Amphidrome®

Operation & Maintenance Manual
Amphidrome® System &
Amphidrome Plus® System

f.r. mahony & associates, inc.
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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.

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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 wastewater, 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 nitrogen to the innocuous form, nitrogen gas (N_2). The completion of this process occurs in two steps, by completely different bacteria, 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 wastewater 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 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). Extensive research has been conducted on both the activated sludge process and the RBC process but to a lesser degree on the other types of treatment.

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.

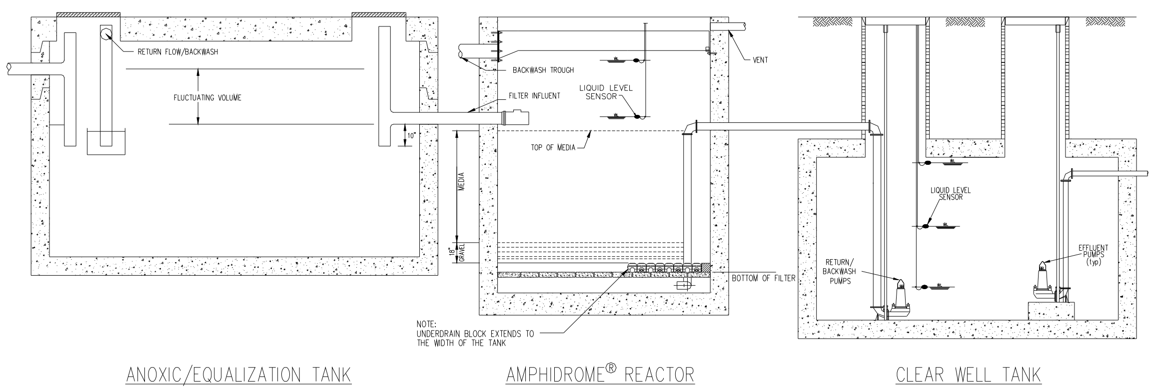

Figure 1. Cross Section View Of Amphidrome™ Reactor and Tanks

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 removal of SOM is achieved by the oxidation of carbonaceous matter, which is accomplished by the aerobic growth of heterotrophic bacteria. The biochemical transformation is described by the following normalized mass based stoichiometric equation in which the carbonaceous matter is a carbohydrate (CH_2O) and the nitrogen source for the bacteria is ammonium (NH^+_4).

$$CH_2O + 0.309\ O_2 + 0.085\ NH^+_4 + 0.289\ HCO_3^- + 0.535\ C_5H_7O_2N + 0.633\ CO_2 + 0.515\ H_2O$$

The oxidation of ammonia to nitrate is accomplished by the aerobic growth of chemolithotrophic, autotrophic bacteria and is described by the following normalized mass based stoichiometric equation. The overall equation describes the two-step process in which ammonia is converted to nitrite by Nitrosifyers and nitrite is converted to nitrate by Nitrifyers.

$$NH^+_4 + 3.30\ O_2 + 6.708\ HCO^-_3 + 0.129\ C_5H_7O_2N + 3.373\ NO^-_3 + 1.041\ H_2O + 6.463\ H_2CO_3$$

The final step in the removal of nitrogen from the waste stream occurs when carbonaceous matter is oxidized by the growth of heterotrophic bacteria utilizing nitrate as the terminal electron accepter. The equation describing the biochemical transformation depends on the organic carbon source utilized. The following is the normalized mass based stoichiometric equation with the influent waste stream as the organic carbon source.

$$NO^-_3 + 0.324\ C_{10}H_{19}O_3N + 0.226\ N_2 + 0.710\ CO_2 + 0.087\ H_2O + 0.027\ NH_3 + 0.274\ OH^-$$

Biological removal of nitrogen has been the focus of much attention and many of today's wastewater treatment plants incorporate it. However, the difficultly in promoting these biochemical transformations in one reactor is the different environmental conditions required for each transformation.

This Amphidrome® process is designed to achieve the above reactions simultaneously within one reactor. The aerobic environment within the filter promotes the first two reactions. The return flow, to the anoxic/equalization tank, mixes the nitrates with organic carbon in the raw influent and with organic carbon that has been released from the stored sludge. The anoxic environment within the filter promotes denitrification, the third reaction.

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_5, total suspended solids, settleable solids, COD, pH, alkalinity, DO, temperature, total solids, dissolved solids, nitrogen and phosphorus. Some of these parameters may not be 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. Therefore, bicarbonate alkalinity is an important parameter in the treatment process and should, therefore, be monitored 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 measure 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/equalization 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 wastewater, 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

Since the Amphidrome® system operates as a sequencing batch reactor, effluent grab samples from each batch should be taken. Therefore, if a system discharges twice a day, two samples should be collected, one for each batch treated. If local regulations require a composite sample, then the grab samples from each batch should be blended together in proportionate amounts. The volumes may be apportioned based directly on the volume discharged for each batch, or based on the discharge pump run for each batch.

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 include: 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.

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). See 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). See figure 2.

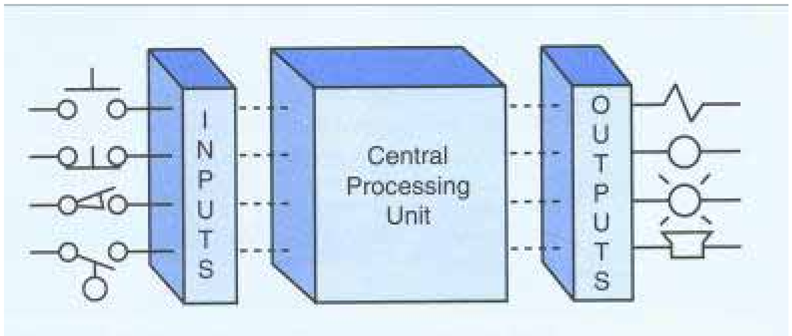

Figure 1 PLC Block Diagram

During operation the CPU does three things, first it reads the input data from the field devices via the input interfaces; second, it performs 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.

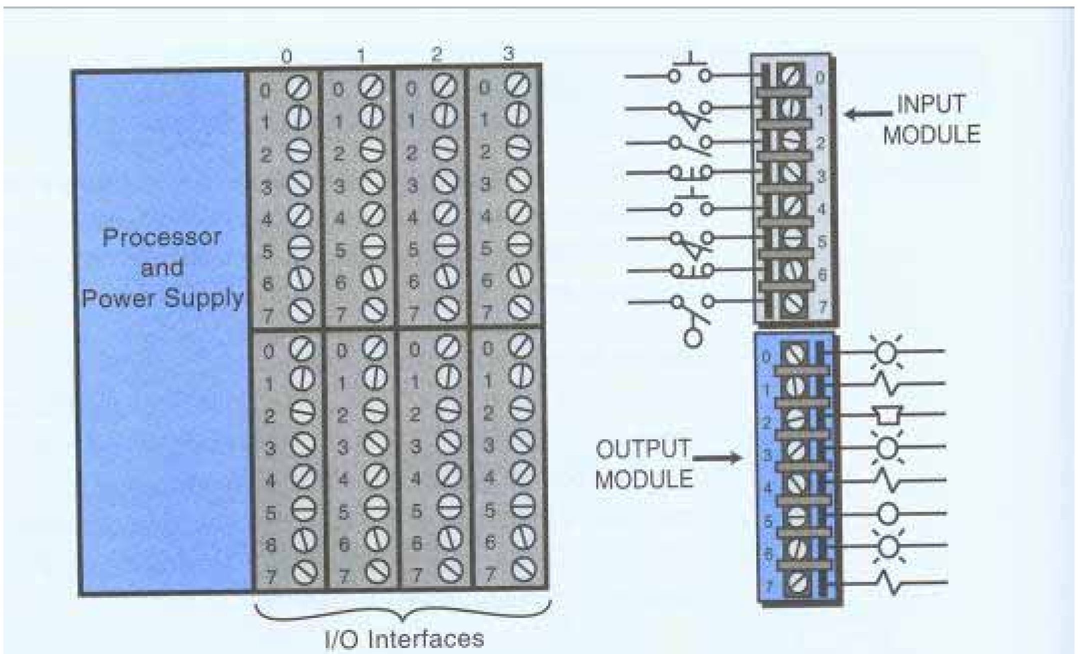

Figure 2 Input/Output Interfaces

The input/output system provides the interface between the field devices and the controller. Incoming signals from sensors are wired to terminals on the input interfaces. The devices to be controlled are wired to the terminals of the output interfaces. The power supply provides the voltages required for the operation of the CPU. Figure 3 below shows the CPU, input modules and output modules in an Amphidrome® system.

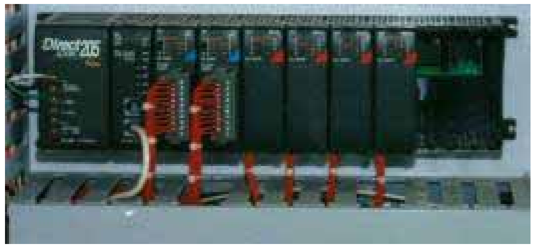

Figure 3 CPU, Input & Output Modules

The input modules have a blue strip and the harness connections. The output modules have a red strip. The CPU is immediately left of the input modules.

Programming of a PLC is usually done with a personal computer, a manufacturer's miniprogrammer, or a "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.

The area within the CPU that is designated for memory storage includes a section dedicated to that portion of the program that requires values to be input by the operator. This section of memory consists of individual registers called V registers. Each V register is numbered and contains a single value. For example, register V2010 may contain a value from 0 – 9999. **A value of 9999 effectively shuts off the command controlled by the respective V register for which it is input**. All of the registers related to the optimization of the process range from the V2000 register to the V3700 registers. These are all operator accessible. Each specific Amphidrome® has its' own memory allocation sheet indicating what function each V register is responsible for. Due to the wide range of design variations possible with the Amphidrome® system, no two plants will have the same memory allocations. Therefore, it is important to be familiar with the specific system for which operation is intended.

Figure 4 DV1000 & DL205 Interface Units

Access to the V2000 and V3000 registers is through one of three possible interface units. The first is the DV1000 operator interface unit, which is attached to the control panel door. With this unit, there are two main modes of operation, one is monitor mode, the other is change preset mode. In the monitor mode, the DV1000 interface allows access to the V2000 and V3000 registers. In the change preset mode, which is the mode required to make any changes to the settings, only the V2000 registers can be accessed. The DV1000 is the standard interface on all small Amphidrome® systems that do not require the use of any V3000 registers. The second interface unit is the DL205 Handheld Programmer. The DL205 allows access to all V registers and allows actual program changes with the proper access codes. The third interface is the DPC321 Touch screen unit (shown in figure 5), which also allows access to all the necessary V registers. In addition, this unit indicates the float position of each float, (i.e. whether or not it is elevated). The touch screen interface eliminates the need for the DL205 and has been made the standard interface for all Amphidrome Plus® units built in 2001 or later.

Figure 5 Touch Screen Interface

Common Features of the Amphidrome® Control Panels

1) All pumps have fail to run lights on the panel.
2) All blowers have fail to pressurize lights on the panel.
3) The Amphidrome® system operates on a 0 – 1440-minute cycle.
4) All Amphidrome® filters have the capability of 16 backwashes.
5) The total number of discharges is recorded.
6) The total number of backwashes is recorded.
7) The total number of failed backwashes is recorded.
8) Effluent pump run times for the last four discharges are recorded.
9) All submersible pump total run times are recorded.

10) Total run times for both the process blowers and backwash blowers are recorded. (See figure 6 below which shows a typical Amphidrome® control panel with all the alarms)

Figure 6 Typical Control Panel

Common Operational Features of all Amphidrome® Systems

1) At the start of a backwash, aeration to a different reactor should cease, (i.e. all other valves should be closed).
2) During aeration, only one reactor should receive air, (i.e. all other valves should be closed).
3) All programs have the potential for twenty-four (24) returns, however, not all have to be utilized.
4) All programs have the potential for six (6) individual aeration periods.

Aeration
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. Since the total amount of air required depends on the strength and the volume of the wastewater, great flexibility in controlling the process air schedule is provided for. **Control of aeration is achieved by four means: 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 the aeration multiplier may be adjusted.** The typical aeration scheme is approximately three to five minutes of air and ten to fifteen minutes without air.

During the treatment cycle, (i.e. 0-1440 minute treatment period), the process blowers have six different time periods during which they may operate. The number and duration of each time period utilized is determined by the operator. Each time period provided has <u>one start time</u>, <u>one stop time</u> and <u>one off time</u>. The process blowers are enabled by inputting both a start and a stop time. The input values must be between 0 and 1440, for one or all of the aeration periods. For example, if the first start time was set at 10 and the first stop was set at 1430, the aeration of the Amphidrome® reactor would be possible between these times only. No aeration will occur outside these cycle times. Additionally, this does not mean that the process blowers would be running continuously throughout this period because in order to achieve intermittent aeration, three other parameters are required.

The second parameter effecting process aeration is the process blower off time. The blowers run intermittently, and control of both the run time, (i.e. on time), and the off time is provided for. Each aeration period has an input labeled *process blower off time*. The length of time the process blowers stay off, after aerating the reactor, is input into the appropriate V register. The value may be changed by the operator and provides the ability to adjust the length of time at which the Amphidrome® reactor operates with an anoxic environment. Each of the six individual periods has its' own off time. Typical off times range from ten to twenty minutes.

The third parameter effecting process aeration is the process blower fixed run time. This value is the length of time, in seconds, that the process blowers will run during any aeration period. The fixed run time is applied to all six aeration periods. For example, if the fixed run time is set for five minutes, than the process blowers will run for at least five minutes during all of the aeration periods that are being used.

The fourth parameter effecting process aeration is the multiplier. The multiplier is a numerical value that is input into the appropriate V register. This value is applied to all six aeration periods and is used to adjust the duration of the process air according to the volume flow into the plant. This is accomplished by recording the time it takes for the second float in the clear well to drop out after the start of each return. **See description of middle float under the clear well in the controls' section.** Since any flow above the middle float represents flow that has entered since the last discharge, calculating the time from the start of a return flow cycle to the time the middle float drops out provides a gauge for the volume of influent flow up to the current cycle time. The computer takes the value of the multiplier, multiplies it by the time it took the float to drop out and calculates a time value in seconds. This value is then added to the fixed time. The sum of these two numbers is the actual blower run time. For example if the *fixed blower on time* is 180 seconds, the multiplier is 10 and during the last return flow cycle it took 5 minutes for the middle float in the clear well to drop out, then the computer multiplies five times ten to get 50 seconds. It then adds 50 seconds plus 180 seconds, resulting in 230 seconds. Therefore, until the next return when the time for the middle float to drop out may be different, the actual process blower on time is 230 seconds. The off time is whatever value has been input for the respective aeration period.

Process Blowers

Each blower has a pressure switch in the airline. Should any blower fail to provide air, the switch will provide a blower fail signal at the control panel.

Only one process blower is needed to provide the required process air. The process blowers alternate with each cycle. If one process air blower fails, an alarm is activated and the second process blower starts.

The run time for the blowers is recorded in either a V register or in the register labeled "Process blower run time" on the appropriate screen of the touch screen interface.

Backwash Blowers
During a backwash, the backwash blowers operate in conjunction with both the process blowers to backwash the Amphidrome® reactor.

Each blower has a pressure switch in the line that is connected to the panel to provide a fail to pressurize signal should a blower fail to provide air when activated.

The run time for the blowers shall be recorded as stated above.

Return Flow and Backwash Pumps
These pumps are identical; however, only the return flow pump is used for a return cycle. During the return cycle, the pump comes on at a predetermined time for a predetermined time after the high float in the Amphidrome® filter is elevated. The actual return times and the duration of each return is operator adjustable via the appropriate V register.

If during a return, the low float in the clear well drops out, the return pump stops, thereby, ending the return cycle before the scheduled end. The scheduled end is a time input into a V register.

The program does not allow a return to occur if it is scheduled within thirty minutes of a backwash.

The backwash pump only runs during a backwash cycle.

Effluent Pumps
The effluent pumps discharge at a predetermined time into the cycle. The ability to have two start times and two stop times is provided for. The operator enters the times into the appropriate V register.

One effluent pump will start if the high float in the clear well is elevated. See section below regarding the clear well floats.

The cumulative run times of each effluent pump are recorded as stated above.

Typically, two effluent pumps are supplied and designed to alternate with each discharge. If one pump fails, the other pump will run. For systems with two separate discharge lines, two pumps--one pump for each system should come on to discharge.

For units that have an enclosed UV disinfection unit, only one effluent pump will run at any time. In addition, the UV units come on for five minutes prior to the pumps so that the lamps are at full intensity has the liquid begins to flow.

Single Train Amphidrome® System

Floats

Amphidrome® Reactor Floats (2)

High 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.

Low 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.

Clear Well Floats (3)

High float:

If elevated, initiates a discharge for a predetermined time that is input into the appropriate V register, (typically 5 minutes). If the float has not dropped within the time that was input, then the second pump comes on and the first pump fail alarm is sounded. For Amphidrome® systems with an enclosed UV disinfection unit, the high float first starts the UV unit for 5 minutes and then the above sequence follows.

Middle float:

Effluent discharge is to the middle float. The middle float is also used to calculate a fraction of the run time of the process blowers. At each return the computer monitors the time it takes from the start of the return cycle to the time the middle float drops out. This time is then multiplied by a predetermined factor, which is input by the operator into the appropriate V register. (See prior section on aeration.)

Low float:

Stops all pumps in the clear well. The float should be set at the minimum level, (i.e. 1/2 of the return flow and backwash pumps should be exposed).

Single Train, Amphidrome Plus®

Floats

Amphidrome Plus® Reactor Floats (2)

The Amphidrome Plus® Reactor typically operates for a portion of the batch treatment process. To enable the Amphidrome Plus® Reactor, a value between 0-1440 must be input onto one of the two start times and one of the two stop times provided. These times are operator adjustable. The Amphidrome Plus® should not go through bump cycles when it is idle. (See details regarding a bump in the section on the backwash pumps.)

High float:

> Stops the influent feed pump. If the float remains elevated for twenty (20) minutes after either a backwash or the influent level raised the float, then a high level alarm is sent.

Low float:

> Initiates the Amphidrome Plus® feed pumps if the Amphidrome Plus® is operational.

Process Blowers

All single train Amphidrome Plus® systems will have two solenoid valves to direct air to the respective reactor. The panel has a light for each valve that will indicate when it is in the open position.

One or both of the process blowers will be used to backwash the Amphidrome Plus® reactor, depending on the size of the reactor. Typically only one is required. If the Amphidrome Plus® reactor is smaller than the main reactor so that the process cannot be used to operate at the fixed rotation, than variable frequency drives (VFDs) are used. VFDs are located in the control panel the Amphidrome® reactor, than variable frequency drives are used to slow the rotational speed of the blower in order to obtain the proper backwash airflow for the Amphidrome Plus® reactor.

Backwash Blowers

The backwash blowers are used to backwash the larger Amphidrome® Reactor <u>ONLY</u>, not the Amphidrome Plus® Reactor.

Amphidrome Plus® Feed Pump

The Amphidrome Plus® feed pump supplies water to the Amphidrome Plus® reactor during the time in the cycle when the reactor is operational. Two start times and two stop times for the feed pump are provided for in the program. These times define the operational periods of the Plus reactor. Either one or both times may be utilized. This depends on whether the system is operating for two batches per day or one. The start and stop times are entered, by the operator, into the appropriate V register.

Amphidrome Plus® Backwash Pump

The Amphidrome Plus® backwash pump is used to backwash the Amphidrome Plus® filter. The time into the cycle to initiate the backwash of the filter is predetermined and is operator adjustable. The backwash sequence is also adjustable so that the blower and pump start and stop times, within the backwash cycle, are operator adjustable. The appropriate V registers contain this information.

The backwash pump for the Amphidrome Plus® reactor is also used to bump the reactor. A bump is the name given to the procedure for removal of nitrogen gas (N_2) from the filter bed. During a bump, the backwash pump pumps water up through the bed for 3 minutes, dislodging trapped nitrogen gas. Typically, the duration of a bump is 3 minutes, and the frequency is every 120 minutes. These parameters are adjustable through the appropriate V registers.

Methanol (Carbon Source) Feed Pumps

Two chemical metering pumps are used. One pump is dedicated to the Amphidrome® reactor, and one pump is dedicated to the Amphidrome Plus® reactor. The pump dedicated to the Amphidrome Plus® will only run when the Amphidrome Plus® feed pump is running. The chemical metering pump dedicated to the Amphidrome® reactor will only run during a return cycle.

The total run time of the chemical metering pumps will be recorded as mentioned. **If one of the pumps is turned off either at the panel or at the pump itself, a false run time will be recorded. To avoid this false time, a value of 9999 should be input into the start and stop times for the pump.**

Since the amount of organic carbon required for denitrification depends on the strength, volume of the wastewater and the carbon to nitrogen ratio(C:N), great flexibility in the control of the chemical feed is provided. **Control is achieved three ways first, two possible operational periods are provided, second a fixed run time that is adjustable is provided, and finally, an adjustable multiplier is provided.**

During the treatment cycle, (i.e. 0-1440 minute treatment period), the chemical metering pumps have two different time periods during which they may operate. The number of periods used is the same as the number of batches treated per day, (i.e. one or two). The duration of each time period utilized is determined by the operator. Both time periods provided have one start time and one stop time. The chemical feed pumps are enabled by inputting both a start and a stop time. The input values must be between 0 and 1440 for each of the periods. For example, if the first start time was set at 400 and the first stop was set at 1400, the ability to feed chemical would be possible between these times only. However, this does not mean that the chemical feed pumps would be running continuously during this time, since several additional operational requirements must be satisfied for the pumps to operate. Two other parameters, which govern the chemical feed, are required.

The second parameter is the fixed run time. The value of the fixed run time is the minimum amount of time that the chemical metering pump will run and is input into the appropriate V register. This value allows the operator to choose a minimum run time for which the respective chemical metering pump will run during its operational period. For example, if a value of 60 minutes is entered, then the pump will run for at least 60 minutes of the specified operational period.

The third input is a multiplier, which is linked to the second float in the clear well. **See details regarding the second float and the multiplier for aeration.** The multiplier is a numerical value that is input into the appropriate V register. The multiplier for the chemical feed systems is linked to the middle float in the clear well the same way as the multiplier for aeration is linked. **See description of middle float under the clear well, in the controls' section.** For each return the computer records the time from start of return to when the second float drops out. This value is then multiplied by the value of the multiplier. The result is a time in seconds that is added to the fixed run. The sum of the two values is the total run time for the chemical feed pump.

Alkalinity Feed Pump
The chemical feed pump (for alkalinity) has two (2) start and stop times that are determined by the operator. **(See the previous section.)**

The total run time of the chemical metering pumps will be recorded as mentioned above. **<u>If a pump is turned off either at the panel or at the pump itself, a false run time will be recorded.</u>**

Single Train, Amphidrome Plus® With Amphidrome® Feed Pumps

Floats

Floats in the Amphidrome® Feed Pump Station (4)
The two pumps in the Amphidrome® feed pump station alternate. The Amphidrome® feed pumps each have two (2) start times and two (2) stop times. The ability to lock out both the return flow pump and the Amphidrome® feed pumps, for a predetermined time, is provided. This allows additional control over what flows forward, just prior to the discharge. The time value is entered into the appropriate V register by the operator and is, therefore, adjustable.

Both Amphidrome® feed pumps will shut off if the liquid level in the Amphidrome® filter elevates the high float in the filter. The pumps will then stay off for a specified length of time. Two registers are provided to allow for two different off times of the Amphidrome® feed pumps. These off times will depend on which float or floats are elevated in the Amphidrome® feed pump chamber, (i.e. the liquid level in the chamber). For example, if the third float is elevated (indicating a high level in the Amphidrome® feed pump chamber), then the off time will correspond to a specific V register. If only the second float is elevated, then the off time will correspond to a second V register. The value in the second register should be greater then the value input into the register that is linked to the third float.

High float (4^{th}):

Alarm and second pump on, but not both pumps on.

Third float (from bottom)

If this float is elevated and the feed the pump shuts off due to the high float in the filter, the feed pump will stay off for a predetermined time that is input into a V register. This value will be shorter then the corresponding value that is linked to the second float.

Second float

This float has two functions: first, it is a pump on float. Second, if this float is elevated and the feed pump shuts off due to the high float in the filter, the feed pump will stay off for the predetermined time that is input into a V register. This time will be longer than the corresponding value for the third float.

Low Float

All pumps off.

Dual Train, Amphidrome Plus®

All dual train systems are supplied with motorized butterfly valves for the air lines to the Amphidrome® reactor. Solenoid valves are used for the air lines to the plus reactors.

If the system is a dual train with a single Amphidrome Plus® then motorized valves will be used on the effluent lines from the Plus reactor.

Process Blowers

The process blowers alternate as mentioned above. In a dual train design, one side "the primary side" will be aerated according to the aeration process described above. However, the ability to aerate the side not under aeration, "the secondary side or idle side" is provided for. Aeration of the primary side is not continuous. The blowers run for a calculated time and then are idle for a predetermined adjustable time. It is during these off periods that the secondary side will be aerated.

To use this option of aerating the secondary side, a start and stop time is entered into the appropriate V register. When this option is utilized, the blowers will not stop before switching to the secondary reactor. They will continue to run and the respective motorized butterfly valves will open and close. Therefore, when the air gets diverted from one reactor to the other, the two air valves will operate simultaneously. One valve will begin to open and the other will begin to close.

Amphidrome Plus® Feed Pump

For a dual train with a single Amphidrome Plus® reactor, two (2) start times and two (2) stop times for each train are provided. This allows each train to utilize the Plus reactor for two separate operational periods.

The corresponding effluent valves will operate in conjunction with each operational period.

Amphidrome Plus®Backwash Pump
Backwash of the Plus filter must be scheduled to occur during a period that is active and will occur from whichever train is utilizing the Plus unit at the time.
Two time slots for backwash of the Plus reactor are provided.

Dual Train, Amphidrome Plus® with Influent Pumps

Chemical Metering Pumps (i.e. Methanol and Alkalinity)
When a system has influent pumps, all chemical feeds (i.e. methanol and alkalinity) shall be linked to the influent pump run times, **NOT THE SECOND FLOAT IN THE CLEAR WELL.** The pumps will have a fixed run time and a multiplier. The multiplier will be linked to the influent pump run times. The value of the multiplier times the influent pump run time will be added to the fixed run time to give the total run time.

Dual Train, Amphidrome Plus® with Amphidrome® Feed Pumps

Each train will have its own individual Amphidrome® feed pumps station which will operate as specified above in the section regarding a single train Amphidrome Plus® with Amphidrome® feed pumps.

Operational Scenario Of The Amphidrome® System

As mentioned previously, 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 or two submerged attached growth bioreactors 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 twenty four (24) 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 either one batch or two batches per day.
- The beginning of the cycle time, (i.e. time 0) is chosen by the operator by setting the tripper on the mechanical clock within the control panel. **See details on the clock in the controls' section of the O & M manual.**

- Time zero should be adjusted so that the diurnal flow patterns are split equally between the batches.
- Typically at startup, all aeration periods are utilized and the sequences are set up so that blower on time is 3 – 5 minutes and the 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. The Amphidrome® system has all tanks located below grade with access hatches or manhole covers at grade level to allow for inspection and maintenance of the system. To ensure proper operation of the system, the operator must do inspection of the system internals to ensure proper operation.

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 and two tests on each Amphidrome® Plus 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 or one in the reverse direction, depending on which filter is being tested.

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 in the Amphidrome® filter decreases and should be measured over equal increments of time until the forward flow slows down to less than a 1 inch change in ten minutes. (If the filter being tested is an Amphidrome Plus® filter, the Amphidrome® Plus feed pump must be used to raise the level in the filter). 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, the total change in height and the surface area of the reactor, can be used to calculate the flow rate through the filter. 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. Only the return flow pump is used for this test. 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*, and shown in Appendix A.

Test 3: Backwash Flow Test:
The purpose of this test is to estimate the average volume flow rate for a backwash. This value is necessary to control the amount of sludge that is removed from the reactor during a backwash. For the Amphidrome® reactor, test 3 is a repeat of test 2, but with both the return flow pump and the backwash pump running. There is no test 2 for the Amphidrome Plus® reactor because the reactor does not have return cycles; and therefore, there is no return pump only a backwash pump. As in test 2, the level in the 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 and the backwash pump should start. For the Amphidrome Plus® reactor, only the backwash pump is 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*, and shown in Appendix A.

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.

Sampling and Analysis:
During the initial start up period (approximately 30-90 days), sampling and analysis, (both laboratory and field), should be performed more frequently than during routine operation. Since the typical treatment goals are the removal of BOD_5, TSS, TKN, NH_3, and NO_3^-, these parameters, as well as pH, alkalinity, and flow should be closely monitored. Test kits for both NH_3, and NO_3^- are recommended so that the operator can test these parameters once or twice weekly for process control.

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 in 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 that 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.**

Flow:

Typically, recording daily flow is a permit requirement on all systems over 10,000 gpd. Flow recording equipment (flow meter, totalizer and chart recorder) are typically supplied with these plants. In addition to the total and average daily flow, the operator should also record flow per batch. For plants with chart recorders, this is simply done by reviewing the flow chart. For plants set up to treat more than one batch per day, the operator should compare the flow per batch to ensure that each batch treats the same volume of wastewater. For example, if flow through a facility is 10,000 gpd and two batches per day are used, the flow per batch should be as close to 5,000 gpd as possible. This is accomplished by setting the PLC reset time to the appropriate time of day to split the diurnal flow. **See section in controls regarding the clock.** The flow chart also indicates the time of discharge, which should be periodically compared to the programmed time for discharge. **Since the facility is programmed to discharge due to high water level in the clear well, the chart will also indicate any discharges that have occurred out of sequence due to a high water level in the clear well.**

Sludge Wasting and Sludge Removal:

Sludge wasting refers to the removal of sludge from either the Amphidrome® reactor or the Amphidrome Plus® reactor and is achieved by backwashing. Both the frequency and duration of the backwash is 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. Therefore, determining whether or not enough biomass exists must be judged by four parameters: 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.

Chemical Metering Pumps

Problem	Possible Cause	Solution
Pump will not operate	Switch off at panel or on pump Circuit breaker tripped or blown fuse	Check switches. Check breaker and replace fuse. If condition continues, have circuit checked by a qualified technician.
Pump will not operate in automatic	Pump not called for	Check program to see if pump should be operating.
No chemical being delivered	Pump lost prime Drum or mix tank empty Suction hose not submerged in chemical Suction line, discharge line or pump head clogged Suction line or discharge line kinked	Check for air leaks, re-prime pump. Replace drum, refill tank. Check suction hose. Inspect and clean. Check lines and remove any kinks.

Automatic Valves

Problem	Possible Cause	Solution
Valve not actuating	Switch off Fuse blown	Check switch. Replace fuse. Have circuit checked by a qualified technician.
Not operating in automatic only	Not called for	Check program to see if valve should be actuating.
Air leaking by valve	Valve out of adjustment	Check manufacturer’s literature for proper valve adjustment.
Manual actuation necessary		Consult manufacturer’s O & M manual for proper manual operation.

Flow Sensor and Meter

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

Chart Recorder

Problem	Possible Cause	Solution
No display / pens do not operate	Circuit breaker off Improper wiring Recorder malfunctioning	Check breaker and reset. Have wiring checked by a qualified technician. Have recorder checked by a qualified technician. Repair or replace recorder if necessary.
Improper flow rate No flow Pen off chart	Incorrect programming Pump off Improper wiring Sensor / meter malfunctioning	Consult manufacturer's literature for proper programming instruction / reprogram. Check pump. Check wiring. Troubleshoot sensor / meter.

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.

Chemical Flow Monitoring

Problem	Possible Cause	Solution
No flow signal	No flow	Troubleshoot pump.
	Improper wiring	Have wiring checked.
	Improper digipulse adjustment	Consult manufacturer’s literature for proper adjustment.
	Digipulse monitor clogged	Remove monitor, clean if necessary, reassemble according to manufacturer’s instructions.

24 Hr. (15 MIN) Tab Timer

Problem	Possible Cause	Solution
Timer not working	No power	Check power source.
Timer losing or gaining time	Power interruption Bad timer	Investigate power outages or panel being turned off. Replace timer.
Timer not resetting PLC	Tripper not set	Set tripper to desired time.
Timer resetting PLC at incorrect time	Tripper set incorrectly Timer losing time Timer not set at correct time Timer not adjusted to Daylight Savings or Standard time	Check to see that tripper is set at proper time. See above. Adjust timer to correct time of day. Adjust timer accordingly.

PLC

Problem	Possible Cause	Solution
No display or interface	Power loss or interruption Wire between interface and CPU is disconnected	Check power source. Ensure panel is energized. Reconnect line.
PLC not responding to commands while in: 1. Monitoring mode 2. Change preset mode	 Improper keystrokes Incorrect or no password entry	 Consult controls instructions in O & M manual. Incorrect password being entered.
PLC does not reset	24 Hr. timer malfunctioning	Troubleshoot timer.

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.
	Denitrification carbon source carryover	Decrease supply of carbon to Amphidrome Plus® process if possible.

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®.
	Dirty Amphidrome Plus® reactor	Increase backwash of Plus reactor.

Nitorgen 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, begin addition of alkaline source.
	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).
	Insufficient biomass in Amphidrome Plus®	Decrease backwashing frequency of Amphidrome Plus® filter (if applicable).
	Low application rate to Amphidrome Plus® filter	Check the start and stop times of feed pumps to determine the overall total operational time, and compare this against the actual run times of the Amphidrome Plus® feed pump. Check forward flow rate through filter. Increase backwash of Amphidrome Plus® filter to improve flow through rate. Troubleshoot Amphidrome Plus® feed pump.
	Insufficient carbon source –Amphidrome Plus® filter or Amphidrome®	Increase carbon source supply to Amphidrome Plus®.

Supplemental BOD

Problem	Possible Cause	Solution
Supplemental BOD carryover causing elevated effluent BOD	Excessive addition of supplemental BOD	Check feed rate of supplemental BOD – adjust feed rate down to obtain lower effluent BOD level while maintaining proper nitrate removal.
	Insufficient mixing of BOD source and process wastewater	Check chemical feed line location – ensure located for sufficient mixing.
	Improper programmed run time for chemical feed system	Check programmed run times and adjust accordingly.
Insufficient nitrate removal	Inadequate supplemental BOD feed rate	Increase feed rate. Troubleshoot chemical feed system. Ensure correct concentration or solution of BOD source.

Alkalinity

Problem	Possible Cause	Solution
Effluent alkalinity less than 100 mg/l	Insufficient alkalinity in influent wastewater	Supplement alkalinity in process by using alkalinity chemical feed system.
	Insufficient supplemental alkalinity feed	Increase alkalinity feed or solution strength. Troubleshoot feed system to ensure proper feed rates.

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.