0.25 mg/L. Effluent nitrate concentrations averaged 6.4 mg/L over the thirteen-month test, with a median concentration of 5.4 mg/L. Total nitrogen was determined by adding the concentrations of the TKN (organic plus ammonia nitrogen), nitrite and nitrate, resulting in an average TN in the Amphidrome™ System effluent of 15 mg/L for the thirteen-month verification period, with a median concentration of 14 mg/L. The Amphidrome™ System averaged 59 percent reduction of TN for the verification test period, with a median removal of 62 percent.

Alkalinity, pH, dissolved oxygen (DO), and temperature were measured during the verification test. These parameters can provide insight into the condition of the system and can impact total nitrogen removal. Table 4-7 shows the results for alkalinity, DO, and pH. Temperature measurements are shown in Figure 4-7 and Table 4-6.

The pH of the influent was very consistent throughout the test, ranging from pH 7.2 to 7.6 with a median value of 7.4. The effluent from the Amphidrome™ System showed a decrease in pH, but in a similar range, consistently remaining in the pH 6.6 to 7.7 range with a median value of 7.1. The alkalinity of the influent averaged 180 mg/L as $CaCO_3$ with a maximum concentration of 230 mg/L and minimum of 160 mg/L. The effluent alkalinity was consistently lower than the influent (as expected when nitrification/denitrification is occurring), with an average concentration of 110 mg/L and a median concentration 110 mg/L. The effluent alkalinity varied based on the performance of the nitrification and denitrification process.

The Dissolved Oxygen in the influent wastewater was low, as would be expected. The average DO in the influent to the septic tank was 0.3 mg/L, and was less than 1.0 mg/L on all but two days. The Amphidrome™ System is designed to operate as an aerobic/anoxic system, with the blower on the System moving air through the media on a timed basis. During non-aeration periods, FRMA claims the bed goes anoxic to promote denitrification. The DO in the effluent from the Amphidrome™ System was normally in the range of 4 to 6 mg/L with a few days higher or lower (minimum was 2.3 mg/l, maximum was 9.6 mg/L). The average DO was 6.1 mg/L over the thirteen months of verification testing.

4.3.3.2 Discussion

As discussed earlier in the startup section, at the end of the startup period (January 15 to March 12, 2001), the Amphidrome™ System effluent was showing some removal of total nitrogen (40 mg/L influent and 24 mg/L effluent). A well-acclimated microbial population appeared present for the treatment of $CBOD_5$. Both the nitrification and denitrification organisms appeared to be present in the system, based on the removal of TKN and ammonia, and overall removal of Total Nitrogen. Beginning in April and early May the nitrification process became more firmly established as can be seen by the lower ammonia and TKN concentrations in the effluent (10 mg/L or less). Denitrification also was occurring as shown by the effluent Total Nitrogen concentrations, which dropped below 20 mg/L. Based on the assumption that all of the TKN removed is eventually converted to nitrate, nitrate removal was in the range of 14-21 mg/L (March 21 – May 8 data).

Another measure of nitrification and denitrification can be made by the change in effluent alkalinity and pH. The theoretical relationship of alkalinity consumed to TN removed shows that 3.5 mg/L is consumed for each 1 mg/L of TN removed (7.1 mg alkalinity is consumed per 1 mg nitrogen converted to nitrate in the nitrification process, and 3.6 mg alkalinity is produced per mg TN removed by the denitrification process). The individual daily alkalinity data does not balance well with the actual TN data for this test, but on an entire verification test basis, the balance is close. The average measured TN removed was 22 mg/L, whereas the predicted TN removed is 20 mg/L using the alkalinity data. Even though the individual alkalinity mass balances do not accurately predict TN removal levels for this dataset, the information provides an indicator of system conditions. During the April and May period, as the TN removal improved, the alkalinity decreased as would be expected and the effluent pH was lower. By the start of the Washday stress test on May 8, all of the data indicated that both nitrification and denitrification was occurring in the system.

The Washday stress test was run from May 7 through 11, 2001. The System performance during and following the stress period remained steady indicating that the System was not impacted by the stress test. By the end of the monitoring period in May and during early June the performance was very steady with TN concentration in the effluent in the 13 to 15 mg/L range, which represented removal efficiencies of 58 to 71 percent.

On July 3, a routine monthly sample was collected and the data clearly showed that some type of upset had occurred. The nitrification process was severely impacted as shown by influent and effluent ammonia levels of 24 mg/L and 25 mg/L, respectively. The nitrate levels dropped to less than 0.1 mg/L, which would be typical of influent wastewater, and indicating no nitrate was being produced by the nitrifying organism. Further, the alkalinity of the influent and effluent were similar (effluent was actually slightly higher). It was not clear what caused this upset to occur. There was no obvious change in influent wastewater and no changes were made to the Amphidrome™ System. All mechanical parts of the System appeared to operating properly. As discussed earlier, the removal of $CBOD_5$ and TSS was also impacted as shown the July 3, 2001 data.

The Working Parent stress test started on July 9 and continued until July 13, 2001. The System began to recover from the upset with improved $CBOD_5$ and TSS performance, but the nitrification process was much slower in its recovery. Some removal of TKN, ammonia and TN was occurring during the Working Parent stress test monitoring in mid July, but at a lower performance level than during the previous two months. All of the data suggests that whatever caused the loss of the nitrifying population, it occurred before the Working Parent stress test. During the stress test, there was no sign that the stress test itself was having any additional impact on the system.

The monthly samples on August 1 and September 5 showed a significant improvement in the removal of TKN and ammonia indicating that the nitrifying population was re-established. Nitrate levels in the effluent increased somewhat (3.3 to 7.9 mg/L) and TN in the effluent was in the 14 to 15 mg/L range.

The Low Load stress test began on September 17 and continued until October 8, 2002. During this stress period, the nitrification process became very efficient, dropping the TKN and ammonia levels in the effluent to less than 1 mg/L. Nitrate concentrations increased to 14 to 19 mg/L and TN was 14 to 20 mg/L. As the Low Load stress test ended, virtually all of the TN in the effluent was in the form of nitrate. Once the system returned to normal full flow conditions, the TKN and ammonia concentrations in the effluent rose slightly (1.2 to 4.8 mg/L), and nitrate concentrations decreased to 10 to 14 mg/L. Overall, the TN removal performance was steady at the end of the monitoring period with concentrations in the effluent of 10 to 14 mg/L, similar to the results obtained in May prior to the upset.

The Low Load stress test had very little impact on the overall TN removal performance, but did change the balance between the TKN/ammonia and nitrate concentrations in the effluent. TKN and ammonia levels were very low and nitrate levels were elevated. This change may be due to the operational approach used by the Amphidrome™ System. The system provides periods of aeration followed by no aeration in combination with the recycle sequence. With the significantly reduced flow during the Low Load stress test, the amount of aeration relative to the flow was higher, which may have resulted in the improved performance of the nitrifiers in removing TKN and ammonia. However, the denitrification process was not able to remove the additional nitrate, possibly due to additional oxygen being present. Thus, the effluent contained higher levels of nitrate, produced by the improved nitrification in the system. The overall TN performance was steady, only the balance between TKN/ammonia and nitrate was changed. FRMA adjusted the aeration system by reducing the aeration by ten percent (aeration time set to 410 seconds) on October 25 to try to improve the denitrification performance. The reduced aeration time was maintained for the remainder of the test.

During the October 2001 to January 2002 period, including the Power/Equipment Failure stress test in December, the system produced steady results, with TN in the effluent of 10 to 16 mg/L, a removal efficiency of 57 to 77 percent. The TN in the effluent was a mix of TKN and nitrate.

After the Low Load stress test ended and flows returned to design levels, the nitrification and denitrification processes returned to the performance and balance levels found during the May and June 2001 period, prior to the upset condition in early July. The Power/Equipment Failure stress test, performed on December 3 did not have a major impact on the System. The TKN and ammonia levels did increase somewhat compared the previous data point in November, but TN performance remained similar as the nitrate levels decreased somewhat during the post stress test monitoring period.

The Vacation stress test was started on February 4 and continued until February 13. During this period, there was no influent flow to the System, except on the first and last day of the stress test. The TKN and ammonia concentrations in the effluent decreased in the effluent samples taken immediately after flow was resumed to the System. The nitrate levels increased in a manner similar to the findings following the Low Load stress test. TN concentrations remained steady in the effluent ranging from 12 to 17 mg/L. By the end of the post stress test monitoring period, the effluent concentrations had returned to a mix of TKN and nitrate concentrations with TKN of 5.5 mg/L and nitrate of 6.8 mg/L. These data, supported by the results form the Low Load stress test, suggest that the Amphidrome™ System responded to decreases in flow by exhibiting improved nitrification and less denitrification. The TN performance, however, did not change significantly, with effluent concentrations remaining in a tight range near the long-term average and median of 15 mg/L and 14 mg/L, respectively.

The system performance remained consistent for the duration of the verification test. The TKN and ammonia nitrogen effluent concentration were consistently in the 7.6 to 9.5 mg/L range. The nitrate levels remained in the 3.0 to 4.8 mg/L range. The TN concentration in the effluent ranged from 11 to 15 mg/L. Alkalinity concentration in the effluent were in the 100 to 120 mg/L range, as compared to influent alkalinity levels in the 160 to 190 mg/L range.

The verification test provided a sufficiently long test period to collect data that included both a long run of steady performance by the Amphidrome™ System and a period of reduced nitrification and denitrification efficiencies. During the months of April through June, following startup, the TN removal was in the 45 to 71 percent range, with effluent concentrations typically in the 13 to 16 mg/L range. An upset condition of some type dramatically impacted the nitrification process in early July. Following the upset, the System recovered by the end of July and continued to remove substantial amounts of TN. During the last eight months of the verification test, the TN removal was in the 52 to 77 percent range. Effluent TN concentration ranged from 10 to 20 mg/L, with most concentrations in the 13 to 15 mg/L range. Data collected from the two low or no flow stress tests indicate that overall system performance for TN is not significantly impacted. However, the concentrations of TKN/ammonia and nitrate changed significantly during these lower flow periods. Nitrification was enhanced during low flow periods with a commensurate increase in nitrate concentrations in the effluent.

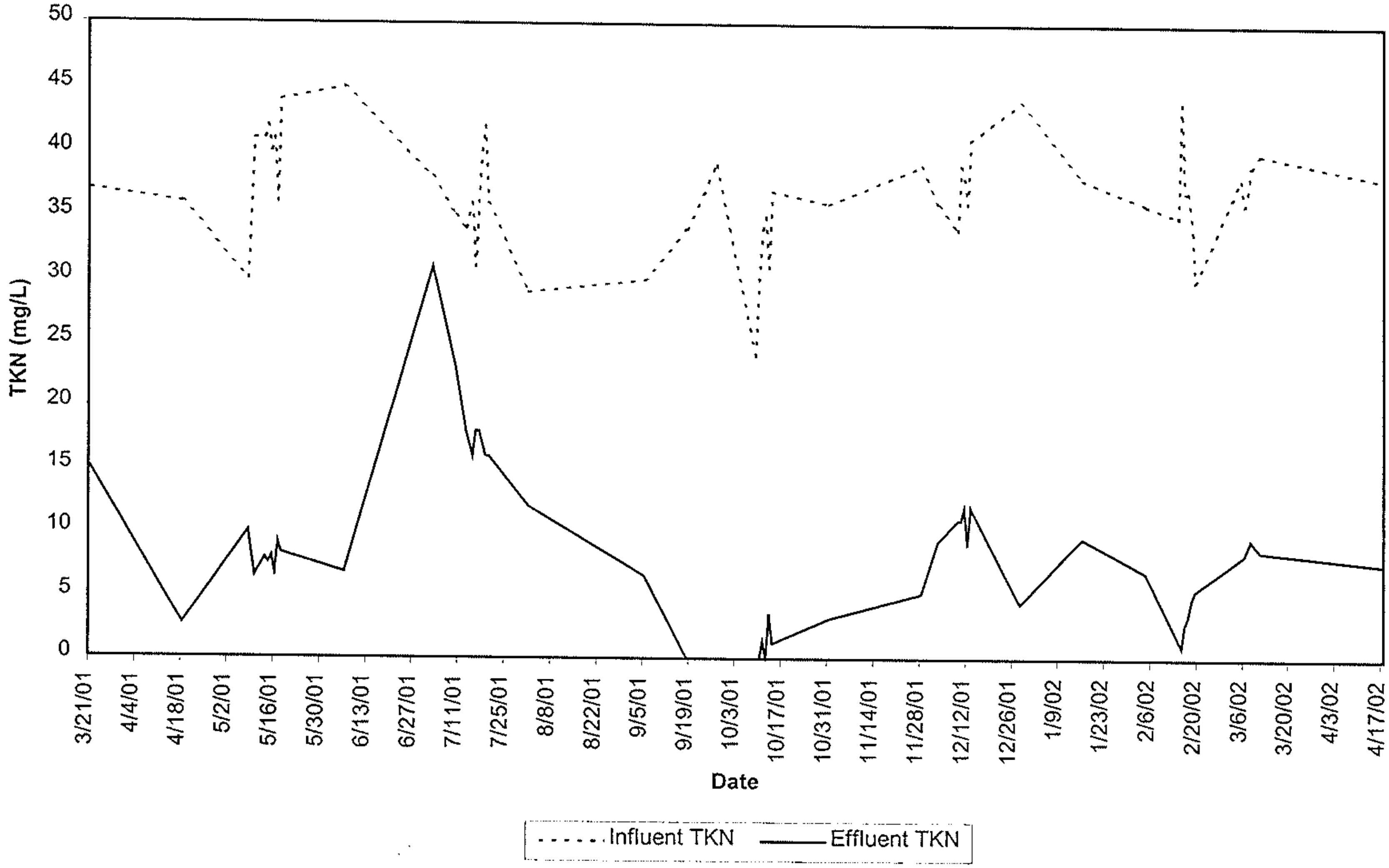

Figure 4-3. Amphidrome™ System Total Kjeldahl Nitrogen Results

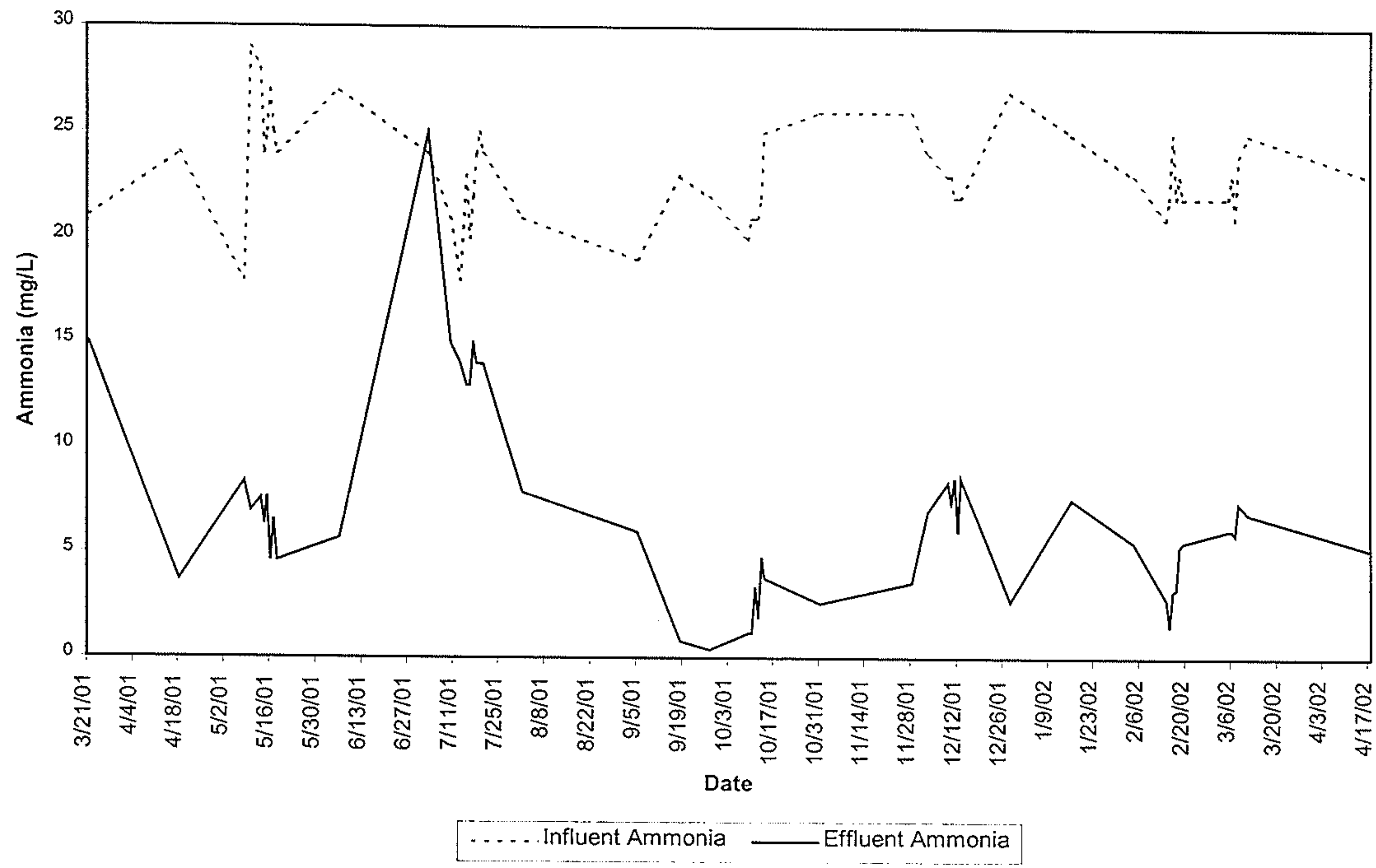

Figure 4-4. Amphidrome™ System Ammonia Nitrogen Results

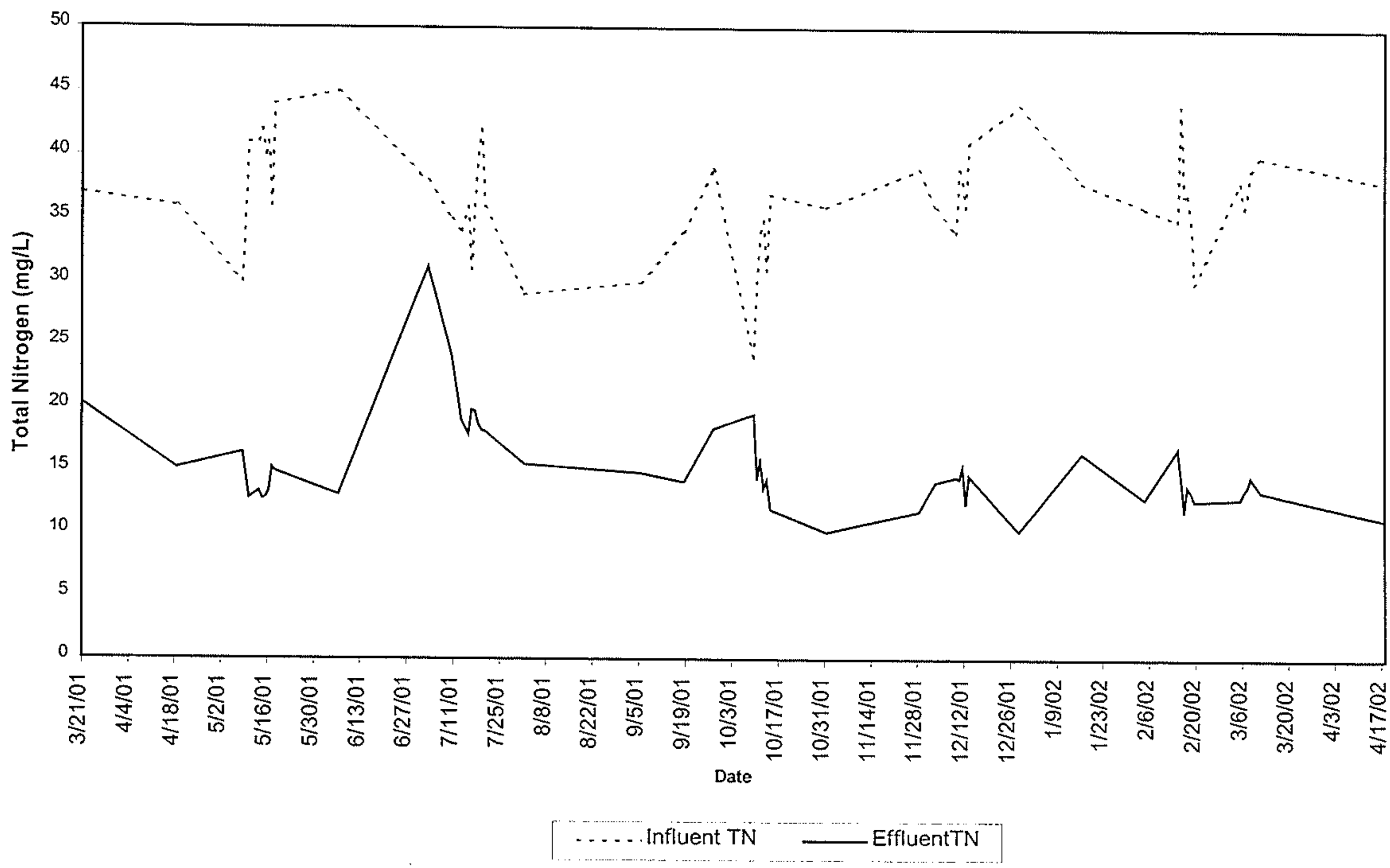

Figure 4-5. Amphidrome™ System Total Nitrogen Results

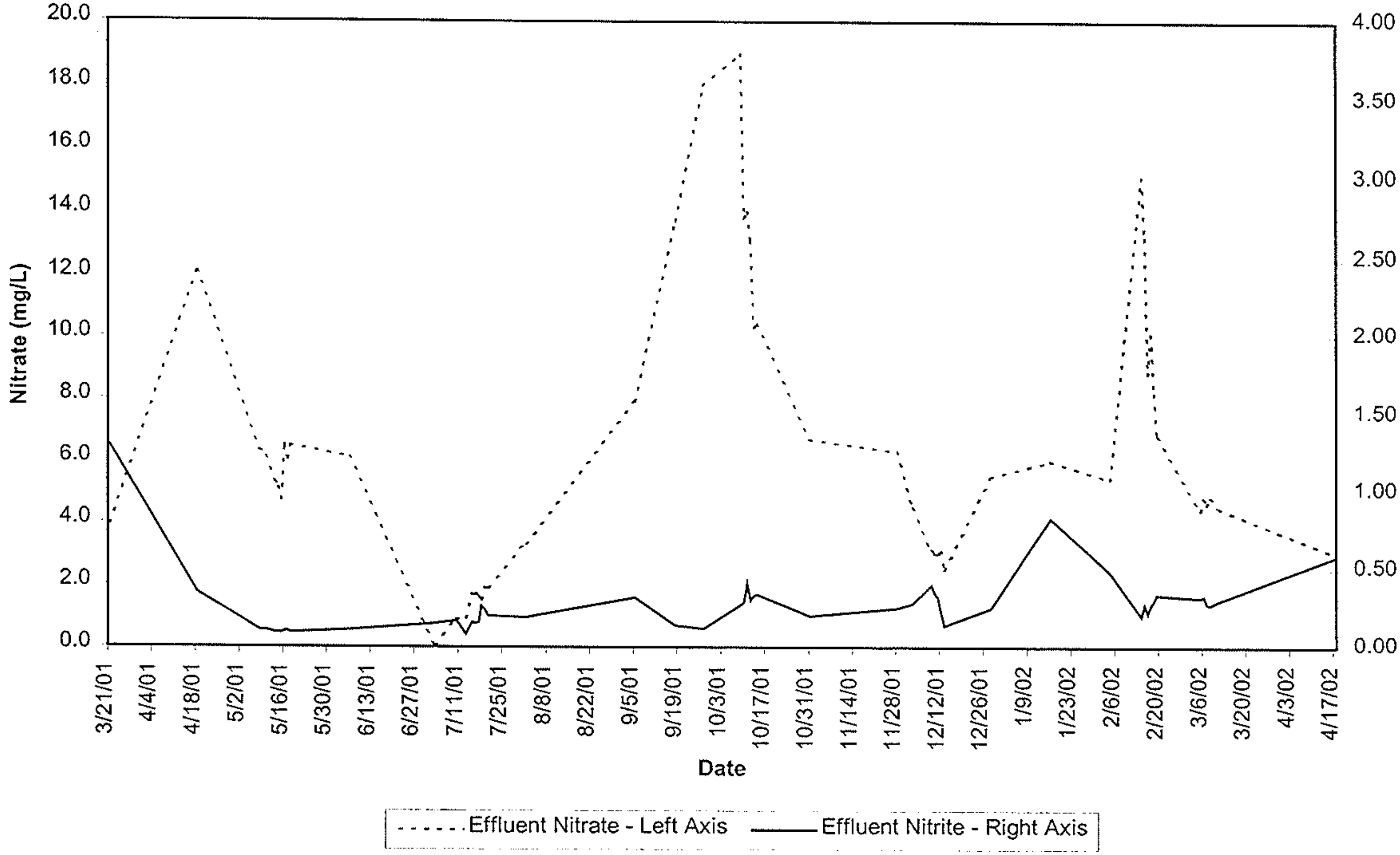

Figure 4-6. Amphidrome™ System Nitrite and Nitrate Effluent Concentrations

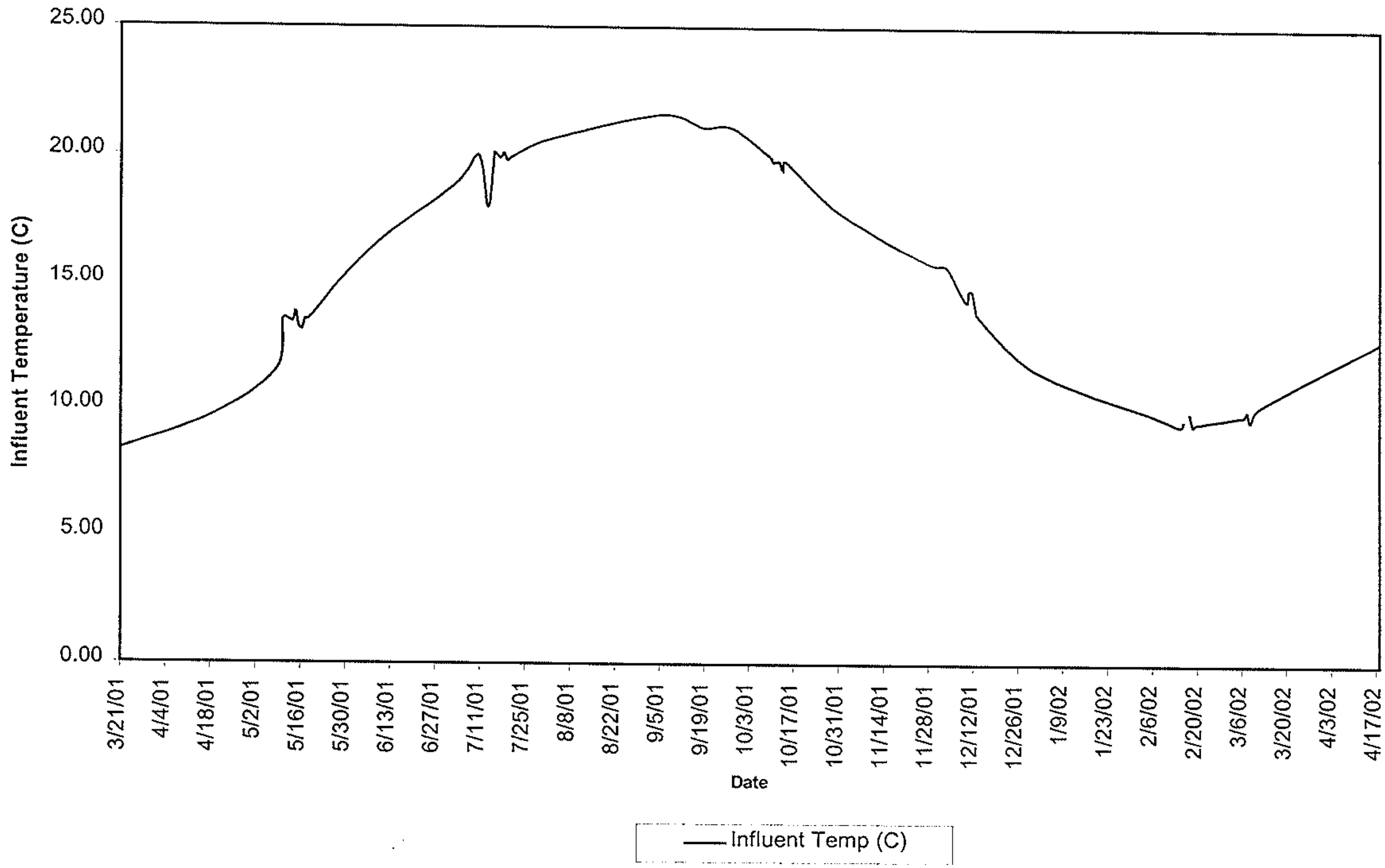

Figure 4-7. Amphidrome™ System Influent Temperature

Table 4-6. Amphidrome™ System Influent and Effluent Nitrogen Data

Date	TKN (mg/L)		Ammonia Nitrogen (mg/L)		Total Nitrogen (mg/L)		Nitrate-Nitrogen (mg/L)	Nitrite-Nitrogen (mg/L)	Temperature (°C)
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Effluent	Effluent	Influent
03/21/01	37	15	21	15	37	20	3.9	1.3	8.4
04/18/01	36	2.7	24	3.7	36	15	12	0.35	9.7
05/08/01	30	10	18	8.4	30	16	6.3	0.11	12
05/10/01	41	6.5	29	7.0	41	13	6.1	0.11	14
05/13/01	41	7.9	28	7.6	41	13	5.3	0.09	13
05/14/01	42	7.5	24	6.4	42	13	5.1	0.09	14
05/15/01	40	8.0	25	7.7	40	13	4.7	0.09	13
05/16/01	41	6.7	27	4.6	41	13	6.5	0.10	13
05/17/01	36	9.1	25	6.6	36	15	6.0	0.10	14
05/18/01	44	8.3	24	4.6	44	15	6.5	0.09	14
06/06/01	45	6.8	27	5.7	45	13	6.1	0.11	16
07/03/01	38	31	24	25	38	31	0.05	0.15	19
07/10/01	35	23	21	15	35	24	0.90	0.17	20
07/13/01	34	18	18	14	34	19	0.90	0.08	18
07/15/01	36	16	23	13	36	18	1.7	0.16	20
07/16/01	31	18	20	13	31	20	1.7	0.15	20
07/17/01	36	18	22	15	36	20	1.6	0.16	20
07/18/01	40	17	24	14	40	19	1.5	0.26	20
07/19/01	42	16	25	14	42	18	1.9	0.24	20
07/20/01	36	16	24	14	36	18	1.9	0.20	20
08/01/01	29	12	21	7.9	29	15	3.3	0.19	21
09/05/01	30	6.6	19	6.0	30	15	7.9	0.32	22
09/18/01	34	<0.5	23	0.8	34	14	14	0.14	21
09/27/01	39	<0.5	22	0.4	39	18	18	0.12	21
10/09/01	24	<0.5	20	1.2	24	20	19	0.27	20
10/10/01	30	<0.5	21	1.2	30	14	14	0.29	20
10/11/01	34	1.4	21	3.4	34	16	14	0.41	20
10/12/01	35	<0.5	21	1.9	35	14	13	0.30	20
10/13/01	31	3.6	22	4.8	31	14	10	0.33	20
10/14/01	37	1.2	25	3.8	37	12	10	0.34	20

Table 4-6. Amphidrome™ System Influent and Effluent Nitrogen Data (continued)

Date	TKN (mg/L)		Ammonia Nitrogen (mg/L)		Total Nitrogen (mg/L)		Nitrate-Nitrogen (mg/L)	Nitrite-Nitrogen (mg/L)	Temperature (°C)
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Effluent	Effluent	Influent
10/31/01	36	3.2	26	2.6	36	10	6.7	0.20	18
11/28/01	39	5.2	26	3.6	39	12	6.3	0.25	16
12/03/01	36	9.3	24	7.0	36	14	4.5	0.28	16
12/09/01	34	11	23	8.4	34	15	3.1	0.40	14
12/10/01	39	11	23	7.4	39	14	3.0	0.35	15
12/11/01	38	12	22	8.6	38	15	3.0	0.32	15
12/12/01	36	9.0	22	6.0	36	12	3.1	0.22	14
12/13/01	41	12	22	8.6	41	15	2.5	0.14	14
12/28/01	44	4.4	27	2.7	44	10	5.5	0.25	12
01/16/02	38	9.6	25	7.6	38	16	6.0	0.83	11
02/04/02	36	6.9	23	5.5	36	13	5.4	0.48	9.9
02/14/02	35	1.5	21	2.8	35	17	15	0.20	9.4
02/15/02	44	1.0	22	1.5	44	14	13	0.27	9.6
02/16/02	37	2.8	25	3.2	37	12	8.8	0.22	NR
02/17/02	37	3.4	22	3.3	37	14	10	0.27	9.9
02/18/02	35	4.8	23	5.3	35	13	8.2	0.30	9.4
02/19/02	30	5.5	22	5.5	30	13	6.8	0.34	9.5
03/05/02	38	8.1	22	6.1	38	13	4.4	0.32	9.8
03/06/02	36	8.3	23	6.1	36	13	4.8	0.33	9.8
03/07/02	37	8.9	21	5.9	37	14	4.6	0.28	10
03/08/02	39	9.5	24	7.4	39	15	4.8	0.27	9.6
03/11/02	40	8.6	25	6.9	40	13	4.5	0.30	10
04/17/02	38	7.6	23	5.2	38	11	3.0	0.58	13
Number	53	53	53	53	53	53	53	53	52
Average	37	8.5	23	7.0	37	15	6.4	0.27	15
Median	37	8.3	23	6.1	37	14	5.4	0.25	14
Maximum	45	31	29	25	45	31	19	1.3	22
Minimum	24	1.0	18	0.4	24	10	0.05	0.08	8.4
Std. Dev.	4.2	6.4	2.4	4.7	4.2	3.6	4.5	0.20	4.3

Values below the detection limit set equal to zero (0) for statistical calculations
N/R – not reported

Table 4-7. Amphidrome™ System Alkalinity, pH, and Dissolved Oxygen Results

Date	Alkalinity (mg/L as $CaCO_3$)		Dissolved Oxygen (mg/L)		pH (S.U.)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
03/21/01	200	110	0.4	NR	7.6	7.0
04/18/01	190	56	1.9	NR	7.6	6.8
05/08/01	160	120	NR	NR	7.3	6.9
05/10/01	190	98	0.6	NR	7.4	7.0
05/13/01	180	130	0.4	NR	7.5	7.0
05/14/01	170	130	0.7	NR	7.5	7.4
05/15/01	180	140	0.5	NR	7.4	7.0
05/16/01	180	120	0.4	NR	7.4	7.2
05/17/01	180	110	0.3	NR	7.5	7.1
05/18/01	190	98	0.3	NR	7.6	7.3
06/06/01	180	110	0.4	NR	7.6	7.4
07/03/01	190	210	0.4	6.2	7.3	7.2
07/10/01	180	190	0.8	NR	7.5	7.1
07/13/01	170	180	0.7	NR	7.5	7.5
07/15/01	190	170	0.1	NR	7.6	7.3
07/16/01	200	180	0.1	NR	7.6	7.5
07/17/01	180	180	0.1	NR	7.4	7.1
07/18/01	190	160	0.2	NR	7.2	7.3
07/19/01	200	160	0.2	NR	7.2	7.1
07/20/01	190	150	0.1	NR	7.4	7.2
08/01/01	170	140	0.3	2.3	7.5	7.3
09/05/01	170	110	0.3	4.5	7.3	7.0
09/18/01	180	74	0.3	6.1	7.4	7.0
09/27/01	190	54	0.1	6.3	7.3	6.9
10/09/01	170	66	0.2	5.4	7.5	7.1
10/10/01	180	66	<0.1	5.3	7.4	7.5
10/11/01	190	80	<0.1	5.3	7.3	6.9
10/12/01	180	72	0.1	6.4	7.2	6.8
10/13/01	180	94	0.1	5.5	7.4	7.0
10/14/01	190	88	<0.1	4.9	7.4	6.9

Table 4-7. Amphidrome™ System Alkalinity, pH, and Dissolved Oxygen Results (continued)

	Alkalinity (mg/L as $CaCO_3$)		Dissolved Oxygen (mg/L)		pH (S.U.)	
Date	Influent	Effluent	Influent	Effluent	Influent	Effluent
10/31/01	200	70	0.3	3.8	7.4	6.6
11/28/01	190	98	0.2	5.0	7.4	6.9
12/03/01	170	120	0.1	9.5	7.3	7.4
12/09/01	180	130	0.2	4.3	7.5	7.1
12/10/01	190	140	0.1	4.6	7.5	7.4
12/11/01	180	130	0.1	4.6	7.4	7.0
12/12/01	180	110	0.4	9.6	7.4	7.3
12/13/01	190	130	0.4	NR	7.6	7.1
12/28/01	230	92	0.3	5.8	7.5	7.2
01/16/02	190	100	0.2	7.3	7.6	7.7
02/04/02	180	98	0.2	NR	7.4	7.2
02/14/02	170	58	0.2	8.9	7.5	7.1
02/15/02	200	76	0.2	8.4	7.3	7.0
02/16/02	190	98	0.2	8.0	7.4	7.0
02/17/02	180	98	0.2	7.9	7.5	7.2
02/18/02	170	100	0.1	5.6	7.5	7.4
02/19/02	180	110	0.4	7.5	7.4	7.3
03/05/02	160	110	0.5	5.9	7.4	6.9
03/06/02	170	100	0.6	7.8	7.4	6.8
03/07/02	180	100	0.2	5.6	7.4	6.7
03/08/02	180	110	0.5	4.8	7.4	6.9
03/11/02	190	100	1.1	5.6	7.5	6.8
04/17/02	190	120	0.1	5.9	7.4	6.9
Number	53	53	52	32	53	53
Average	180	110	0.3	6.1	N/A	N/A
Median	180	110	0.2	5.7	7.4	7.1
Maximum	230	210	1.9	9.6	7.6	7.7
Minimum	160	54	0.0	2.3	7.2	6.6
Std. Dev.	11	36	0.3	1.7	N/A	N/A

N/A – not applicable
N/R – not reported

4.3.4 Residuals Results

During the treatment of wastewater in the Amphidrome™ System, solids accumulate in the anoxic tank. Inert solids are removed in the anoxic tank just as in a normal septic tank. Biological solids accumulate from influent wastewater solids and from the recycling of any solids trapped on the sand media or generated during treatment in the Amphidrome™ System. Eventually, a buildup of solids will reduce the capacity of the anoxic tank and the solids will need to be removed.

The approximate quantity of the residuals accumulated in the system was estimated by measuring the depth of solids in the anoxic tank. Measurement of solids depth was difficult in the anoxic tank, as access to the unit is limited to manways in the top of the unit. Solids depth was estimated at three locations from each of the two manways using a Core Pro solids-measuring device. A column of water and solids was removed from the tank, and the undisturbed solids depth in the clear tube was measured with a ruler. The measurements were made in February 2002 after 13 months of operation, and again in March 2002 after approximately fourteen months (January 15, 2001 to March 8, 2002) of operation. The results are presented in Table 4-8.

Table 4-8. Solids Depth Measurement

	Anoxic Tank Solids/Scum Depth in Inches			
Manway Location	East	Middle	West	Average
February 4, 2002-Anoxic Tank Influent End	18	20	27	22
February 4, 2002-Anoxic Tank Effluent End	19	16	31	22
February 4, 2002 Scum Depth on Influent End	0	0	0	0
February 4, 2002 Scum Depth on Effluent End	0	0	0	0
March 8, 2002-Anoxic Tank Influent End	15	22	28	22
March 8, 2002-Anoxic Tank Effluent End	32	13	14	20
March 8, 2002 Scum Depth on Influent End	0	0	0	0
March 8, 2002 Scum Depth on Effluent End	0	0	0	0
March 8, 2002-Clear Well	0	0	0	0

In order to characterize the solids in the anoxic tank, total suspended solids and volatile suspended solids were measured in samples collected in March 2002. These data are presented in Table 4-9. These concentrations represent the solids concentration in the total sample collected, which included the solids and the water present in the sample tube. Based on an average of twenty one inches of solids present in the tube and an additional 38 inches of water, the concentration needs to be multiplies by a factor of 2.8 to estimate the actual solids concentration in the settled solids layer.

Table 4-9. TSS and VSS Results for the Amphidrome™ System Solids Samples

Date	Location	TSS (mg/L)	VSS (mg/L)
3/8/02	Anoxic Tank	10,000	1,900

The mass of solids present in the septic tank can be estimated from these data. The average concentration of solids in the anoxic tank, 10,000 mg/L, multiplied by the tank total volume of 1500 gallons shows that the solids accumulated during the test was approximately 130 pounds. The percent solids in the settled solids layer can be estimated using the average solids depth of 21 inches and the total water column height of 60 inches. Multiplying the "dilution" ratio of 60/21 times the concentration solids (10,000 mg/L) shows that the actual solids layer had a concentration of approximately 2.8 % or 28,000 mg/L. The total mass can be estimated using the average depth of solids and the tank dimensions. The anoxic tank holds a volume of approximately 31 gallons per inch of depth. Therefore, the solids volume, based on an average 21 inches depth (March 2002), was about 654 gallons. Based on a solids concentration of 28,000 mg/L (estimated concentration in the settled solids layer), the weight of dry solids accumulated was approximately 150 pounds. Both methods give a similar solids estimate.

The volatile solids represented 19 percent of the solids in the tank. This value seems low for a biological system of this type. The data were checked and for this one sample the volatile solids were low compared to the total solids.

4.4 Operations and Maintenance

Operation and maintenance performance of the Amphidrome™ System was monitored throughout the verification test. A field log was maintained that included all observations made over the thirteen-month test period. Data was collected on electrical and chemical usage, noise, and odor. Observations were recorded on the condition of the Amphidrome™ System, any changes in setup or operation (pump adjustments, nozzle cleaning, etc.) or any problems that required resolution. A complete set of field logs is included in Appendix G.

4.4.1 Electric Use

Electrical use was monitored by a dedicated electric meter serving the Amphidrome™ System. The meter reading was recorded biweekly in the field log by BCDHE personnel. Table 4-10 shows a summary of the electrical use from startup through the end of the verification test. The complete set of electrical readings is presented in a spreadsheet in Appendix F. The average electrical use was 4.1 kilowatts per day based on the entire data set. The basic system tested used one pump for discharge and one pump to recycle the Clear Well water back through media. A blower was used to add air to the system. There was one period in June 2001 when the electrical use went up to 24 to 32 KW/day for a twelve-day period (see spreadsheet in Appendix F). It is not known what caused this increased use of power, but the upset condition noted in the previous discussions occurred during or after this period.

Table 4-10. Summary of Amphidrome™ Electrical Usage

	KW/day
Readings	188
Average	4.1
Median	3.3
Maximum	32
Minimum	0.0
Std. Dev.	4.7

4.4.2 Chemical Use

The Amphidrome™ system did not require or use any chemical addition as part of the normal operation of the unit.

4.4.3 Noise

Noise levels associated with mechanical equipment were measured once during the verification period. A decibel meter was used to measure the noise level. Measurements were taken one meter from the unit and one and a half meters above the ground, at 90° intervals in four (4) directions. The meter was calibrated prior to use. Table 4-11 shows the results from this test.

Table 4-11. Amphidrome™ Noise Measurements

Location	First Reading (decibels)	Second Reading (decibels)	Average
Background	37.5	38.0	37.7
Amphidrome™			
East	56.2	56.4	56.3
South	55.1	54.3	54.7
West	59.1	60.0	59.5
North	56.4	56.2	56.3
All Locations			56.7

Decibels are a log scale so averages are calculated on a log basis

4.4.4 Odor Observations

Monthly odor observations were made over the last eight months of the verification test. The observation was qualitative based on odor strength (intensity) and type (attribute). Intensity was stated as not discernable; barely detectable; moderate; or strong. Observations were made during periods of low wind velocity (<10 knots). The observer stood upright at a distance of three (3) feet from the treatment unit, and recorded any odors at 90° intervals in four (4) directions (minimum number of points). All observations were made by the same BCDHE employee. Table 4-12 summarizes the results for the odor observations. As can be seen, there were no discernible odors found during any of the observation periods.

Table 4-12. Odor Observations

Date	Number of Points observed	Observation
9/10/01	8	No discernable odor
10/20/01	8	No discernable odor
11/22/01	8	No discernable odor
12/09/01	8	No discernable odor
01/27/02	8	No discernable odor
02/17/02	8	No discernable odor
03/02/02	8	No discernable odor
03/31/02	8	No discernable odor

4.4.5 Operation and Maintenance Observations

The Amphidrome™ System is a sequencing batch reactor that uses gravel and sand for the media in the biofilter section. The System is based on the principals of a submerged growth filter operating under both aerobic and anoxic conditions. The system is comprised of an anoxic/equalization tank, the filter housing holding the media, a blower and distribution plate system for air injection (Amphidrome Reactor™), and a Clear Well. The entire System is run by a PLC that controls the pumps and blower, monitors the level switches, and makes some adjustments based on flows sensed by level changes and pump times in the Clear Well.

The installation, operation, and maintenance requirements for the System are described in detail in two documents, the Single Family Installation Instructions, and the Operation & Maintenance Manual (Appendix A). The Amphidrome™ System, as tested, had two pumps, five level/float switches, a back check valve, and one blower. The System is dependent on controlling the oxygen conditions in the submerged biofilter (through blower time control), on recycle of treated wastewater to the anoxic tank, and on pump timer cycles for discharge and for backwash. All of these processes are controlled by the PLC, and appear to be dependent on specific site conditions. Therefore, in the opinion of the MASSTC operating staff, while involvement by a homeowner would be minimal, the system is sophisticated, complex, and needs to be setup and maintained by experienced operators, who can make necessary adjustments to the system. With this level of system complexity, a service contract with an authorized service provider would seem to necessary.

According to the O&M Manual, the PLC does not allow operator access to the main program logic, but the operator does have a large degree of flexibility in adjusting the System by accessing the memory registers of the PLC. Adjusting the memory registers allows the operator to optimize the system by adjusting pump cycles, run times, blower on-off cycles, etc. In order to take advantage of this flexibility, however, FRMA states; ". . . a thorough understanding of both the Amphidrome™ System and the biological processes involved is required." During the verification test, the MASSTC operators observed the unit, which did not require any regular cleaning or maintenance, but did not change or adjust the PLC. All PLC adjustments were performed by FRMA trained people.

During the first two months of verification testing (April and May), FRMA adjusted the PLC on four occasions. The airflow was adjusted in early April and the backwash cycle was adjusted in mid May. On May 24, the cycle times were adjusted to try to improve the performance, but were returned to the initial conditions on June 1. On October 25, 2001, the fixed airflow time was reduced by 10 percent to try to improve denitrification. On October 21, the anoxic cycle was also adjusted. These adjustments were made to try to improve performance and match the aerobic/anoxic cycles to the wastewater and system conditions.

In addition to PLC changes, the internal clock required adjustment to daylight savings time in April and October. The clock also was "off" by a couple of hours on two occasions that seemed to correspond to times when the power was off to the unit. FRMA adjusted the clock during the site visits to check on other parts of the system.

During the test, one mechanical problem occurred when the discharge pump failed. In November 2001, the high water alarm sounded, indicating that water levels were above the normal operating range in the Clear Well. MASSTC operators attempted to manually activate the discharge cycle, but no discharge occurred. The emergency number provided by FRMA was called and a response was received within a couple of hours. Based on the observations of the MASSTC operators, FRMA instructed that the flow be discontinued to the unit. FRMA arrived on site within 24 hours and replaced the pump in the Clear Well resolving the problem.

In the opinion of the test site operators, the System was easy to operate and maintain from a homeowners perspective, as there is very little maintenance or adjustment that the average homeowner can or should perform. The System, as mentioned above, does have a PLC control and relatively sophisticated operating cycle. Therefore, it will be necessary for homeowners to have a qualified maintenance organization operate and maintain the System.

FRMA recommends bimonthly (once every two months) System inspections once the startup period ends and the System is operating properly. These inspections include checking the System visually (noting clarity of the effluent, any odor, color, or solids present, etc.), and performing analyses of the effluent using field test kits for ammonia and nitrate. The PLC records for pump and aeration run times are recorded to provide a record of the System's operation since the last inspection. Pump operation, particularly return flow (up flow through the Reactor) and backwash flow, is observed to ensure proper operation. The backwash cycle is activated to ensure both the pumps and blowers are working properly. The aeration system is inspected and the bubble pattern above the media observed. The bubble pattern should be evenly distributed over the media.

FRMA provides examples of Inspection and Maintenance Check Lists, Operator Logs, Preventive Maintenance Lists (Appendix A). A narrative description of all of the System components is also provided in the Manual. There are several pages of troubleshooting guidelines that can help an operator evaluate equipment malfunctions and potential causes of poor quality effluent.

Based on fifteen months of observation, it is estimated that regular maintenance checks, requiring approximately two hours by a person knowledgeable of the System, is appropriate to ensure the System is in good operating condition (after initial startup and optimization of the unit, which may take several site visits). The skill level needed is the equivalent of a Class II Massachusetts treatment plant operator.

The anoxic tank should be checked for solid depth and if solids have built up in the tank, pumping of the tank should be scheduled. The troubleshooting checklist in the Operation and Maintenance Manual indicates that solids removal should be scheduled when the solids are within two feet of the outlet from the anoxic tank. The outlet in the standard anoxic tank is set for a water depth of four feet. Therefore, pumping of solids would typically be performed when solids depth was about two feet or twenty-four inches. Solids depths were approaching this level at the after fourteen months of operation indicating a residence with wastewater similar to the

MASSTC wastewater will need to pump solids approximately every two years (possibly more frequently). General guidance for standard residential septic tank systems is to pump solids every 3 to 5 years The more frequent pumping of solids from the anoxic tank is to be expected based on the additional solids load generated by the Reactor system. The regular maintenance checks should include measurement of solids level in the anoxic tank.

The verification test ran for a period of thirteen months, which provided sufficient time to evaluate the overall performance of the System. However, a much longer period (several years) would be needed to evaluate the life cycle for the equipment, pumps, floats, filter and distribution assembly, etc. The basic components of the System appear durable and should perform well under typical home wastewater conditions.

No particular special design considerations are necessary relative to placement. The Amphidrome™ System is mostly underground, except for the blower unit. While the blower makes only limited noise, some siting considerations for blower placement may be desired. Consideration of appropriate placement for the blower is mentioned in the FRMA manuals.

The Installation, and Operation and Maintenance Manuals (Appendix A) provided by FRMA are comprehensive and provide information for installation, startup, operation, and servicing of the Amphidrome™ System. The Manuals include information on the theory of biological treatment and descriptions of observations that can be made to visually check the condition of the System. FRMA indicates that visual color and turbidity inspections, along with observations of suspended solids and odor in the effluent, can give an indication of possible upset conditions. FRMA also recommends the use of field test kit(s) to monitor the effluent quality for ammonia and nitrate. They also recommend regular sample collection and analysis for parameters such as BOD_5, TSS, TKN, NH_3, and NO_3.

4.5 Quality Assurance/ Quality Control

The VTP included a QA/QC Plan (QAPP) with critical measurements identified and several QA/QC objectives established. The verification test procedures and data collection followed the QAPP, and summary results are reported in this section. The full laboratory QA/QC results and supporting documentation are presented in Appendices D, E, and F.

4.5.1 Audits

Two audits of the MASSTC and Barnstable County Health Department Laboratory were conducted by NSF during the verification test. These audits, in August 2001 and January 2002, found that the field and laboratory procedures were generally being followed. Recommendations for changes or improvements were made and the responsible organizations responded quickly to these recommendations. The findings of these audits were that the overall approach being used in the field and the laboratory were in accordance with the established QAPP.

The only finding that needed immediate attention during the first lab audit in August 2001 was the lack of method blanks in the nitrite and nitrate tests at the proper frequency. The calibration standards gave a very good linear relationship and the analyses were considered valid. Corrective action was accomplished immediately. All other findings were paper work related, such as updating training records and SOPs. Recommendations were made to improve the detail placed in the field logs, and to be sure that calibrations were documented and field duplicate samples collected as planned. The second audit in January 2002 found that recommendations had been implemented and no new findings were identified for immediate corrective action. The field and lab managers were reminded of activities that needed to be completed before the end of the test in accordance with the Test Plan.

A third audit was conducted at the end of the verification test. This audit reviewed the records and procedures that were used. A list of documents and data needed for the final report was prepared and discussed with the field and laboratory managers.

Internal audits of the field and laboratory operations were also conducted at least quarterly by BCDHE. These audits specifically reviewed procedures and records for the ETV project. Any shortcomings found during these internal audits were corrected as the test continued.

4.5.2 Daily Flows

One of the critical data quality objectives was to dose the System on a daily basis to within 10 percent of the design flow. For the Amphidrome™ System, the design flow was 400 gpd. The QC objective was to dose the System at 400 gpd plus or minus 10 percent, based on a monthly average of the daily flows. The dose volume was calibrated twice per week and if the volume changed by more than ten percent the dosing pump run time was adjusted in the test site PLC. The objective was met for all 13 months of the verification test period. The monthly averages were presented in Table 4-4. The daily flows for all months are presented in spreadsheet format in Appendix F. The field logs in Appendix G provide the twice per week calibration data that is summarized in the spreadsheets.

4.5.3 Precision

Precision measurements were performed throughout the verification test by collection and analysis of duplicate samples. Field duplicates were collected to monitor the overall precision of the sample collection and laboratory analyses. There were three or four similar verification tests running simultaneously at the MASSTC. Field duplicates were generally collected on each sampling day, with the sample selected for replication rotating among the three or four technologies. The results for the field duplicates are presented in a spreadsheet in Appendix D. Summaries of the data are presented in Tables 4-13 through 4-15.

The precision for nitrogen compounds was generally excellent, particularly given the low levels of ammonia, TKN, and nitrate in some of the effluent samples. A few sample results were outside the target window of either 10 percent RPD (nitrite, nitrate) or 20 percent RPD (TKN, NH_3), but in most cases, the results were for samples that were very low in concentration. As an example, one set of data for TKN showed replicate one as 0.9 mg/L and replicate two as 0.5 mg/L with a detection limit of 0.5 mg/L. The calculated RPD for this sample is 57 percent. Even though the relative percent difference (RPD) is high, the data is reasonable given the low concentration found in the samples.

The test plan did not differentiate between laboratory precision and field precision. Typically, field precision targets are wider than laboratory goals to account for sampling variation, in addition to the laboratory variation. Also, the precision goals for nitrite and nitrate were set very tight (10 percent RPD), which would appear to be tighter than required for acceptable wastewater analysis and evaluation of these parameters. Using the 10 percent RPD criteria, 8 out of 49 field duplicates for nitrate exceeded the target, and 7 out of 50 duplicates for nitrite exceeded the window. TKN showed 10 out of 59 field duplicates exceeded the target of 20 percent RPD. Ammonia results were similar with 6 out of 60 samples above the target of 20 percent RPD, with all exceedances for samples having a concentration of less than 1 mg/L.

Table 4-13. Duplicate Field Sample Summary – Nitrogen Compounds

Statistics	TKN (mg/L)			Ammonia (mg/L)		
	Rep 1	Rep 2	RPD	Rep 1	Rep2	RPD
Number	60	60	59	60	60	60
Average	14	15	13	8.9	8.8	11
Median	7.5	8.1	6.5	5.0	5.0	4.5
Maximum	49	51	135	29	28	133
Minimum	<0.5	<0.5	0.0	<0.2	<0.2	0.0
Std. Dev.	14	14	22	9.1	9.0	21
Statistics	Nitrite (mg/L)			Nitrate (mg/L)		
	Rep 1	Rep 2	RPD	Rep 1	Rep2	RPD
Number	50	50	46	50	50	49
Average	0.32	0.33	5.3	6.9	6.9	6.3
Median	0.30	0.30	2.0	6.2	6.1	4.3
Maximum	0.95	1.1	33	15	15	36
Minimum	<0.05	<0.05	0.0	<0.1	0.70	0.0
Std. Dev.	0.20	0.22	8.4	4.1	4.2	8.3

Table 4-14. Duplicate Field Sample Summary – CBOD, BOD, Alkalinity, TSS

Statistics	$CBOD_5$ (mg/L)			BOD_5 (mg/L)		
	Rep 1	Rep 2	RPD	Rep 1	Rep2	RPD
Number	50	50	50	10	10	10
Average	10	10	20	220	210	10
Median	6.7	6.7	14	230	220	11
Maximum	60	54	110	280	270	23
Minimum	1.9	2.3	0.51	140	150	1.1
Std. Dev.	11	9.5	19	44	43	6.6
Statistics	TSS (mg/L)			Alkalinity (mg/L as $CaCO_3$)		
	Rep 1	Rep 2	RPD	Rep 1	Rep2	RPD
Number	60	60	59	60	60	60
Average	32	31	31	120	120	3.4
Median	7	9	12	110	100	1.8
Maximum	260	260	190	220	220	27
Minimum	1	<1	0	56	54	0
Std. Dev.	57	54	43	46	46	5.6

Table 4-15. Duplicate Field Sample Summary – pH, Dissolved Oxygen

Statistics	pH (S.U.)			Dissolved Oxygen (mg/L)		
	Rep 1	Rep 2	RPD	Rep 1	Rep2	RPD
Number	60	55	55	12	12	12
Average	7.4	7.4	0.4	5.9	5.9	0
Median	7.4	7.5	0.1	5.8	5.8	0
Maximum	8.0	8.0	3.8	9.9	9.9	0
Minimum	6.6	6.8	0	2.5	2.5	0
Std. Dev.	1.0	0.3	0.6	2.2	2.2	0
	Calculated using log scale			All replicates gave same value		

The $CBOD_5$ and TSS data tended to have poorer precision than the other analyses, because this data is based on treated effluent samples that are below 10 mg/L. Comparison of average values and median values shows that much of the TSS data is at low concentration. Both $CBOD_5$ and TSS have detection limits of 1 or 2 mg/L. TSS are generally reported to one significant figure at levels below 10 mg/L. It is expected that precision will be poorer at the lower concentrations and near the detection limit of the methods. Further, the influence of variability in sample collection can be seen in this data as well. The laboratory precision data presented in Table 4-17 shows a tighter precision for TSS (13 percent in lab versus 31 percent for field duplicates). The difficulty of getting a well-mixed sample for low level suspended solids undoubtedly added to the lower precision for the TSS test. Overall, the TSS results showed 26 out of 59 samples were outside the target of 20 percent RPD and 18 out of 50 samples were outside the target for $CBOD_5$. Only 2 out of 16 $CBOD_5$ samples exceeded the target when the concentration was above 10 mg/L. While this data indicates that precision is lower at the lower concentrations, the overall data set provides the needed information that showed the ability of the treatment system to significantly reduce TSS and $CBOD_5$ in the wastewater. Laboratory procedures, calibrations, and data were audited and found to be in accordance with the published methods and good laboratory practice.

The laboratories performed lab duplicates on a frequency of at least one per batch or 10 percent of samples. The laboratory precision data is summarized in Tables 4-16 and 4-17. The various nitrogen analyses showed excellent precision, as did the alkalinity results. Nitrite results showed no samples (60 total) exceeded the very tight target of 10 percent RPD. Nitrate results showed 14 out 211 values exceeded the 10 percent RPD target, but only 1 result out 211 exceeded a 20 percent difference. Only one ammonia duplicate out of 53 was outside the $\pm$ 20% RPD objective for field duplicates, and only 4 out of 59 TKN replicates exceeded $\pm$ 20%. The laboratory duplicates included ETV samples and other samples that were part of the GAI batch runs.

The $CBOD_5$ and TSS precision was generally within the target objective of 20 percent RPD, except when the concentrations were low. As discussed earlier, when effluent samples were below 10 mg/L the calculated percent differences were higher, as would be expected. The $CBOD_5$ and BOD_5 analyses used very similar procedures, and were performed together under the same conditions in the laboratory. The BOD_5 data showed much higher precision (average of 8 percent) than the $CBOD_5$ (average 15 percent) primarily due to the higher concentrations of

BOD_5 (influent wastewater samples). In summary, 18 out of 57 results exceeded the $CBOD_5$ target of 20 percent RPD, but none of the samples over 10 mg/L exceeded the target (0 out of 17); BOD_5 results showed 7 out of 64 results were above the target; and 8 out of 44 TSS samples showed RPD above 20 percent. On-site audits and review of procedures and calibrations indicated that good laboratory practice was being followed. There were no identified, systematic errors that would account for the difference. The data for all analyses was judged acceptable and useable for evaluating the treatment efficiency.

Table 4-16. Laboratory Precision Data – Nitrogen Compounds

	TKN	Ammonia	Nitrite	Nitrate
Statistics	RPD	RPD	RPD	RPD
Number	59	53	67	211
Average	7.6	3.1	2.7	3.1
Median	4.7	0	0.0	2.1
Maximum	55	36	18	25
Minimum	0.0	0	0.0	0.0
Std. Dev.	11	6.6	4.3	3.7

Table 4-17. Laboratory Precision Data – $CBOD_5$, BOD_5, Alkalinity, TSS

	$CBOD_5$ (mg/L)			BOD_5 (mg/L)		
Statistics	Rep 1	Rep 2	RPD	Rep 1	Rep2	RPD
Number	57	57	57	64	64	64
Average	18	18	15	160	160	7.7
Median	5.9	6.7	7.6	170	170	4.4
Maximum	100	100	73	500	530	32
Minimum	<2.0	2.0	0.0	<2.0	<2.0	0.0
Std. Dev.	24	24	15	120	120	8.1
	TSS (mg/L)			Alkalinity (mg/L as $CaCO_3$)		
Statistics	Rep 1	Rep 2	RPD	Rep 1	Rep2	RPD
Number	44	44	44	48	48	48
Average	72	73	13	83	84	6.1
Median	52	54	5	80	80	1.8
Maximum	290	310	130	190	190	40
Minimum	1	4	0	2	2	0
Std. Dev.	73	72	24	58	59	12

4.5.4 Accuracy

Method accuracy was determined and monitored using a combination of matrix spikes and lab control samples (known concentration in blank water) depending on the method. Recovery of the spiked analytes was calculated and monitored during the verification test. Accuracy was in control throughout the verification test. All TKN and ammonia recoveries for lab control samples were within the accuracy window of 80 to 120 percent. Matrix spike samples for TKN and ammonia, in real world samples not necessarily ETV samples, were generally within the window of 70 to 130 percent recovery. One matrix spike sample out of 50 was low for ammonia and 4 samples gave low recoveries for TKN. Each data set was examined and each dataset was judged valid and useable. All recoveries for all spiked samples for alkalinity, BOD_5, nitrite, and nitrate were within the established windows. Only 1 result out of 51 spiked samples was outside the recovery target for $CBOD_5$. Tables 4-18 and 4-19 show a summary of the recovery data. All quality control data is presented in Appendix D.

Table 4-18. Accuracy Results – Nitrogen Analyses

Statistics	TKN (% Recovery)		Ammonia (% Recovery)	
	Matrix Spike	Lab Control Sample	Matrix Spike	Lab Control Sample
Number	54	59	50	57
Average	95	100	99	107
Median	96	99	100	107
Maximum	137	114	112	120
Minimum	62	86	51	91
Std. Dev.	16	6.2	9.3	7.2
Statistics	Nitrite (% Recovery)		Nitrate (% Recovery)	
	Matrix Spike	Lab Control Sample	Matrix Spike	Lab Control Sample
Number	50	54	24	119
Average	104	99	98	99
Median	104	99	97	98
Maximum	123	120	113	116
Minimum	80	82	85	81
Std. Dev.	10	9.7	8.4	8.0

Table 4-19. Accuracy Results – CBOD, BOD, Alkalinity

Statistics	$CBOD_5$ (% Recovery)	BOD_5 (% Recovery)	Alkalinity (% Recovery
	Lab Control Sample	Lab Control Sample	Lab Control Sample
Number	51	54	61
Average	100	101	100
Median	101	101	100
Maximum	106	109	113
Minimum	77	84	93
Std. Dev.	5	4	3

The balance used for TSS analysis was calibrated routinely with weights that were NIST traceable. Calibration records were maintained by the laboratory and inspected during the on site audits. The temperature of the drying oven was also monitored using a thermometer that was calibrated with a NIST traceable thermometer. The pH meter was calibrated using a three-point calibration curve with purchased buffer solutions of known pH. Field temperature measurements were performed using a thermometer that was calibrated using a NIST traceable thermometer provided to the field lab by the BCDHE laboratory. The dissolved oxygen meter was calibrated daily using ambient air and temperature readings in accordance with the SOP. The noise meter was calibrated prior to use and all readings were recorded in the field logbook. All of these traceable calibrations were performed to ensure the accuracy of measurements.

4.5.5 Representativeness

The field procedures, as documented in the MASSTC SOPs (Appendix C), were designed to ensure that representative samples were collected of both influent and effluent wastewater. The composite sampling equipment was calibrated on a routine basis to ensure that proper sample volumes were collected to provide flow weighted sample composites. Field duplicate samples and supervisor oversight provided assurance that procedures were being followed. As discussed earlier, the challenge in sampling wastewater is obtaining representative TSS samples and splitting the samples into laboratory sample containers. The field duplicates showed that there was some variability in the duplicate samples. However, based on 60 sets of field duplicates, the overall average TSS of the replicates was very close (32 and 31 mg/L). This data indicated that while individual sample variability may occur, the long-term trend in the data was representative of the concentrations in the wastewater.

The laboratories used standard analytical methods and written SOPs for each method to provide a consistent approach to all analyses. Sample handling, storage, and analytical methodology were reviewed during the on-site and internal audits to verify that standard procedures were being followed. The use of standard methodology, supported by proper quality control information and audits, ensured that the analytical data was representative of the actual wastewater conditions.

4.5.6 Completeness

The VTP set a series of goals for completeness. During the startup and verification test, flow data was collected for each day and the dosing pump flow rate was calibrated twice a week as specified. The flow records are 100 percent complete. Electric meter records were maintained in the field logbook. Electric meter readings were performed twice a week and summarized in a spreadsheet. All electric meter readings were taken and were 100 percent complete.

The goal set in the VTP for sample collection completeness for both the monthly samples and stress test samples was 83 percent. All monthly samples were collected and all stress test samples were collected in accordance with the VTP schedule. Therefore, sample collection was 100 percent complete.

A goal of 90 percent was set for the completeness of analytical results from the BCDHE laboratory and GAI. All scheduled analyses for delivered samples were completed and found to be acceptable, useable data. Completeness is 100 percent for the laboratory.

The only analytical work that was not 100 percent complete was effluent temperature and dissolved oxygen measurements made in the field. Some measurements were not taken as the Amphidrome™ System only discharged once per day. In the first months of the test, the discharge was missed and the composite sample was used for these measurements. This data was not valid and was not reported. Procedures were changed and most of the measurements were obtained in the last months of the verification test. These two field parameters were not critical parameters in the data objectives and were being collected to provide basic water quality information.

5.0 REFERENCES

5.1 Cited References

(1) NSF International, *Protocol for the Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction*, November 2000, Ann Arbor, Michigan.

(2) NSF International, *Test Plan for The Massachusetts Alternative Septic System Test Center for Verification Testing of F. R. Mahony Amphidrome™ Model "Single Family Unit" Nutrient Reduction Technology,* January 2001

(3) Stensel, H.D., R.C. Brenner, K.M Lee, H. Melcer, and K. Rakness, *Biological Aerated Filter Evaluation,* Journal of Environmental Engineering, Vol. 114, No. 3, ASCE. 1988

(4) United States Environmental Protection Agency: *Methods and Guidance for Analysis of Water*, EPA 821-C-99-008, 1999. Office of Water, Washington, DC.

(5) United States Environmental Protection Agency: *Methods for Chemical Analysis of Water and Wastes,* Revised March 1983, EPA 600/4-79-020

(6) APHA, AWWA, and WEF: *Standard Methods for the Examination of Water and Wastewater*, 19th Edition, 1998. Washington, DC.

5.2 Additional Background References

(7) United States Environmental Protection Agency: *Environmental Technology Verification Program - Quality and Management Plan for the Pilot Period (1995 – 2000)*, USEPA/600/R-98/064, 1998. Office of Research and Development, Cincinnati, Ohio.

(8) NSF International, Environmental Technology Verification – *Source Water Protection Technologies Pilot Quality Management Plan*, 2000. Ann Arbor, Michigan.

(9) United States Environmental Protection Agency: *USEPA Guidance for Quality Assurance Project Plans, USEPA QA/G-5*, USEPA/600/R-98-018, 1998. Office of Research and Development, Washington, DC

(10) United States Environmental Protection Agency, *Guidance for the Data Quality Objectives Process, USEPA QA/G-4*, USEPA/600/R-96-055, 1996. Office of Research and Development, Washington, DC.

(11) ANSI/ASQC: *Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs (E4)*, 1994.

Appendix A

FRMA Literature and
Homeowners Installation Manual
Operation & Maintenance Manual

Appendix B

Verification Test Plan

Appendix C

MASSTC Field SOP's

Appendix D

Lab Data and QA/QC Data

Appendix E

Field Lab Log Book

Appendix F

Spreadsheets with calculation and data summary

Appendix G

Field Operations Logs

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	BIOLOGICAL WASTEWATER TREATMENT – NITRIFICATION AND DENITRIFICATION FOR NITROGEN REDUCTION
APPLICATION:	REDUCTION OF NITROGEN IN DOMESTIC WASTEWATER FROM INDIVDUAL RESIDENTIAL HOMES
TECHNOLOGY NAME:	AMPHIDROME™ MODEL SINGLE FAMILY SYSTEM
COMPANY:	F.R. MAHONY & ASSOCIATES, INC.
ADDRESS:	273 WEYMOUTH STREET ROCKLAND, MA 02370 PHONE: (781) 982-9300 FAX: (781) 982-1056
WEB SITE:	http://www.frmahony.com
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NSF International (NSF), in cooperation with the USEPA, operates the Source Water Protection (SWP) program under the ETV Water Quality Protection Center. The SWP program recently evaluated the performance of a submerged growth biological filter treatment system for nitrogen removal for residential applications. This verification statement provides a summary of the test results for the F.R. Mahony & Associates, Inc. (FRMA), Amphidrome™ Model Single Family System. The Barnstable County Department of Health and the Environment performed the verification testing.

The U.S. Environmental Protection Agency (EPA) created the Environmental Technology Verification (ETV) Program to facilitate deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by substantially accelerating the acceptance and use of improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

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

ABSTRACT

Verification testing of the Amphidrome™ Model Single Family System was conducted over a thirteen-month period at the Massachusetts Alternative Septic System Test Center (MASSTC) located at Otis Air National Guard Base in Bourne, Massachusetts. Sanitary sewerage from the base residential housing was used for the testing. An eight-week startup period preceded the verification test to provide time for the development of an acclimated biological growth in the Amphidrome™ System. The verification test included monthly sampling of the influent and effluent wastewater, and five test sequences designed to test the unit response to differing load conditions and power failure. The Amphidrome™ System proved capable of removing nitrogen from the wastewater. Influent TKN and total nitrogen (TN) averaged 37 mg/L with a median of 37 mg/L. The total nitrogen concentration in the effluent averaged 15 mg/L over the verification period, with a median concentration of 14 mg/L. The system operating conditions (pumps and float settings, aeration cycles), controlled by a PLC, were adjusted four times during the first two months of the verification test and after six months of verification test operation. Mechanical equipment, pumps, level switches, alarms, etc. operated properly throughout the test, except for a discharge pump failure after nine months of operation. The Amphidrome™ System is a sophisticated PLC controlled system that requires a trained operator to monitor the system and ensure that the system pump cycle times, aeration periods, and backwash settings are set to the site specific conditions.

TECHNOLOGY DESCRIPTION

The Amphidrome™ Reactor is a submerged growth sequencing batch reactor used in conjunction with an anoxic/equalization tank (for this test a 1,500 gallon two compartment septic tank, standard unit uses a 2,000 gallon tank), and a Clear Well tank for wastewater treatment. The anoxic tank provides solid - liquid separation, and anoxic conditions for denitrification. The bioreactor consists of a deep bed sand filter, which alternates between aerobic and anoxic treatment. The reactor operates similar to a biological aerated filter, except that the reactor changes from aerobic to anoxic conditions during the sequential cycling of the unit. Air (oxygen) is supplied to the system by a blower. The air is introduced at the bottom of the filter by a distribution system that produces fine bubbles to enhance oxygen transfer. According to FRMA, the unique system design allows soluble organic removal, nitrification, and denitrification processes to occur in one reactor.

The verification testing was performed using a full scale, commercially available unit, which was received as a self-contained system ready for installation. The cyclical action of the system is created by allowing a batch of wastewater to pass by gravity flow from the anoxic/equalization tank through the submerged sand filter (down flow mode) and into the Clear Well. The flow is then reversed using a pump to move water from the Clear Well up through the filter and into a return pipe, which carries the wastewater back to the anoxic tank. These cycles are repeated multiple times during a 24-hour period. According to FRMA, the conditions in the filter change from aerobic to anoxic based on the timing of the aeration cycles. The typical cycle is 3 to 5 minutes of aeration, followed by 15 minutes without aeration. The filter is backwashed using a combination of aeration and pumped water from the Clear Well. Treated wastewater is discharged once per day from the Clear Well by pumping to the receiving location. Each Amphidrome™ System is supplied with a Programmable Logic Controller (PLC), which controls the frequency and duration of pump operation, aeration cycles, backwash, and discharge, as well as all alarm functions and data collection.

VERIFICATION TESTING DESCRIPTION

Test Site

The MASSTC site is located at the Otis Air National Guard Base in Bourne, Massachusetts. The site uses domestic wastewater from the base residential housing, and sanitary wastewater from other military buildings in testing. A chamber located in the main interceptor sewer to the base wastewater treatment facility provides a location to obtain untreated wastewater. The raw wastewater, after passing through a one-inch bar screen, is pumped to a dosing channel at the test site. This channel is equipped with four recirculation pumps that are spaced along the channel length to ensure mixing, such that the wastewater is of similar quality at all locations along the channel. Wastewater is dosed to the test unit using a pump submerged in the dosing channel. A programmable logic controller (PLC) is used to control the pumps and the dosing sequence or cycle.

Methods and Procedures

The Amphidrome™ System was installed by a contractor, in conjunction with the BCDHE support team, in December 1999 as part of an earlier test program. The unit was installed in accordance with the Installation Instructions supplied by FRMA. In order to prepare for ETV testing, the entire system was emptied of wastewater and cleaned. Solids were removed from the septic tank and the Clear Well. All pumps, lines, and associated equipment were cleaned. The sand filter was repeatedly flushed by recirculating clean water through the system. The entire unit was then drained and remained off until the startup period. On January 15, 2001, the septic tank was filled with wastewater and the standard dosing sequence began. An eight-week startup period allowed the biological community to become established and the operating conditions to be monitored.

The system was monitored during the startup period, including visual observation of the system, routine calibration of the dosing system, and collection of influent and effluent samples. Six sets of samples were collected for analysis. Influent samples were analyzed for pH, alkalinity, temperature, BOD_5, TKN, NH_3, and TSS analyses. Effluent samples were analyzed for pH, alkalinity, temperature, $CBOD_5$, TKN, NH_3, TSS, dissolved oxygen, NO_2, and NO_3.

The verification test consisted of a thirteen-month test period, incorporating five sequences with varying stress conditions simulating real household conditions. The five stress sequences performed at two-month intervals, included Washday, Working Parent, Low Load, Power/Equipment Failure, and Vacation test sequences. Monitoring for nitrogen reduction was accomplished by measurement of nitrogen species (TKN, NH_3, NO_2, NO_3). Biochemical and carbonaceous oxygen demand (BOD_5/$CBOD_5$) and other basic parameters (pH, alkalinity, TSS, temperature) were monitored to provide information on overall system performance. Operational characteristics, such as electric use, residuals generation, labor to perform maintenance, maintenance tasks, durability of the hardware, noise and odor production, were also monitored.

The Amphidrome™ System has a design capacity of 400 gallons per day. The verification test was designed to load the system at design capacity (± 10 percent) for the entire thirteen-month test, except during the Low Load and Vacation stress tests. The Amphidrome™ System was dosed 15 times per day with approximately 26-27 gallons of wastewater per dose. The unit received five doses in the morning, four doses mid-day, and six doses in the evening. The dosing volume was controlled by adjusting the pump run time for each cycle, based on twice weekly pump calibrations.

The sampling schedule included collection of twenty-four hour flow weighted composite samples of the influent and effluent wastewater once per month under normal operating conditions. Stress test periods were sampled on a more intense basis with six to eight composite samples being collected during and following each stress test period. Five consecutive days of sampling occurred in the twelfth month of the verification test. All composite samples were collected using automatic samplers located at the dosing channel (influent sample) and at the discharge of the unit. Grab samples were collected on each sampling day to monitor the system pH, dissolved oxygen, and temperature.

Samples were cooled during sample collection, preserved, if appropriate, and transported to the laboratory. Analyses were in accordance with USEPA approved methods or Standard Methods. An established QA/QC program was used to monitor field sampling and laboratory analytical procedures. QA/QC requirements included field duplicates, laboratory duplicates and spiked samples, and appropriate equipment/instrumentation calibration procedures. Details on the analytical methods and QA/QC procedures are provided in the full Verification Report.

PERFORMANCE VERIFICATION

Overview

Evaluation of the Amphidrome™ System at MASSTC began on January 15, 2001, when the System pumps were activated, and the initial dosing cycles activated. Flow was set at 400 gpd, resulting in 15 doses per day with a target of 26.7 gallons per dose. Six samples of the influent and effluent were collected during the startup period, which continued until March 13, 2001. Verification testing began at that time and continued for thirteen months, until April 17, 2002. During the verification test, 53 sets of samples of the influent and effluent were collected to determine the system performance.

Startup

Overall, the unit started up with no difficulty. The installation instructions were easy to follow and installation proceeded without difficulty. FRMA representatives setup the PLC, which controlled all recirculation, aeration, backwash, and discharge times. No changes were made to the unit during the startup period. No special maintenance was required during startup.

The Amphidrome™ System performance for $CBOD_5$ and TSS was good after the first week of operation, and continued to improve over the next seven weeks. At the end of the eight-week startup, effluent $CBOD_5$ was 5.0 mg/L and TSS was 4 mg/L. There was some TN reduction occurring, with effluent concentrations varying between 21 and 28 mg/L, compared to influent concentrations of 34 to 46 mg/L. However, it did not appear that the nitrifying organisms were firmly established in the system. Low wastewater temperature was considered the primary reason for the slow trend toward improved reduction in TN. The temperature of the influent wastewater was remained in the 7 to 8 ^{o}C range through March 13.

Verification Test Results

The daily dosing schedule was designed for 15 doses to be applied every day, except during the Low Load (September 2001) and Vacation stress (February 2002) periods. Volume per dose and total daily volume varied only slightly during the test period. The daily volume, averaged on a monthly basis, ranged from 369 to 403 gallons per day. This was within the range allowed in the protocol for the 400 gallons per day design capacity.

The sampling program emphasizes sampling during and following the major stress periods. This results in a large number of samples being clustered during five periods, with the remaining samples spread over the remaining months (monthly sampling). Both average and median results are presented, as the median values compared to average values can help in analyzing the impacts of the stress periods.

The TSS and BOD_5/$CBOD_5$ results for the verification test, including all stress test periods, are shown in Table 1. The influent wastewater had an average BOD_5 of 210 mg/L and a median BOD_5 of 200 mg/L. The TSS in the influent averaged 150 mg/L and had a median concentration of 130 mg/L. The Amphidrome™ effluent showed an average $CBOD_5$ of 5.0 mg/L with a median $CBOD_5$ of 4.3 mg/L. The average TSS in the effluent was 5 mg/L and the median TSS was 3 mg/L. $CBOD_5$ concentrations in the effluent typically ranged from 1 to 10 mg/L, except for two samples, and TSS ranged from 1 to 11 mg/L, except for 3 samples during the thirteen month verification test.

Table 1. BOD_5/$CBOD_5$ and TSS Data Summary

	BOD_5 Influent (mg/L)	$CBOD_5$ Effluent (mg/L)	Removal Percent	TSS Influent (mg/L)	TSS Effluent (mg/L)	TSS Removal Percent
Samples	53	53	53	53	53	53
Average	210	5.0	96	150	5	97
Median	200	4.3	98	130	3	98
Max	370	20	>99	340	40	>99
Min	67	1.0	90	61	1	64
Std. Dev.	73	3.4	1.4	67	7	29

The nitrogen results for the verification test, including all stress test periods, are shown in Table 2. The influent wastewater had an average TKN concentration of 37 mg/L, with a median value of 37 mg/L, and an average ammonia nitrogen concentration of 23 mg/L, with a median of 23 mg/L. Average TN concentration in the influent was 37 mg/L (median of 37 mg/L), based on the assumption that the nitrite and nitrate concentrations in the influent were negligible. The Amphidrome™ effluent had an average TKN concentration of 8.5 mg/L and a median concentration of 8.3 mg/L. The average NH_3-N concentration in the effluent was 7.0 mg/L and the median value was 6.1 mg/L. The nitrite concentration in the effluent was low, averaging 0.27 mg/L. Effluent nitrate concentrations averaged 6.4 mg/L with a median of 5.4 mg/L. Total nitrogen was determined by adding the daily concentrations of the TKN (organic plus ammonia nitrogen), nitrite, and nitrate. Average TN in the Amphidrome™ effluent was 15 mg/L (median 14 mg/L) for the thirteen-month verification period. The System averaged a 59 percent reduction of TN for the entire test, with a median removal of 62 percent.

Table 2. Nitrogen Data Summary

	TKN (mg/L)		Ammonia (mg/L)		Total Nitrogen (mg/L)		Nitrate (mg/L)	Nitrite (mg/L)	Temperature (C)
	Influent	Effluen	Influent	Effluen	Influent	Effluent	Effluen	Effluent	Influent
Samples	53	53	53	53	53	53	53	53	42
Average	37	8.5	23	7.0	37	15	6.4	0.27	15
Median	37	8.3	23	6.1	37	14	5.4	0.25	14
Maximum	45	31	29	25	45	31	19	1.3	22
Minimum	24	1.0	18	0.4	24	10	0.05	0.08	8.4
Std. Dev.	4.2	6.4	2.4	4.7	4.2	3.6	4.5	0.20	4.3

Verification Test Discussion

Beginning in late March and early April, temperatures began to increase and the nitrifying population clearly became more firmly established, as indicated by the decrease in the TKN and ammonia concentrations in the effluent to 10 mg/L or less. Nitrate concentrations increased somewhat in this same period, but the data show that denitrification was also occurring. Organic concentration in the effluent was low, as measured by $CBOD_5$ concentrations of 4.0-5.0 mg/L. During May and June, the TN concentration in the effluent was in the range of 13 to 16 mg/L. The Washday stress test in May 2001 showed no negative impact on nitrogen reduction.

In early July 2001, the data show that there was loss of the nitrifying population in the unit, with TKN and ammonia nitrogen levels in the effluent increasing to 31 and 25 mg/L, respectively. The nitrate levels dropped to less than 0.1 mg/L, which would be typical of influent wastewater. It was not clear what caused this upset to occur. There was no obvious change in influent wastewater and no changes were made to the Amphidrome™ System. All mechanical parts of the System appeared to operating properly.

The Working Parent stress test started on July 9 and continued until July 13, 2001. The System began to recover from the upset with improved $CBOD_5$ and TSS performance, but the nitrification process was much slower in its recovery. Some removal of TKN, ammonia and TN was occurring during the Working Parent stress test monitoring in mid July, but at a lower performance level than during the previous two months. All of the data suggests that whatever caused the loss of the nitrifying population, it occurred before the Working Parent stress test. During the stress test, there was no sign that the stress test itself was having any additional impact on the system.

The monthly samples on August 1 and September 5 showed a significant improvement in the removal of TKN and ammonia, indicating that the nitrifying population was re-established. Nitrate levels in the effluent increased somewhat (3.3 to 7.9 mg/L) and TN in the effluent was in the 14 to 15 mg/L range.

The Low Load stress test began on September 17 and continued until October 8, 2002. During this stress period, the nitrification process became very efficient, dropping the TKN and ammonia levels in the effluent to less than 1 mg/L. Nitrate concentrations increased to 14 to 19 mg/L and TN was 14 to 20 mg/L. As the Low Load stress test ended, virtually all of the TN in the effluent was in the form of nitrate. Once the system returned to normal full flow conditions, the TKN and ammonia concentrations in the effluent rose slightly (1.2 to 4.8 mg/L), and nitrate concentrations decreased to 10 to 14 mg/L. Overall, the TN removal performance was steady at the end of the monitoring period with concentrations in the effluent of 10 to 14 mg/L, similar to the results obtained in May prior to the upset, except that the primary component of the TN concentration was nitrate. FRMA decreased the aeration time by ten percent to try to improve denitrification performance.

During the November 2001 to January 2002 period, including the Power/Equipment Failure stress test in December, the system produced steady results, with TN in the effluent of 10 to 16 mg/L, a removal efficiency of 57 to 77 percent. The TN in the effluent was a mix of TKN and nitrate, similar to the May and June 2001 period, prior to the upset condition in early July. The Power/Equipment Failure stress test, performed on December 3 did not have a major impact on the System.

The Vacation stress test (no influent flow for eight days) was performed in February 2002. The TKN and ammonia concentrations in the effluent decreased in the effluent samples taken immediately after flow was resumed to the System. The nitrate levels increased in a manner similar to the findings following the Low Load stress test. TN concentrations remained steady in the effluent ranging from 12 to 17 mg/L. By the end of the post stress test monitoring period, the effluent concentrations had returned to a mix of TKN and nitrate concentrations with TKN of 5.5 mg/L and nitrate of 6.8 mg/L. These data, supported by the results from the Low Load stress test, suggest that the Amphidrome™ System responded to decreases in flow by exhibiting improved nitrification and less denitrification. The TN performance, however, did not change significantly, with effluent concentrations remaining in a tight range near the long-term average and median of 15 mg/L and 14 mg/L, respectively.

The system performance remained consistent for the duration of the verification test. The TKN and ammonia nitrogen effluent concentration were consistently in the 7.6 to 9.5 mg/L range. The nitrate levels remained in the 3.0 to 4.8 mg/L range. The TN concentration in the effluent ranged from 11 to 15 mg/L.

The verification test provided a sufficiently long test period to collect data that included both a long run of steady performance by the Amphidrome™ System and a period of reduced nitrification and denitrification efficiencies. During the months of April through June, following startup, the TN removal was in the 45 to 71 percent range, with effluent concentrations typically in the 13 to 16 mg/L range. An upset condition of some type dramatically impacted the nitrification process in early July. Following the upset, the System recovered by the end of July and continued to remove substantial amounts of TN. During the last eight months of the verification test, the TN removal was in the 52 to 77 percent range. Effluent TN concentration ranged from 10 to 20 mg/L, with most concentrations in the 13 to 15 mg/L range. Data collected from the two low or no flow stress tests indicate that overall system performance for TN is not significantly impacted. However, the concentrations of TKN/ammonia and nitrate changed significantly during these lower flow periods. Nitrification was enhanced during low flow periods with a commensurate increase in nitrate concentrations in the effluent.

Operation and Maintenance Results

Noise levels associated with mechanical equipment were measured once during the verification period using a decibel meter. Measurements were made one meter from the unit, and one and a half meters above the ground, at 90° intervals in four (4) directions. The average decibel level was 56.7, with a minimum of 54.3 and maximum of 60.0. The background level was 37.7 decibels.

Odor observations were made monthly for the last eight months of the verification test. The observation was qualitative based on odor strength (intensity) and type (attribute). Observations were made during periods of low wind velocity (<10 knots), at a distance of three feet from the treatment unit, and recorded at 90° intervals in four directions. There were no discernible odors during any of the observation periods.

Electrical use was monitored by a dedicated electric meter serving the Amphidrome™ System. The average electrical use was 4.1 KW/day with a maximum of 32 KW/day. There was one two-week period of high electrical use in June 2001 near the same time of the upset to the nitrification process. The cause of this electrical usage spike is not known. The Amphidrome™ System does not require or use any chemical addition as part of the normal operation of the unit.

During the test, one mechanical problem occurred when the discharge pump failed. The high water alarm sounded and a service call was placed to FRMA. They responded within twenty-four hours and replaced the pump. Overall, the treatment unit appeared to be a durable design. The piping is PVC that is appropriate for the applications. Pumps and level switch life is always difficult to estimate, but the equipment used is made for wastewater applications. The PLC, which is critical to the operation of the system, functioned properly throughout the test.

In the opinion of the test site operators, the System was easy to operate and maintain from a homeowners perspective, as there is very little maintenance or adjustment that the average homeowner can or should perform. Amphidrome™ is a somewhat complex, PLC controlled system, using a sophisticated operating cycle that must be setup and optimized to site specific and changing conditions. During the first two months of verification testing (April and May), FRMA adjusted the PLC on four occasions. The airflow was adjusted in early April and the backwash cycle was adjusted in mid May. On May 24, the cycle times were adjusted to try to improve the performance, but were returned to the initial conditions on June 1. The anoxic cycle was adjusted on October 21, and the fixed airflow time was reduced by 10 percent to try to improve denitrification on October 25, 2001. These adjustments were made to try to improve performance and match the aerobic/anoxic cycles to the wastewater and system conditions. Based on these observations, it will be necessary for homeowners to have a qualified maintenance organization operate and maintain the System.

Hugh McKinnon Director National Risk Management Research Laboratory Office of Research and Development United States Environmental Protection Agency	Date	Gordon E. Bellen Vice President Research NSF International	Date

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

Availability of Supporting Documents

Copies of the *ETV Protocol for Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction,* dated November 2000, the Verification Statement, and the Verification Report are available from the following sources:

1. Source Water Protection ETV Manager (order hard copy)
   NSF International
   P.O. Box 130140
   Ann Arbor, Michigan 48113-0140
2. NSF web site: http://www.nsf.org/etv (electronic copy)
3. EPA web site: http://www.epa.gov/etv (electronic copy)

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

US EPA Environmental Technology Initiative

Onsite Wastewater Technology Testing Report

Massachusetts Alternative Onsite Septic System Test Center

Amphidrome®
Sequencing Batch Reactor

Technology Vendor

F.R. Mahony & Associates, Inc.
273 Weymouth Street
Rockland, MA 02370

February, 2003

1. Technogy Description

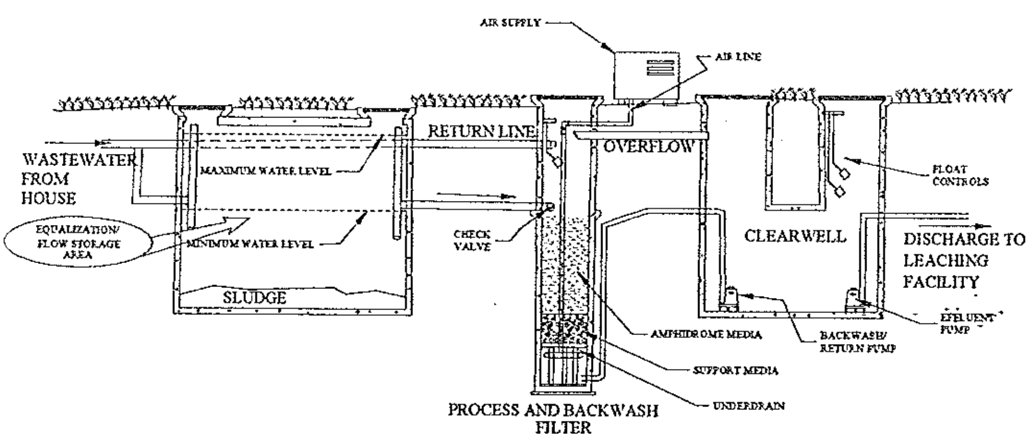
General

The Amphidrome® belongs to a broad class of treatment units called sequencing batch reactors (SBRs). These units process wastewater in "batches" and usually discharge the treated batch of wastewater over a short period of time to ready itself for the incoming load.

Components

The Amphidrome, as configured during these tests, consisted of a 1,500 gallon septic tank (anoxic chamber), a cylindrical reactor vessel (2 ft in diameter x 10 ft in height), and a 500 gallon clearwell from which the final treated effluent was pumped to the soil absorption system (Figure 1). All three replicates were supplied process and backwash air using pumps located remote to the unit and in the same housing. Based on the results of these tests, the vendor recommends the use of a 2,000 gallon septic tank for residential applications in this design-flow range.

Figure 1. Illustration of the Amphidrome® sequencing batch reactor as configured for testing at the Massachusetts Alternative Septic System Test Center.



Siting Considerations and Installation Notes

Relative component elevations are critical to proper system performance. Height of the reactor vessel may complicate some shallow-to-groundwater installations. Installation requires significant training and/or oversight by manufacturer. Above ground components include a blower with housing (variously sized), and an electrical control with an audio and visual alarm. The control panel contains programmable logic controllers (PLC) that require manufacturer's adjustments. Design considerations include the location of access manhole covers for routine maintenance and sampling, and situating the blower to minimize possibility for noise disturbance.

Theory of Operation

This system directs wastewater back and forth between the septic tank (anoxic tank) and the "clear well," passing it through an aggressively aerated reactor vessel. During this aeration part of the cycle, the effluent is nitrified (ammonium is converted to nitrate). At preset intervals, the air supply to the reactor vessel is shut off, allowing anoxic conditions to develop and enabling denitrification (i.e., conversion of nitrate to nitrogen gas) to occur. When the wastewater "batch" is adequately treated (cycled a number of times), it is discharged to the Soil Absorption System (SAS) at predetermined intervals. Processes are time-controlled using a series of programmable logic controllers.

2. Costs

Non-Standard Components: $8,000 (with clearwell, claim). Components + Installation: $10,000 more than conventional (claim). Electrical: $140-150 per year actual (assuming $0.10/ KWh and 3.9 KWh/day). These electrical costs reflect the system loaded continually at the peak (330 gpd) design flow. The vendor claims that under more typical actual flows, electrical costs will decrease based on the decreased pumping and air supply needs. O&M: Quarterly inspection of motors, air flow, effluent and sludge. A service contract is required in Massachusetts (Approximately $400 per year minimum, but varies). Septic tank pumping varies with location. Other Costs: Quarterly effluent quality monitoring is required for some permits ($300 or more annually). Design and permitting costs vary. Replacement: Pumps and blowers ($300) have a one-year warranty by Amphidrome.

3. ETI Testing Protocol Synopsis

The testing duration was two years. The technology was installed in triplicate, with identical components. The Amphidrome received wastewater at the rate of 330 gallons per day, throughout the two-year testing period. The 330 gallon per day volume is the Massachusetts Department of Environmental Protection (MA DEP) minimum design flow for a new residential house of three bedrooms or less.

Delivery of the wastewater was apportioned into fifteen equal doses of 22 gallons each, on a schedule which was designed to mimic the pattern of wastewater use in a typical residence (35% of flow in the morning; 25% flow during midday; 40% in the evening; see ETI QAPP and NSFI/AINSI Standard 40). Periodic calibration of dose volumes delivered to each technology ensured equal dosing to each replicate and to different technologies.

Effluent from the technology flowed to a distribution box and exited to the soil absorption system (SAS) through a single 4' pipe. The resulting load to the SAS was approximately 3 gal/day/sq ft. Pan Lysimeters were installed at depths of one, two and five feet beneath each SAS to collect leachate for analysis. A polyethylene liner with sump collected all leachate from the three technology replicates.

The technologies were sampled at two-week intervals. During each sampling event, technology influent wastewater was sampled at the common source. Technology effluent was sampled at the distribution box. Influent wastewater and technology effluent were sampled using automated samplers, programmed to obtain fifteen flow-weighted samples and composited over a twenty-four hour period. Since the discharge of this technology occurs in a single event, a sample container was positioned at the discharge point to collect a single sample from each unit.

Composite and discrete samples were kept refrigerated at 4 degrees centigrade either by ice packed in the sampler or by use of a refrigerated sampler. Analysis for pH and specific conductance were conducted at MAASTC during sample processing. Subsamples for BOD_5 and fecal coliform were sent to the Barnstable County Department of Health and the Environment laboratory. Subsamples for nitrogen and phosphorus analysis: ammonium (NH_4), nitrate plus nitrite (NO_x), dissolved organic nitrogen, (DON), particulate organic nitrogen (PON), alkalinity, orthophosphate (PO_4) and total phosphorus (TP); were sent to the Coastal Systems Laboratory at the School for Marine Science University of Massachusetts, Dartmouth (SMAST).

Electrical usage was measured by a single electric meter for all three units and recorded monthly. Kilowatt usage was then divided by three to calculate individual unit use.

Mechanical and other non-quantitative performance monitoring.

Alarms, mechanical failures, unusual sounds, and smells were recorded in a logbook as they occurred. Restorative measures taken by the technology vendor to address non-normal conditions were also recorded and appear in Section 6 "Operation and Maintenance" section of this report.

Technology Operating History.

The three replicate systems were installed in early December, 1999, and their operation was officially started for the beginning of testing on February 14, 2000. In early November, 2000, operation of one replicate system (referred to as "B-1") was ceased in order to prepare the unit for testing under a different set of protocols referred to as the Environmental Technology Verification Program Protocols. These later results are reported under a different cover. The two remaining units were operated and tested until April, 2002.

4. Testing Objectives

The Amphidrome was tested to demonstrate removal of nitrogen from the influent wastewater.

5. Contaminant Removal Performance Summary for Amphidrome®

Biochemical Oxygen Demand (BOD$_5$ Removal

BOD$_5$ effluent data suggest that the Amphidrome® system requires little startup time for the reduction of this constituent. The mean BOD$_5$ at the discharges (combining all three units) was 17.9 mg/l (n=134) versus a mean influent level of 195 mg/l (n= 58)

Table 1. Biochemical Oxygen Demand (5-day) removal performance of the Amphidrome® system during testing at the Massachusetts Alternative Septic System Test Center - February, 1999- March 2001.

BOD (mg/l)	Replicate 1	Replicate 2	Replicate 3	Influent	Mean	%Removal
Average	19.5	18.4	16.9	194.6	17.9	90.8%
Median	13.5	15.0	15.0	182.5		
Standard Deviation	19.2	14.1	11.2	65.1		
Maximum	89.0	88.0	74.0	385.0		
Minimum	2.0	3.2	5.0	83.0		
Count	20	57	57	58		

representing a 90.3% removal rate (Table 1, Appendix 1, Appendix 2). Excursions from the secondary-treatment standard of 30 mg/l appear related to a sludge buildup in the system that began after approximately eighteen months of operation. Following the removal of sludge from the first (anoxic) tank of units #2 and #3 (B-2 and B-3) on August 3, 2001, the removal performance of the system for this constituent returned within a few weeks (BOD was 5 mg/l or less on August 28, 2001). The failure of a process blower on the third replicate system (B-3) caused the BOD levels after March 26, 2001 to exceed the secondary standard of 30 mg/l.

Total Suspended Solids (TSS) Removal

The removal of suspended solids by the Amphidrome followed a similar trend as treatment for BOD, with only minor exception (Table 2, Appendix 1, and Appendix 2). Following approximately eighteen months of operation sludge accumulation of sludge in the anoxic chamber resulted in increased carryover of suspended solids to the discharge. Similar to the trend with BOD, suspended solids decreased in the discharges following the removal of sludge from the anoxic chamber on August 3, 2001. The single high TSS value (42. 7 mg/l) at B-3 (replicate #3) on August 28,2001 is unexplained, but could be due to an inadvertent mislabeling/switching of the sample bottle B-3 with that of B-1. This is corroborated by the BOD level at B-1 (which was not being tested under the ETI protocols at the time) which shows a concurrent BOD of 22 mg/l, more likely to coincide

Table 2. Total Suspended Solids (TSS) removal performance of the Amphidrome® system during testing at the Massachusetts Alternative Septic System Test Center. February, 1999-March 2001.

TSS (mg/l)	Replicate 1	Replicate 2	Replicate 3	Influent	Mean	% Removal
Average	9.2	7.3	7.0	172.6	7.5	95.7%
Median	5.0	4.9	4.0	167.5		
Standard Deviation	11.0	9.2	8.1	55.2		
Maximum	47.0	55.8	42.7	364.7		
Minimum	1.0	0.9	0.0	72.0		
Count	20	56	56	56		

with the higher TSS. Likewise, the BOD of 5.0 mg/l noted at B-3 more likely coincided with a TSS of 2.9 mg/l which was reported to be observed at the B-1 discharge (Appendix 1, Appendix 2).

Total Nitrogen Removal

With a single exception, all three replicates of this technology were consistent with each other for the first eight months of operation. The single exception observed on June 14, 2000 at B-2 (Replicate #2) is unexplained and may be due to laboratory error since it is highly inconsistent with both the replicates and values noted on dates either side of this observation.

Table 3. Total Nitrogen (TN) removal performance of the Amphidrome® system during testing at the Massachusetts Alternative Septic System Test Center. February, 1999-March 2001. Data below exclude a start-up period of February 23-May 2, 2000.

Total Nitrogen (mg/l)	Replicate 1	Replicate 2	Replicate 3	Influent	Mean	%Removal
Average	8.3	11.1	11.2	34.5	10.81	68.7%
Median	8.6	9.4	8.9	34.6		
Standard Deviation	1.4	5.6	6.8	3.9		
Maximum	9.9	32.4	38.5	42.3		
Minimum	5.8	6.4	6.7	23.9		
Count	13	50	50	48		

For the calculation of nitrogen removal, data following a start-up period was used. For purposes of this report\"start-up" is considered as that period during which the total nitrogen level (mg/l) in the discharge exceeds 19 mg/l. In the case of the Amphidrome, there is a clear demarcation of start-up at the 12 week sampling event (Appendix 1, Appendix 2). Prior to this (on May 2, 2/000), all units show a Total Nitrogen (TN) level exceeding 22 mg/l. On May 17, 2000, no replicate discharged levels of TN exceeding 13 mg/l. Thus, when the Amphidrome is started during colder months, at least a 12 week start-up appears to be required. In the period following start-up (May 17, 2001) to April 24, 2001, the average TN discharged (excluding the one aberrant value of 27.3 mg/l observed at B-2 on June 14, 2000) was 9.14 mg/l (n=61). Following this date, however, and until sludge accumulation in the anoxic tank was removed on August 3, 2001, TN levels averaging 20.3 mg/l (n=14) were discharged. This observation suggests that the nitrogen removing capability of the system is even more sensitive to the buildup and accumulation of sludge in the anoxic chamber compared with BOD and TSS. Again, following the removal of accumulated sludge on August 3, 2001, treatment for nitrogen resumed with average levels of 8.6 mg/l (n=36) observed until the end of sampling on April 23, 2002. This average excludes two high (26.3 and 37.8 mg/l) levels observed at B-3 due to a failure of a process blower in early April of that year.

Our data indicate that, following a start-up period which may vary depending on ambient temperature, this system is capable of achieving discharge levels of < 12 mg/l, provided that sludge levels are not allowed to accumulate, and the system components are otherwise maintained in accordance with the manufacturer's recommendations. The reason for the lower mean nitrogen levels in Replicate #1 compared with #2 and #3 (Table 3) is that this unit was halted prior to the accumulation of sludge[1].

Fecal Coliform Removal

Fecal coliform is often used as a surrogate measure of public health significance. Wastewater treatment systems that remove fecal coliform are thought to concurrently reduce the discharge of human pathogens. In general, there is 1- 2log (90-99%) removal of fecal coliform in the Amphidrome system, with no apparent seasonal trends in performance.

Table4. Fecal Coliform removal performance of the Amphidrome® system during testing at the Massachusetts Alternative Septic System Test Center. February, 1999-March 2001.

Fecal Coliform CFU/100 ml	Replicate 1	Replicate 2	Replicate 3	Influent	Mean	%Removal
Log Mean	3.4E+04	3.9E+04	2.9E+04	3.2E+06	3.3E+04	96.7
Maximum	2.7E+05	5.4E+05	1.1E+06	2.6E+07		
Minimum	4.0E+03	8.0E+02	3.0E+03	3.0E+05		

[1] B-1 or Replicate #1 was cleaned and restarted for testing under Environmental Technology Verification Protocols which will be reported under separate cover.

6. Operation and Maintenance Monitoring – Amphidrome

In general, the Amphidrome System requires that the operator of the system begin with an approximate set of settings for the various cycles that may not reflect settings for optimum performance. Accordingly, at any site, a period of adjustment must occur. During our testing, between the period 3/17/2000 – 5/18/2000, the operator made adjustments at least 12 times. The vendor collected and analyzed many discharge samples throughout the testing period using field test kits. This practice was presumably to indicate what field adjustments were necessary to the operating parameters. Adjustments were periodically made to all units during the entire testing period. The relatively high number of adjustments were made presumably due to the fact that the units installed were among the first units designed for single-family usage.

During the testing period, a float switch was replaced (8/15/01), and a motor was replaced (11/13/01). The vendor believed that the motor replacement resulted from an electrical surge, possibly a strike by lightning.

The Programmable Logic Controllers installed in the three units tested did not have internal clocks. The lack of this feature resulted in occasional disruption of the cycle times at times when the facility experienced power failures. Internal clock mechanisms will presumably be placed in any models sold after our testing dates.

The noise generation of the unit was difficult to measure due to the fact that the blowers for all three units were placed in the same housing and operated simultaneously.

Maintenance

The components of the Amphidrome must only be serviced by qualified personnel. Sludge levels can be determined using a standard "sludge judge" or other manual type device, or using various electronic devices. The manufacture states that annual pumping is recommended on systems configured similar to the units tested. The reactor vessel can easily be inspected by opening the circular top, which allows access to control and alarm floats for inspection and testing. Similarly, the clearwell is accessed by opening the top, which allows inspection of both pumps and control floats. The electrical panel houses the PLC and controls for access by a computer or similar device. Manual overrides of pumps and blowers, as well as alarm switches were easily accessible for inspection/testing. As with all advance treatment units in Massachusetts, the unit must be under a contract for the operation maintenance for the life of the system. DEP requires that the operator of this system must hold a Class 4 Wastewater Treatment Plant Operator certification.

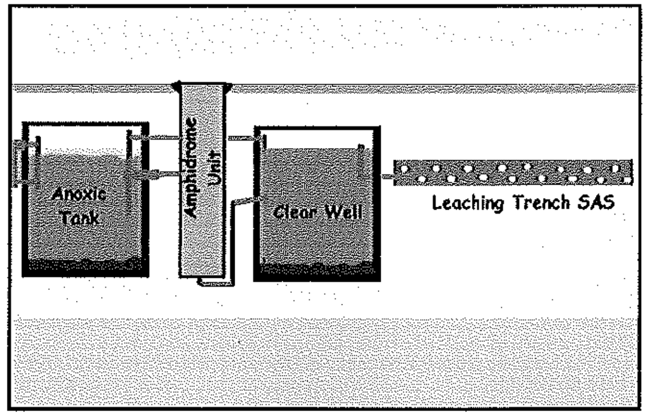
Massachusetts Alternative Septic System Test Center

Amphidrome

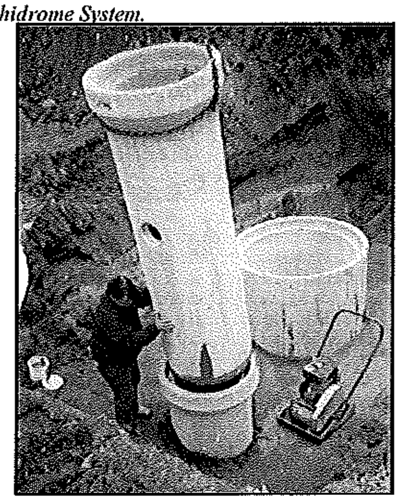
Technology Fact Sheet -*Interim Findings*

The Massachusetts Alternative Septic System Test Center is a collaborative project of the Buzzards Bay Project National Estuary Program, Massachusetts Office of Coastal Zone Management, Massachusetts Department of Environmental Protection, Barnstable County Department of Health and the Environment, and UMass Dartmouth School for Marine Science and Technology. The Test Center was established in recognition of the need in Massachusetts for cost-effective wastewater disposal systems suitable for sites with limited space, poor soils, high groundwater elevations, or where advanced pollutant removal is required. Its mission is twofold. First, to evaluate the performance and operation costs of new and innovative wastewater disposal technologies in a carefully controlled and unbiased manner, and provide this information to regulators and consumers. Second, to assist vendors in getting their technologies more quickly approved for use in Massachusetts, and at a lesser cost.

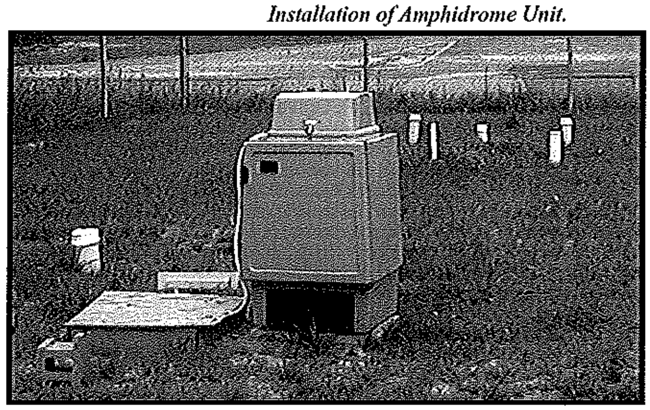
Technology Name:	Amphidrome
Technology Type:	Sequencing batch reactor.
Manufacturer:	F.R. Mahony & Associates, Inc. 273 Weymouth Street Rockland, MA 02370 (781) 982-9300
Contact:	Keith Dobie, President
Company Website:	www.frmahony.com
Performance & Permitting Info at MA DEP and BCHED Websites:	www.state.ma.us/dep/brp/wwm/t5pubs.htm#it www.capecod.net/alternativeseptic
Testing Objectives:	Nitrogen sensitive areas, suitable for retrofits, use for reduced separation to groundwater and small SAS size.
Testing Period:	Testing started 3/00 and is ongoing. Results shown for 3/00 to 2/01.
Testing loadings:	System loading was 990 gpd, (in 15 doses AM/PM), SAS was 2.96 gallons per sq. ft per day.



Generalized design of Amphidrome System.



Installation of Amphidrome Unit.



Siting Considerations and Installation Notes

The system consists of a septic tank, reactor vessel, and "clear well" or pump chamber. Relative component elevations are critical to proper system performance. Height of the reactor vessel may complicate shallow-to-groundwater installations. Installation requires significant training and/or oversight by manufacturer. Above ground components include a blower with housing (variously sized), and an electrical control with an audio and visual alarm. The control panel contains programmable logic controllers (PLC) that require manufacturer's adjustments. Designer should consider situating the blower to minimize possibility for noise disturbance.

Actual and Manufacturer's Estimated Costs (3-bedroom home) and Labor

Non-Title 5 Components: $8,000 (with clearwell, claim).
Components + Installation: $10,000 more than conventional (claim).
Electrical: $91 per year actual (local rates, annual KWh= 823)
O&M: Quarterly inspection of motors, air flow, effluent and sludge. A service contract is required in Massachusetts (Approximately $400 per year minimum, but varies). Septic tank pumping averages $60 per year.
Other Costs: Quarterly effluent quality monitoring is required for some permits ($300 or more annually). Design and permitting costs vary.
Replacement: Pumps and blowers ($300) have a one-year warranty by Amphidrome.

Theory of Operation

This system directs wastewater back and forth between the septic tank (anoxic tank) and the "clear well," passing it through an aggressively aerated reactor vessel. During this aeration part of the cycle, the effluent is nitrified (ammonium is converted to nitrate). At preset intervals, the air to the reactor vessel is shut off, allowing anoxic conditions to develop, enabling denitrification (*i.e.*, conversion of nitrate to nitrogen gas) to occur. When the wastewater "batch" is adequately treated (cycled a number of times), it is discharged to the Soil Absorption System (SAS) at predetermined intervals.

Permitting and Use in Massachusetts (*as of June 2001*)

Certification for General Use: No approval in this category. Remedial Use Approval: Amphidrome has approval in remedial situations where a system is failed, failing or nonconforming where relief is sought to construct an SAS within two feet (or three feet for percolation rates exceeding two minutes per inch) of the high groundwater elevation, to construct an SAS reduced in size by up to 50 percent or in areas where at least 2 feet of suitable material is available beneath the SAS. Provisional Use: No approval in this category, application currently under review. Piloting Approval: Approved for use in nitrogen-sensitive areas. For design flow of less than 2000 GPD, for residential systems up to 660 gpd per acre, for nonresidential systems up to 550 gpd per acre. For systems 2000 gpd or larger approved for 440 gpd per acre.

The company further seeks to demonstrate that the ability to achieve a discharge limit of less than 10 mg/l which will allow construction in any nitrogen sensitive area. In addition, higher hydraulic loading rates are being requested (see the approval letter of June 29, 1995 on DEP Website)

Operation and Maintenance Issues
[This information will be included in the final report findings.]

Explanation of the Graphs
The graphs to the right show the mean of three replicates for each parameter over the testing period, compared to Title 5 performance and influent measured in parallel samples during the same period. Fecal coliform results are expressed as geometric means. In the nitrogen graph, NH4 represents ammonia, NOx represents nitrate + nitrite, DON is dissolved organic nitrogen, and PON is particulate organic nitrogen. Total nitrogen is the sum of these four parameters.

Soil absorption system samples include wastewater disposal system effluent and precipitation. The recharge of precipitation to groundwater for the Title 5 system was estimated to be between 8 percent-16 percent of effluent discharge based on local rainfall, estimated groundwater recharge rates, SAS size and dosage rates. A 10% interim rate was adopted. Amphidrome was tested at 3 times the dosage rate of the Title 5 system, so a 3.4 percent rainfall dilution rate was adopted. The results for nitrogen removal include this estimated dilution factor (note bars labeled "SAS adj.") Results shown for biological oxygen demand (BOD), total suspended solids (TSS), and fecal coliforms were not adjusted for dilution by precipitation, because the adjustment was negligible in evaluating overall performance. This interim approach, is being compared to specific conductivity, chlorides, and bromide tracer to better refine this estimate, and develop system specific dilution factors. **Thus, the "SAS adjusted" values reported here for nitrogen discharge to groundwater should be considered preliminary.**

Summary of Interim Findings
This technology exceeds secondary treatment (*i.e.*, TSS and BOD less than or equal to 30 mg per liter) to allow for the reduced separation to groundwater, or reduced soil absorption system size. BOD and TSS concentrations at the base of the SAS for this technology and the Title 5 system are similar. This technology discharged below 19 mg/l TN to allow for use in nitrogen sensitive areas with design flow of 660 gpd. At the SAS base, this system was estimated to remove 64 percent of nitrogen inputs compared to 19 percent for a Title 5 system during the same period. This system was not tested at the Test Center for seasonal or intermittent use or for high hydraulic loading conditions.

The Technical Review Committee does not recommend adoption of nitrogen loading ratings for this technology until the two-year testing period is complete. Differences in nitrogen removal among technologies tested are not necessarily significant. Nitrogen removal performance may vary with soil types and other site differences. The Buzzards Bay Project will recommend nitrogen loading rates for this technology for planning purposes and watershed loading evaluations at a later date.

Funding for the Massachusetts Septic System Test Center was provided by the US EPA, through Cooperative Agreements x991657 and x981007, the Massachusetts Department of Environmental Protection (319-99-01, 319-00-02), Massachusetts Office of Coastal Zone Management, Massachusetts Environmental Trust, Barnstable County Department of Health and Environment, UMass Dartmouth SMAST, and other organizations. Other information on this initiative can be found at www.buzzardsbay.org. These fact sheets were reviewed by a multi-agency work group. The views or opinions expressed are not necessarily those of the Commonwealth of Massachusetts, the US EPA, or any of the funding organizations and agencies. The information presented here represents the technical findings of the Massachusetts Septic System Test Center after at least one year of system testing. Manufacturer claims of cost and longevity, warranties, or stated costs have not been verified. Modifications to system designs from those tested, or installation under other soil or climate conditions may result in different system performance. This fact sheet was prepared and printed by the Buzzards Bay Project.

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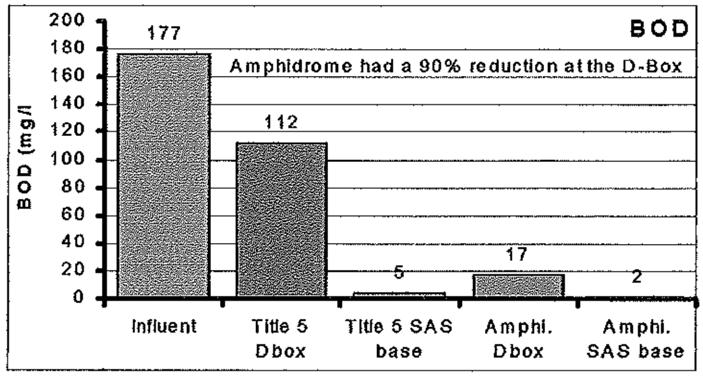

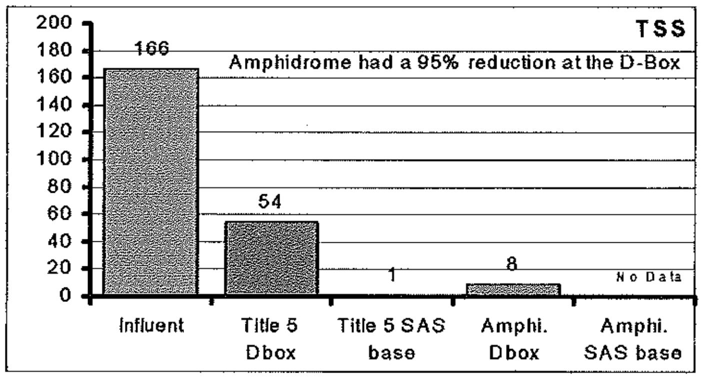

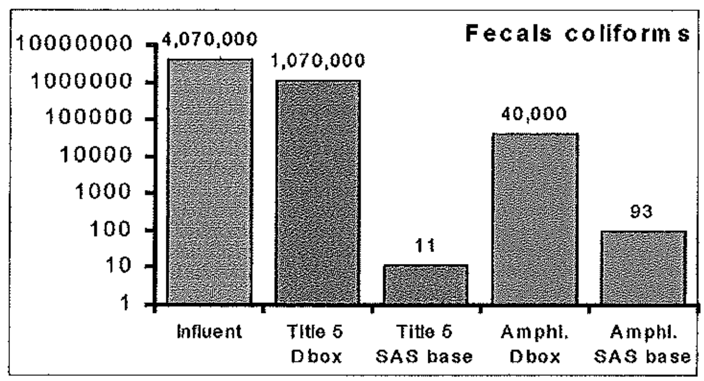

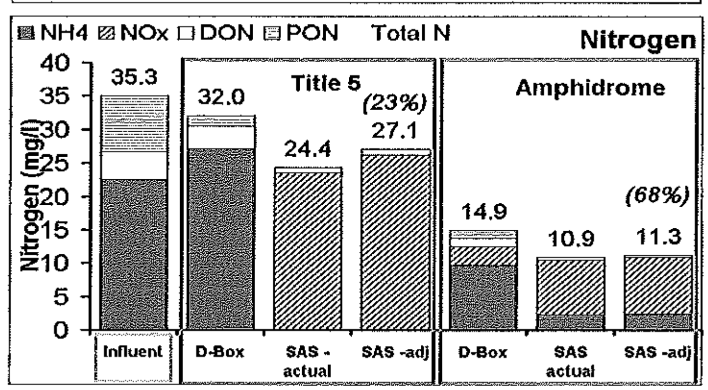

Commonwealth of Massachusetts
Jane Swift, Governor
Executive Office of Environmental Affairs
Bob Durand, Secretary
Buzzards Bay Project
Dr. Joe Costa, Executive Director
2870 Cranberry Highway East Wareham, MA 02538
508.291.3625

STATE OF MAINE
DEPARTMENT OF HUMAN SERVICES
DIVISION OF HEALTH ENGINEERING
10 STATE HOUSE STATION
AUGUSTA, MAINE
04333-0010

ANGUS S. KING, JR.
GOVERNOR

KEVIN W. CONCANNON
COMMISSIONER

June 18, 1999

F. R. Mahoney & Associates, Inc.
Attn.: W. Keith Dobie, Sr.
131 Weymouth Street
Rockland, MA 02370

Subject: Denial, Product Registration, Amphidrome Wastewater Treatment System

Dear Mr. Dobie:

The Division has reviewed the manufacturer's literature and other information submitted to this office for the Amphidrome Wastewater Treatment System. No cover letter, written request, or any other correspondence was enclosed with this information.

Under provisions of Section 1902 of the Maine State Plumbing Code, Subsurface Wastewater Disposal Rules (copy enclosed), any manufacturer or distributor submitting a new product for code registration needs to demonstrate that:

1. The product is designed to protect public health, prevent the creation of any nuisance, and prevent environmental pollution to the same extent as comparable products presently authorized by Department for use in this code, and

2. The product is based on sound engineering principles and can be expected to provide the same level of protection to public health and the environment as offered by the authorized products presently authorized by the Department for use in this code.

Such demonstration may be achieved by submitting a letter to the Division of Health Engineering from: a) a certifying organization, such as the International Association of Plumbing and Mechanical Officials (IAPMO), Building Officials and Code Administrators (BOCA), or other suitable organization stating their approval of the product, or b) the American Society for Testing and Materials (ASTM) indicating the requested product (used as indicated in the request) meets the ASTM standard as specifically listed in the appropriate section of any nationally recognized plumbing code, such as BOCA, IAPMO (same as International Plumbing Code), or equal.

OFFICE - 157 CAPITOL STREET TTY (207) 287-2070 FAX: (207) 287-4172

According to the limited information you provided, specifically, the copy of a report to the Massachusetts Department of Environmental Protection, dated March 1998, the Amphidrome system is capable of significant reductions in BOD5 and TSS. However, only three sources were sampled, and one of those had no influent figures (ref. Table 3 of the report dated March ,1998). A total of 28 samples were taken. No other supporting data were submitted, although manufacturer's literature was submitted.

On that basis, the Division has determined that while Amphidrome Wastewater Treatment System is based upon a reasonable premise, the information submitted in support of use of this system in Maine is woefully inadequate.

Further, this office is persuaded that the while Amphidrome Wastewater Treatment ***System*** is appropriately reviewed under the experimental system criteria of Section 1901 of the Rules. You may wish to formally apply for experimental system approval.

If you have any questions please feel free to contact me at (207) 287-5695.

Sincerely,

James A. Jacobsen

James A. Jacobsen, Manager
Wastewater and Plumbing Control Program
Division of Health Engineering
e-mail: james.jacobsen@state.me.us

Enc.: Section 19, CMR 241

xc: File

The

Amphidrome™

Wastewater Treatment System

F R MAHONY
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The Amphidrome™ Process

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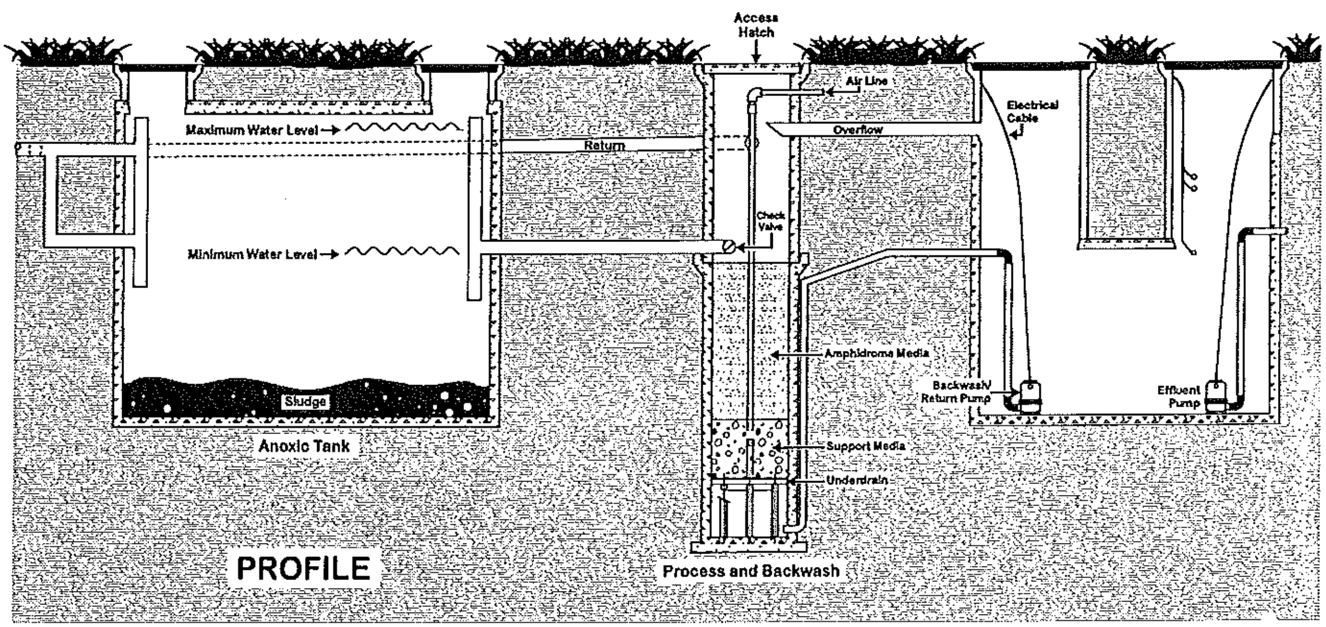
The equalization/return flow area and the anoxic pretreatment/sludge storage area may be in the same tank with a fluctuating water level, or in separate tanks. When a single tank is used, the upper portion of the tank has a fluctuating water level and functions as the equalization/return flow storage area, and the lower level of the tank has a fixed volume and functions as an anoxic pretreatment/sludge storage area. If separate tanks are used, the equalization/return flow tank has a fluctuating level, and the anoxic pretreatment/sludge storage tank has a fixed level. The system may also use a combination of these two configurations.

The equalization/return flow storage area is intended to equalize and store forward flow prior to treatment in the biological media filter. The anoxic pretreatment/sludge storage area is intended to: (1) settle solids from incoming material and return flow for storage in the sludge storage area, and (2) provide a degree of denitrification for the return flow using the incoming flow as a carbon source (soluble carbon released from the stored sludge is also a source of carbon for the denitrification process), and (3) to store and biologically digest settled sludge.

The granular media biological filter is multifunctional. It functions as a filter and as a fixed-film reactor. As a fixed film reactor it oxidizes carbonaceous BOD, ammonia and organic nitrogen-based compounds while operating in an aerobic mode, and reduces nitrite and nitrate while operating in an anoxic mode. The incoming waste and the accumulated biomass are used as the primary sources of carbon for the denitrification process. For high strength nitrogenous wastes, supplementary carbon from an outside source may be required. The final component in the flow train is the clearwell, which provides storage for flow to be recycled or used for backwash.



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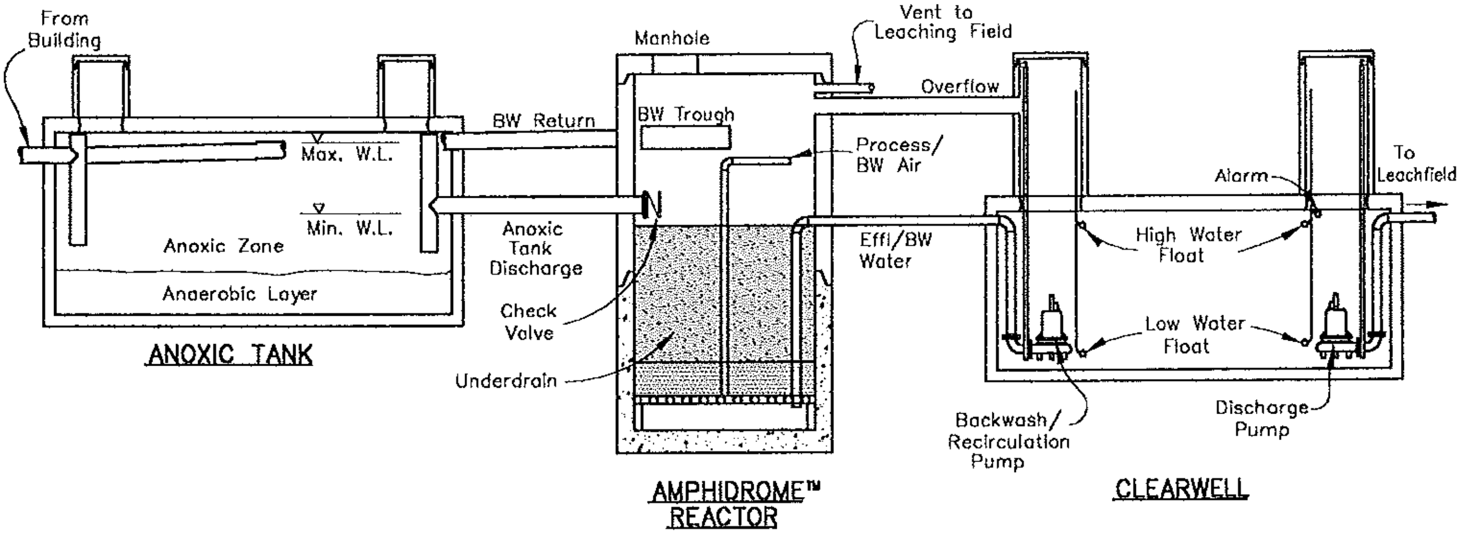
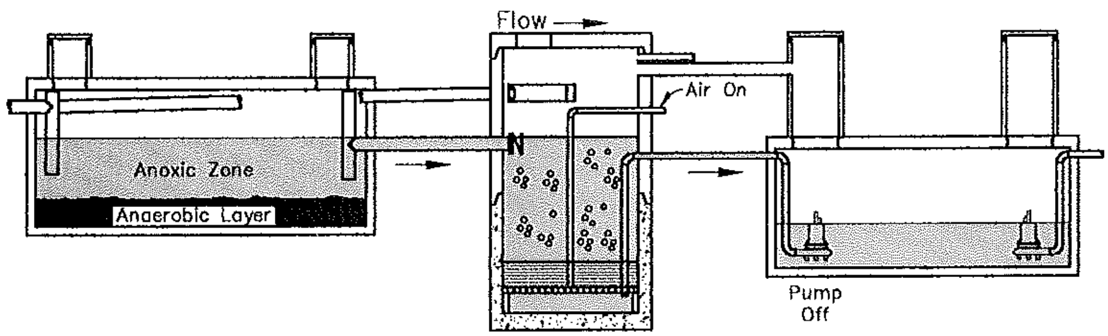
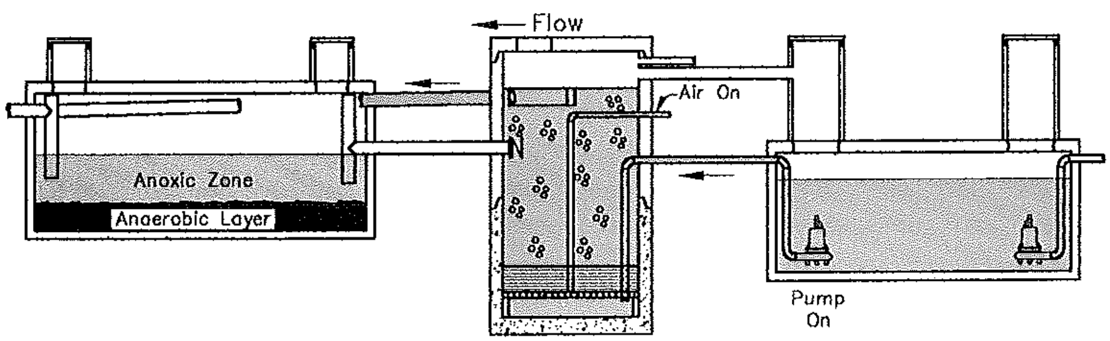


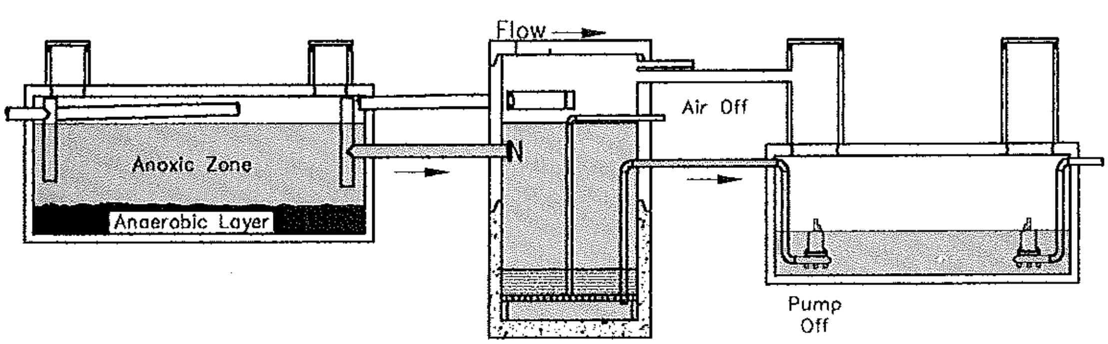
ColOX™ Cycle



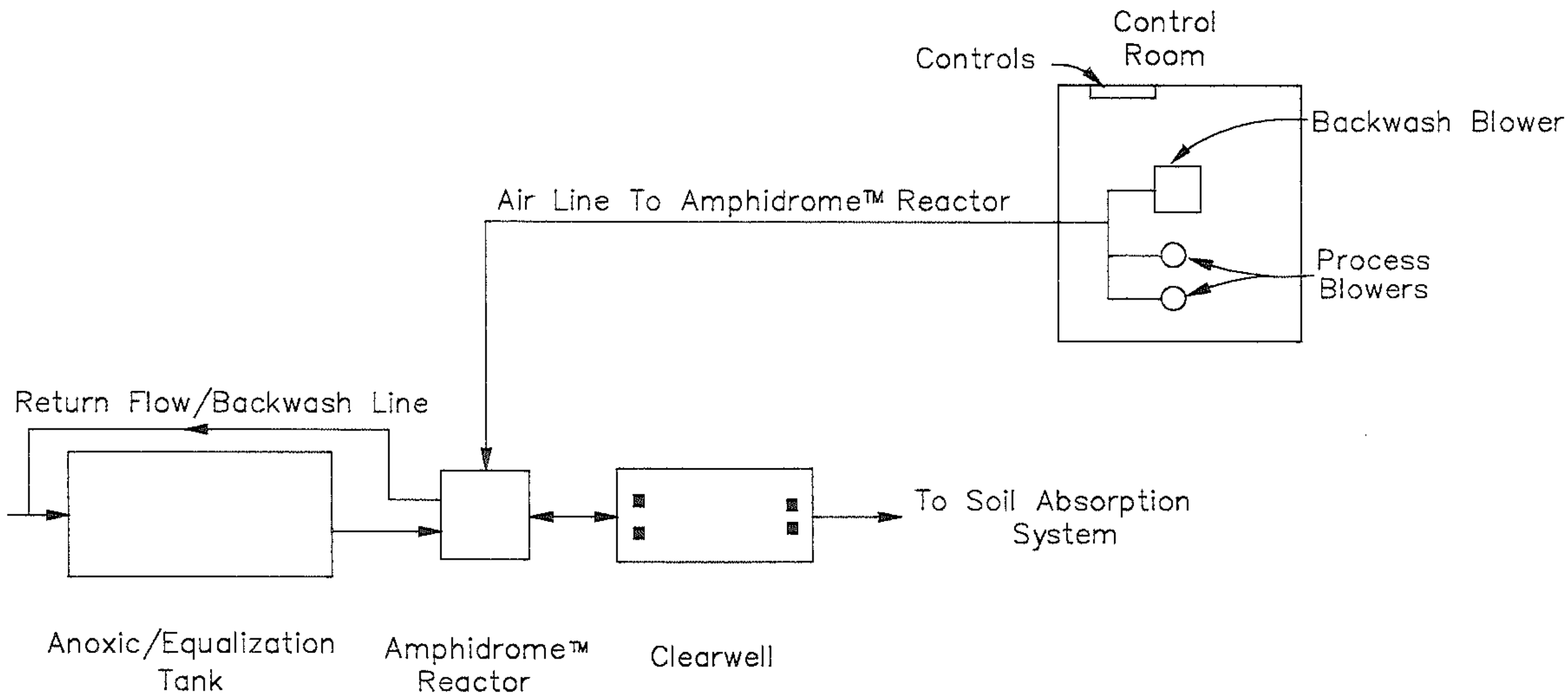
Return ColOX™



Denite® Cycle



Amphidrome™ System Process Schematic



Amphidrome™ System
Process Schematic

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Water Supply & Pollution Control Equipment
131 Weymouth Street, Rockland, Massachusetts 02370

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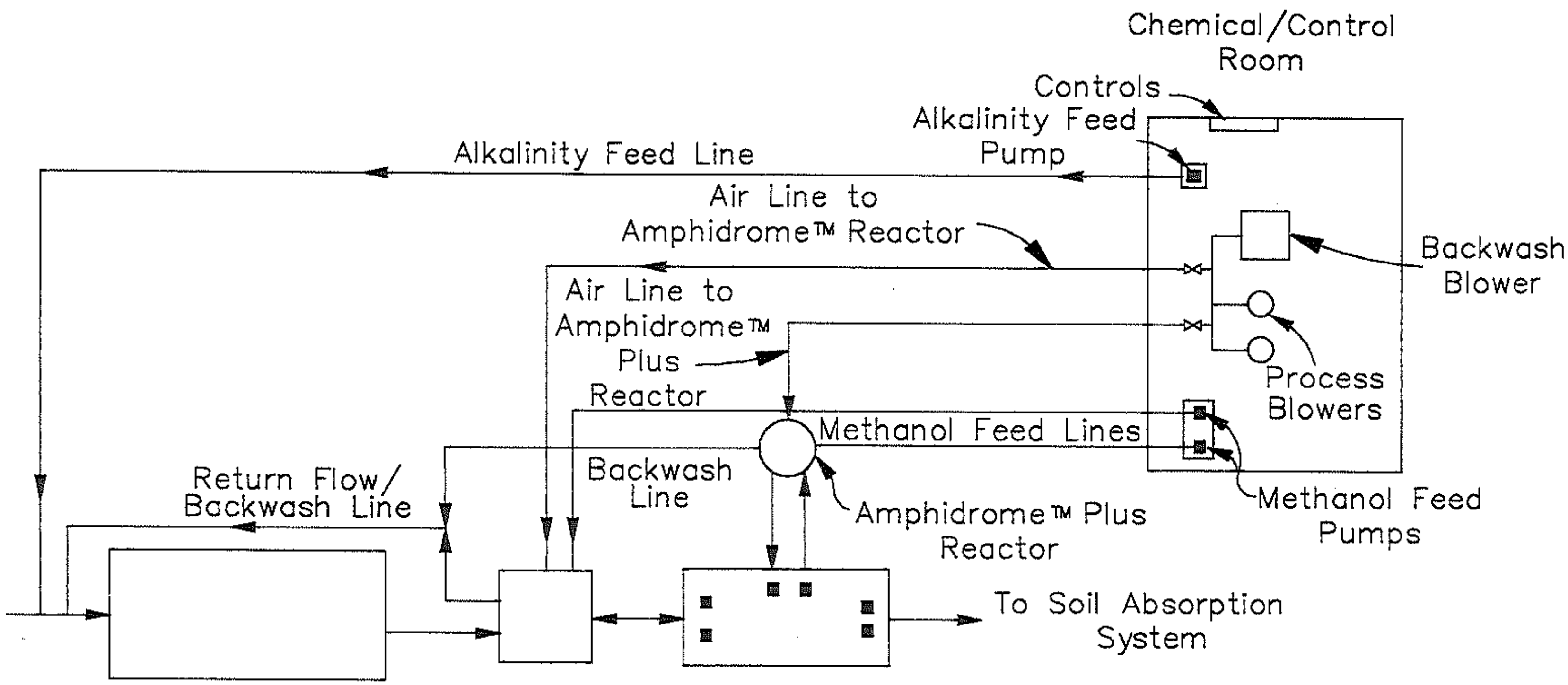
Not to Scale

Amphidrome Plus™ System Process Schematic



Amphidrome Plus™ System Process Schematic
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Not to Scale

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AUGUSTA, MAINE
04333-0011

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KEVIN W. CONCANNON
COMMISSIONER

October 13, 1998

F. R. Mahony & Associates, Inc.
131 Weymouth Street
Rockland, MA 02370

Subject: Amphidrome Wastewater Treatment System

Dear Sirs:

Thank you for your brochure and copy of an article from Volume 1, Number 4 of *Environment Cape Cod* received September 14, 1998 regarding Amphidrome Wastewater Treatment System. There was no correspondence included with these items.

Under provisons of Section 1802 of the Rules (copy enclosed), any manufacturer or distributor submitting a new product for code registration needs to demonstrate that:

1. The product is designed to protect public health, prevent the creation of any nuisance, and prevent environmental pollution to the same extent as comparable products presently authorized by Department for use in this code, and

2. The product is based on sound engineering principles and can be expected to provide the same level of protection to public health and the environment as offered by the authorized products presently authorized by the Department for use in this code.

Such demonstration may be achieved by submitting a letter to the Division of Health Engineering from: a) a certifying organization, such as the International Association of Plumbing and Mechanical Officials (IAPMO), Building Officials and Code Administrators (BOCA), or other suitable organization stating their approval of the product, or b) the American Society for Testing and Materials (ASTM) indicating the requested product (used as indicated in the request) meets the ASTM standard as specifically listed in the appropriate section of any nationally recognized plumbing code, such as BOCA, IAPMO (same as International Plumbing Code), or equal.

We would also need copies of any relevant manufacturing literature and engineering data, as well as any supporting plans and mechanical drawings.

If you have any questions please feel free to contact me at (207) 287-5695.

Sincerely,

James A. Jacobsen

James A. Jacobsen, Manager
Wastewater and Plumbing Control Program
Division of Health Engineering
e-mail: james.jacobsen@state.me.us

Enc: Chapter 18
xc: General Correspondence File

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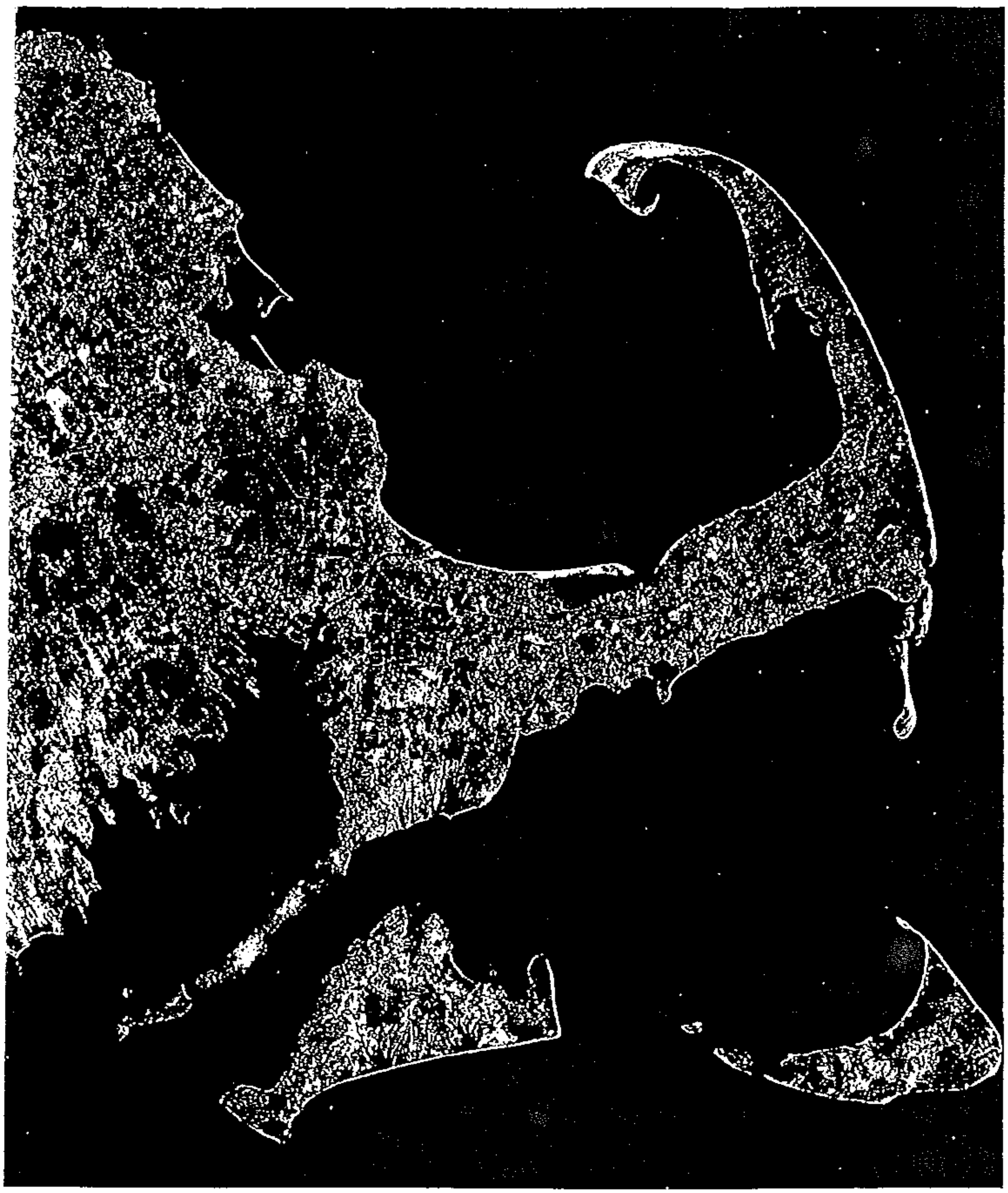

Alternative Septic Systems: Results of Monitoring Reported to Massachusetts DEP as of March, 1998

Susan Rask
Barnstable County Department of Health and Environment
P.O. Box 427
Barnstable, MA 02630

Introduction

The Barnstable County Department of Health and Environment has for several years been actively involved in educating health officials and the public about alternative septic treatment technology, especially technologies which are capable of removing nitrogen. The Massachusetts Department of Environmental Protection (DEP) has granted various levels of approval to a number of alternative technologies, and a fairly large number of these have now been installed across the state. DEP requires most systems to monitor the effluent quality; monitoring results are reported to DEP who will evaluate the data to determine if effluent quality meets standards established by DEP, especially for nitrogen removal. This paper reports the results of effluent monitoring for a number of alternative septic systems installed on Cape Cod and elsewhere in the state through March 1998. Data is presented for Bioclere®, FAST®, RUCK®, Amphidrome®, and Jet Aerobic® systems.

Overview of alternative systems

Alternative septic systems are designed to treat wastewater to higher quality than is routinely achieved through use of a conventional septic system (septic tank and leaching field). Conventional septic systems provide anaerobic break down of wastes within the septic tank, and some degree of aerobic treatment of the sewage effluent after it enters the leaching field. Unlike conventional septic systems, alternative systems generally treat wastewater actively, to promote more rapid and complete breakdown of waste. Most alternative systems actively aerate waste to speed up the digestion of organic matter and breakdown biochemical oxygen demand (BOD5) and total suspended solids (TSS). The earliest alternative systems -- those that remove BOD and TSS -- were originally designed to improve effluent quality so that wastewater could be more successfully disposed of in slowly permeable soils

More recently, especially in coastal areas, interest has focused on removing nitrogen from sewage effluent. Nitrogen removal involves a two step, bacterially-mediated process. Nitrogen is present in the septic tank primarily as ammonia and organic nitrogen (urea, proteins, and amino acids, the majority of which convert readily to ammonia in the septic tank). For nitrogen loss to occur, ammonia (NH_3) must first be converted to nitrate (NO_3), a step known as nitrification. This process, which is bacterially mediated, requires oxygen and must occur under aerobic conditions. The second step, denitrification, involves the conversion of nitrate to inert nitrogen gas (N_2). Again, this step is bacterially mediated but can only occur under anaerobic (no oxygen) conditions. Both processes must occur if nitrogen is to be lost; thus, total nitrogen loss can be limited by either the nitrification or denitrification step.

While nitrogen reduction is a well-established procedure at sewage treatment plants, adapting this technology for small, on-site septic systems has been challenging. Systems must be designed to provide both aerobic and anaerobic treatment components. In addition, on-site systems typically receive large variations in both volume and strength of sewage, which makes the treatment process less biologically stable than in larger treatment plants. On-site units must be designed to accommodate this, but at a cost that is affordable for single residential installations.

The efficiency of nitrogen removal for most small on-site systems is still not fully established. For this reason, DEP has granted only *Provisional Use Approval* for most systems that are used to remove nitrogen. Provisional Use Approval allows the installation of 50 systems of each technology. These systems must be monitored for nitrate, ammonia and total Kjeldahl nitrogen in effluent and DEP will use the data gathered to determine nitrogen removal efficiency for each technology.

Installation of numbers of these provisionally approved systems began after they were specifically allowed by the revised 1995 state regulations, *Minimum Requirements for the Subsurface Disposal Of Sanitary Sewage*, commonly referred to as Title 5. A significant body of monitoring data is now being developed for the Bioclere, FAST, Amphidrome, JET Aerobic, and RUCK systems (the RUCK system has been granted General Use approval by DEP, but is required to perform monitoring for nitrogen). The treatment processes used by these technologies are described briefly below.[1]

The Bioclere system is a modified trickling filter: sewage is pumped up and trickles down through layers of plastic media that serve as a growth substrate for the bacteria which treat the sewage. The media theoretically contains both aerobic and anaerobic microzones that allow simultaneous nitrification and denitrification to occur. BOD is also digested under these aerobic conditions by bacteria present on the media surface. Additional nitrogen loss is obtained by recirculating the nitrified wastewater back to the anaerobic septic tank for further denitrification. The Bioclere system, while approved for general use without nitrogen removal, is provisionally approved by DEP as capable of a 55% reduction in total nitrogen for residential use, and a 40% reduction for commercial use. Effluent must meet a total nitrogen limit of 19 mg/L in residential use and 25 mg/L in commercial use.

The FAST system utilizes aeration and activated sludge to treat sewage. The treatment unit consists of a submerged bed of plastic media, which sits within the septic tank. Sewage enters the aeration chamber where air diffusers circulates the sewage through the media where it is aerated, nitrified, and BOD is digested.. After passing over the media, sewage flows back to the anaerobic primary settling zone of the septic tank for denitrification. The sewage is continuously recirculated through this treatment regime. The FAST system is provisionally approved for 55% (residential) and 40% (commercial) nitrogen removal; effluent must meet a total nitrogen limit of 19 mg/L in residential use and 25 mg/L in commercial use.

The JET Aerobic system also utilizes active aeration and circulation of the sewage through plastic media to achieve sewage treatment. Sewage enters a pretreatment compartment where solids settle. After settling, sewage flows to an aeration chamber where an aerator circulates the sewage through plastic media. Aerobic conditions allow nitrification and digestion of BOD to occur. The unit may also be capable of nitrogen reduction if the operation of the aerator is controlled by a timer: air supply is turned on for part of the day and shut off during the night. This theoretically might allow the treatment media to become anoxic so that denitrification could occur. The JET Aerobic unit has received Remedial Use approval from DEP; under this approval the system must meet a BOD and TSS standard of 30 mg/L. The technology vendor has tested one system for nitrogen and may test additional systems in the future.

In the RUCK system greywater (laundry and shower water) and blackwater (toilet and sink

[1]for more detailed information on the design and operation of these treatment technologies, the reader is referred to *A Compendium of Information on Alternative On Site Septic System Technology in Massachusetts* published by the Barnstable County Department of Health and Environment, and the *Innovative and Alternative On-Site Wastewater Treatment Technologies Handbook* by Eric Winkler, published by the University of Massachusetts

wastewater) are plumbed to separate septic tanks. Blackwater (which contains most of the nitrogen) flows from the septic tank to the aerobic RUCK sand filter where it is nitrified. This nitrified effluent then flows to the greywater septic tank where anaerobic conditions and the availability of carbon in the greywater allow denitrification to occur. Denitrified wastewater is then discharged to the leaching facility. The RUCK system has General Use Approval for nitrogen removal for residential use only; it is approved as capable of 55% nitrogen removal and effluent must meet a total nitrogen limit of 19 mg/L.

The Amphidrome system is a sequencing batch reactor. The system consists of a deep bed sand filter that alternates between aerobic and anaerobic conditions. Batches of sewage pass from an anoxic tank through the biological filter to a clear well. Flow is then reversed so that the sewage passes back through the filter to the anoxic tank. Nitrification occurs during the aerobic cycle and denitrification occurs during the anaerobic cycle. After a number of treatment cycles, the batch of treated sewage is released and a new batch of sewage begins treatment. The Amphidrome system has Piloting Use approval from DEP. This allows 15 experimental systems to be installed and monitored. Under its approval, DEP recognizes that the system may be capable of a 55% reduction in nitrogen. The system must meet a 19mg/L total nitrogen standard. In addition, the vendor is seeking to prove that the system is capable of producing effluent with total nitrogen of < 10 mg/L and a 76% nitrogen removal efficiency.

DEP requires that the Bioclere, FAST, RUCK, and Amphidrome systems be monitored regularly when used in nitrogen sensitive areas or where data will be applied towards a system's approval for nitrogen reduction. Boards of Health may also set additional monitoring requirements or performance standards. The following parameters must generally be monitored for: biochemical oxygen demand (BOD5), total suspended solids (TSS), nitrate (NO3), total Kjeldahl nitrogen (TKN, a measurement that includes both dissolved organic nitrogen and ammonia), and ammonia (NH3).

Results and Discussion

Data for effluent quality is presented in several ways (Tables 1-3). For each system, the total number of times the system was sampled is shown. For each parameter, the average value obtained from all sampling dates is shown; ranges of values obtained for that parameter are also shown in parentheses below the average to give the reader an idea of the variability in the data. For total nitrogen, the number of times that the system achieved a nitrogen standard of 19 mg/L over all sample dates is shown in the rightmost column of the data tables, i.e. the system achieved the standard on 4 out of 10 (4/10) sample dates.

Note that total nitrogen in effluent is calculated by adding TKN and NO3 values. For some systems, TKN data is not available. In these cases total nitrogen in effluent has been calculated as the sum of nitrate and ammonia. Use of this calculation may slightly underestimate total nitrogen since it excludes the dissolved organic nitrogen fraction. However, dissolved organic nitrogen usually makes up a relatively small component (<10%) of treated sewage, making this error small in most cases. For some other systems only TKN data is available. Since TKN constitutes only a portion of total nitrogen, the total nitrogen in finished effluent for these systems is noted as being equal to or greater than the system's average effluent TKN value.

Although a 55% or greater removal of nitrogen (at residential installations; 40% removal at commercial installations) is one of the conditions set by DEP for performance of these systems, it is difficult using existing data to evaluate whether most of these systems achieve this goal. This is because most systems recirculate treated effluent back into the a portion of the septic tank or other inflow chamber where it mixes with new sewage that receives no treatment. This dilutes the untreated sewage, making it difficult to establish values for nitrogen, BOD and TSS in the incoming sewage. Since these values cannot be accurately determined for incoming sewage, a comparison cannot be accurately made between treated and untreated sewage and thus the efficiency (percentage removal) of the treatment process cannot be determined. Note, however, that influent nitrogen (NO3, TKN, NH3) data is presented for many of the systems. The inflow chambers of these systems have been sampled but it should be recognized that the values shown reflect dilution of influent sewage by treated sewage and are therefore artificially low. The degree to which the data is skewed downward is a function of the proportion of sewage recirculated to the inflow chamber and varies from system to system to an extent that has not been quantified. Most of these systems would have to be physically reconfigured to include a separate inflow chamber if accurate data is to be gathered for inflow sewage.

Bioclere

The Bioclere system has the largest data set for nitrogen removal of any alternative technology in use in the state. Many Bioclere systems have been installed under general use approval; these systems must monitor only for BOD and TSS. We report data for 13 systems that have been monitored for nitrogen. The systems have been sampled for the time period ranging from 1993 to the present, for a total of 167 samples. Sampling results are presented in Tables 1 and 3. These 13 systems serve both residential and commercial buildings. However, not all of these systems must meet a 19 mg/L (residential) or 25 mg/L (commercial) nitrogen standard due to the fact that many have been installed outside of nitrogen sensitive areas or in remedial situations where nitrogen standards do not apply. Four (Marshfield, Orleans, N. Reading, Stoughton) of the six commercial systems do not have to meet a 25 mg/L standard; most of the residential systems are not required to meet a 19 mg/L standard. In interpreting the data it should be recognized that the systems for which nitrogen standards do not apply may not have been operated to maximize nitrogen removal.

Of the 7 residential systems for which we have data, 4 produced effluent with average total nitrogen < 19 mg /L; the other 3 systems averaged well over 19 mg/L total nitrogen in finished effluent (Table1). Average total nitrogen in finished effluent ranged from 9.4 mg/L (Chatham) to 28.2 mg/L (Fairhaven). Looked at on a sample by sample basis, systems ranged widely in their ability to achieve a 19 mg/L total nitrogen standard, from a high of 100% of all samples dates (7 out of 7) at a system in Cohasset to a low of 25% of all sample dates (2 out of 8) at the system in Fairhaven. Because we cannot accurately quantify total nitrogen levels in incoming sewage, it is not possible to assess whether the Bioclere units meet the requirement of 55% or better removal of total nitrogen.

For commercial systems, 3 out of 6 did not meet a 25 mg/L nitrogen standard. The system in Hanover, which must meet a local requirement of 10 mg/L nitrogen at a downgradient well and so presumably is being operated to maximize nitrogen removal, averaged 33.4 mg/L nitrogen. For two other systems (Orleans, N. Reading) only TKN data is available; total nitrogen in effluent is not known but average TKN levels exceeded 25 mg/L for both these systems. However, these systems are not required to meet a 25 mg/L nitrogen standard. On a sample by sample basis, systems ranged in their ability to achieve a 25 mg/L standard from 50% (3/6, Yarmouth) to 100% (11/11, Marshfield) of all sample dates. The Yarmouth system is under a local requirement to produce effluent with total nitrogen <13 mg/L, so presumably this system is also operated to maximize nitrogen removal.

The differences in performance of these systems appears to be related to the efficiency, or lack thereof, of nitrification in each system. Inspection of data from the 5 systems (Cohasset-1, S. Yarmouth, Marshfield, Hingham, N. Chatham) that average <19 mg/L total nitrogen, and

TYPE of SYSTEM	LOCATION	NUMBER SAMPLES	NO3 INFLUENT mg/L	NO3 EFFLUENT mg/L	TKN INFLUENT mg/L	TKN EFFLUENT mg/L	NH3 INFLUENT mg/L	NH3 EFFLUENT mg/L	Total N EFFLUENT mg/L	Times Finished Effluent <19 mg/L
			SYSTEM AVERAGES							
Bioclere										
residential	Cohasset-1	7	2.30 (0.8-11.3)	10.80 (6.2-16.0)	10.40 (4.0-18.8)	1.55 (0.76-2.4)	9.39 (2.5-13.7)	0 (0.2-1.42)	12.35	7/7
residential	S. Yarmouth	33	0.30 (0.04-0.64)	4.24 (.38-7.35)	13.74 (4.4-17.6)	7.40 (2.9-12.0)	8.20 (5.4-19.1)	4.30 (1.0-10.0)	11.60	25/30
residential	N. Chatham	4		6.90 (1.7-13.5)		2.47 (1.9-4.06)		0.35 (0-1.38)	9.37	4/4
residential	Fairhaven	8		6.94 (.25-16.8)		21.29 (12.0-40.6)		16.72 (8.9-35.8)	28.23	2/8
residential	Sharon	7		17.00 (2.5-31.8)		4.29 (3.0-8.0)		1.74 (0.5-6.0)	21.29	3/7
residential	Cohasset-2	23			75.72 (37.0-145)	27.95 (7.2-55.0)			≥27.95	
residential	Hingham	9		8.67 (4.3-22.5)		7.07 (1.7-22.8)		1.70 (.02-9.45)	15.74	7/9
										<25 mg/L
commercial	Marshfield	11	0.43 (0.1-2.74)	3.51 (.62-7.10)	27.03 (8.9-53.0)	6.97 (.78-17.0)	12.82 (4.8-18.5)	1.80 (0-3.3)	10.48	11/11
commercial	Hanover	24	1.62 (.5-4.6)	3.20 (.5-10.8)	41.52 (22.0-63.0)	30.17 (13.0-48.0)	32.24 (2.5-47.0)	25.98 (.94-41.5)	33.37	3/4
commercial	Yarmouth	6	0.16 (.05-4.0)	9.91 (.4-22.2)			27.28 (16.0-48.7)	13.14 (2.4-46.8)	23.04	3/6
commercial	Orleans	16			61.68 (34.0-107)	32.90 (9.0-54.6)			≥32.90	
commercial	N. Reading	13			44.60 (8.0-73.9)	25.95 (6.4-57.0)			≥25.95	
commercial	Stoughton	6	0.36 (0.1-0.5)	10.13 (5.5-21.9)	39.28 (32.0-45.0)	12.86 (7.7-20.0)	26.72 (24.0-29.8)		22.99	4/6

Table 1. Average nitrogen values for Bioclere systems; range of actual values found appear in parentheses.

which were able to meet this standard on more than 50 % of their sample dates, shows that these systems all have high levels of nitrification. This is evidenced by the relatively high ratio of nitrate to ammonia in system effluent: nitrate levels equal or exceed ammonia levels in the effluent. This ratio indicates that a significant portion of the ammonia has been converted to nitrate and that the nitrification process is working efficiently. In 5 of the other 8 systems (3 of the 8 cannot be examined due to lack of nitrate and ammonia data) which do not on average meet the 19 mg/L standard, and which meet the standard on less than 50% of all sample dates, the ratio of effluent nitrate to ammonia is low; nitrate levels are consistently less than ammonia levels in effluent, indicating that nitrification is not proceeding efficiently. For the Bioclere units that are experiencing a low total nitrogen loss, it appears that the inefficiency of the nitrification step may be responsible.

Mixed results are also seen in these systems' ability to reduce BOD5 and TSS to the secondary treatment standard of 30 mg/L (Table 3). Five of the thirteen systems were able to produce effluent that averages <30 mg/L BOD. Interestingly, 4 of these systems are the same systems that had good total nitrogen removal results. The remaining 8, whose effluent did not on average meet the 30 mg/L standard, are generally the same systems which experienced poor nitrogen loss.

Since both nitrification and the reduction of BOD require oxygen, it is possible the systems which are experiencing low nitrification and poor BOD loss may be oxygen limited. If BOD is high in influent sewage, the microorganisms that oxidize BOD could deplete available oxygen rapidly before BOD is completely consumed. The resulting low oxygen levels would slow oxygen diffusion across the trickle filter media producing anaerobic zones on the treatment substrate that in turn would inhibit the bacterially mediated nitrification process. Unfortunately, it is not possible to evaluate this hypothesis due to a lack of data on BOD levels in influent sewage. A second possibility is that the sewage is being pumped over the filter media at too high a rate. The degree of nitrification and oxidation of BOD depends on actual contact time with the bacteria that perform these functions. With high surface loading (or if some type of channeling through the media develops), effluent may trickle through the treatment path without completing this oxidation. A third possibility for low levels of nitrification relates to the pH of the system. The process of nitrification produces hydrogen ions that cause pH in the system to drop. Nitrifying bacteria operate most efficiently at nearly neutral pH; their metabolic activity drops off as pH drops. If insufficient alkalinity exists in the system to buffer the pH drop caused by nitrification, the nitrification process may be slowed and become much less efficient.

Eight of the thirteen systems were able, on average, to meet the 30 mg/L standard for TSS. All of the system that experienced good BOD reduction also experienced good TSS reduction.

FAST

While DEP reports data for 72 FAST units that have been installed statewide under General Use Approval, only 5 have been monitored for total nitrogen in effluent. Of these 5, efficiency of nitrogen reduction is mixed (Table 2). Three systems achieved average total nitrogen concentrations in effluent of < 19 mg/L; this includes a commercial system operated at a restaurant/hotel in Falmouth. On a sample by sample basis, these three systems achieved <19 mg/L nitrogen on 100% of all sample dates. The other two systems did not achieve an average total nitrogen concentration of < 19 mg/L; the Cohasset-A system averaged 30.8 mg/L and the Scituate system averaged 24.7 mg/L total nitrogen in finished effluent. On a sample by sample basis, the Cohasset system met the 19 mg/L standard on 4 out of 7, or 57% of sampling dates; the Scituate system met this standard 3 out of 8 or 38% of the time. As with the Bioclere systems discussed above, the limited nitrogen loss in the Cohasset system is likely due to poor nitrification; this is evidenced by an average nitrate concentration of 3.84 mg/L versus an which were able to meet this standard on more than 50 % of their sample dates, shows that these systems all have high levels of nitrification. This is evidenced by the relatively high ratio of nitrate to ammonia in system effluent: nitrate levels equal or exceed ammonia levels in the effluent. This ratio indicates that a significant portion of the ammonia has been converted to nitrate and that the nitrification process is working efficiently. In 5 of the other 8 systems (3 of the 8 cannot be examined due to lack of nitrate and ammonia data) which do not on average meet the 19 mg/L standard, and which meet the standard on less than 50% of all sample dates, the ratio of effluent nitrate to ammonia is low; nitrate levels are consistently less than ammonia levels in effluent, indicating that nitrification is not proceeding efficiently. For the Bioclere units that are experiencing a low total nitrogen loss, it appears that the inefficiency of the nitrification step may be responsible.

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As with the Bioclere system, no comparison of influent and effluent can be made for the FAST system. Because we cannot determine the total nitrogen in incoming sewage, it is not possible to assess whether the FAST units meet the requirement of 55% removal of total nitrogen.

The majority of FAST systems easily meet the secondary treatment standards of 30 mg/L for BOD and TSS (Table 3). Of the 72 systems installed statewide (data not presented in this report), 88% were able to produce on average an effluent with BOD <30 mg/L; 95% produced an effluent that averaged less than 30 mg/L TSS.

TYPE of SYSTEM	LOCATION	NUMBER OF SAMPLES	BOD INFLUENT mg/L	BOD EFFLUENT mg/L	TSS INFLUENT mg/L	TSS EFFLUENT mg/L
Bioclere	Cohasset1	7	74	7	69	8
	S. Yarmouth	33	89	34	67	37
	Marshfield	11	199	26,1	210	29
	Fairhaven	8		38		17
	Hanover	24	135	40	156	26
	Yarmouth	6	151	64	53	17
	Hingham	9		14		9
	Sharon	7		10		11
	Cohasset2	23	590	47	181	34
	Orleans	16	275	47	199	46
	N. Reading	13	185	40	116	34
	Stoughton	6	139	31	144	38
	N. Chatham	4		14		6
FAST	Cohasset	8		13		6
	Cohasset	7		22		17
	Scituate	8		5		7
	Falmouth	5		16		17
	Cohasset	5		27		23
Amphi-	Mashpee	11		21		4
drome	Swansea	10	260	23	56	27
	Waquoit	7	132	17	23	36
RUCK	Mashpee	2	114	45	68	23
	Boxford	1	72	28	6	2
	Boxford	1	160	60	65	7
	Mashpee	1	300	53	35	32
	W. Falmouth	1	380		35	
	W. Falmouth	1	303		33	2200
JET						
Aerobic	Rockland	10	165	19	318	17

Table 3. Average BOD and TSS in influent and effluent.

Amphidrome system

DEP reports that three Amphidrome systems have been installed under piloting approval with full nitrogen monitoring. All three systems meet an average 19 mg/L total nitrogen standard for finished effluent (Table 2). The system installed in Mashpee shows average total nitrogen of 6.4 mg/L in finished effluent. On a sample by sample basis, this system achieved 19 mg/L on 11 out of 11 samples or 100% of the time. In addition, it achieved total nitrogen of < 10 mg/L on 8 out of 11 sample dates, or an average of 73% of the time. The Amphidrome system installed in Swansea, a commercial installation at a shopping mall, also shows good results. Total nitrogen in effluent averages 18.0 mg/L; on a sample by sample basis the system achieved a 25 mg/L standard on 9 out of 10 dates, and a 19 mg/L standard on 7 out of 10 or 70% of all sample dates. The system achieved an average total nitrogen of <10 mg/L on 2 out of 10 dates. The system installed in Waquoit also appears to be performing successfully. Total nitrogen, measured as total dissolved nitrogen (TDN, note that TKN was not measured for this system) for this system averaged 17.4 mg/L; on a sample by sample basis the system achieved a 19 mg/L standard on 3 out of 7 sample dates, and it also achieved <10 mg/L on these same three dates. All three systems on average meet the 30 mg/L standard for BOD and TSS (Table 3).

RUCK system

A limited amount of data exists for RUCK systems installed in Massachusetts. Although DEP reports data from 6 systems, five of these systems have each been sampled only one time and the other one was sampled twice. Based on this limited data, every system meets the 19 mg/L nitrogen standard for nitrogen (Table 2). Four of the six systems produced a finished effluent of <10 mg/L total nitrogen. The RUCK systems tested had mixed results meeting the 30 mg/L standard for BOD and TSS (Table 3). One out of four systems (two were not tested) met the standard for BOD; three out of five met the standard for TSS.

JET Aerobic system

Results are reported for one JET system sampled on 10 dates (Tables 2 and 3). Although this system is not approved for nitrogen removal, the manufacturer is testing the system to see if it is capable of reducing nitrogen. Total nitrogen in finished effluent averages 26.9 mg/L; the system achieved a standard of 19 mg/L on 1 out of 10 dates. BOD and TSS reductions on average consistently meet the 30 mg/L standard; BOD averaged 19 mg/L and TSS averaged 17 mg/L.

Conclusions

This paper is a preliminary report on the performance of alternative systems based on limited amounts of data for most systems The Amphidrome and RUCK systems appear, on average, to meet DEP's required standards for total nitrogen in effluent. The performance of the Bioclere and FAST systems is mixed with regard to ability to remove nitrogen. While some systems of each of these technologies performed well, others did not meet treatment standards established by DEP for system performance. Most of the systems that did not perform well for nitrogen loss appear to be limited by incomplete nitrification of wastewater. Nitrification is known to be the more common limiting step to nitrogen loss in sewage treatment.

Another reason that some systems may not meet the 19 mg/L residential nitrogen standard may relate to the assumed levels of total nitrogen in influent sewage. DEP, in assigning a 19 mg/L standard, assumes that total nitrogen in inflow sewage averages 42 mg/L; a 55% removal results in 19 mg/L in effluent. If, in fact, total nitrogen in influent sewage is higher, these systems may be removing a large percentage of nitrogen but not meeting the 19 mg/L standard. For example, if total nitrogen in inflow sewage were 65 mg/L, 55% removal of nitrogen would produce effluent with total nitrogen of 30 mg/L. A system that produced this effluent would be assessed as not performing well when, in fact, it is operating efficiently. This question will not be resolved unless nitrogen levels in inflow sewage can be determined accurately.

More importantly from a practical standpoint, the mixed results seen between different systems of one technology type again emphasize the fact that these systems do not necessarily work consistently from site to site. The operation of each system must be adjusted according to the strength and volume of its own individual sewage load if it is to function well. If a system is to function optimally, it is likely that its operator will have to spend significant time adjusting operation of the system to maximize performance, and will have to perform fairly extensive effluent quality testing to assure that the system is functioning well. This type of monitoring will involve significant costs to the owners but is essential if these systems are to perform effectively. Maintenance and monitoring of these systems cannot be ignored as an essential component of their installation.

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