Unmatched Reliability

Vaughan®

ROTAMIX™ SYSTEMS

INSTALLATION, OPERATION & MAINTENANCE INSTRUCTIONS

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Rotamix

This manual is for all Vaughan Rotamix Systems.

NOTE: The pump for your Rotamix System will require an additional IO&M manual.

Unmatched Reliability Vaughan®

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INSTALLATION, OPERATION, & MAINTENANCE INSTRUCTIONS

SECTION 1: IMPORTANT SAFETY INFORMATION

This equipment is intended for installation by technically qualified personnel. Failure to install it in compliance with national and local electrical codes, building codes and within Vaughan Co. recommendations may result in electrical shock, personal injury or death, fire hazard, unsatisfactory performance, and equipment failure. If further assistance is required contact your local representative or Vaughan Co. *Keep this manual in a safe location for future reference.*

⚠DANGER Indicates a hazard, which, if not avoided, will result in death or serious injury.

⚠WARNING Indicates a hazard, which, if not avoided, could result in death or serious injury.

⚠CAUTION Indicates a hazard, which, if not avoided, may result in minor or moderate injury or damage to the equipment.

NOTICE Indicates special operation or maintenance information.

- Isolate the pump hydraulically and electrically before servicing or inspecting pump. Lock out both power source and isolation valves.
- This pump may handle dangerous or contaminated fluids. There are sharp corners, edges and pinch areas which can cause serious injury. Be careful; wear protective gloves whenever possible. If you cut yourself, seek medical help immediately to avoid serious infection.
- This pump may start automatically if wired to float switches or other equipment. Before inspecting or making adjustments disconnect electrical power and lock out circuit breakers to pump motor and associated equipment. Duplex pumps with alternating relays must both be locked out; otherwise the pump you are working on may not be isolated and could start as “the alternate”. Visually confirm that the pump has come to a complete stop before proceeding.
- Motors may be equipped with built-in thermal overloads to shut off the motors in the event the temperature gets too high (as a result of low voltage, poor ventilation, overloaded lines, etc.) These motors can restart automatically as the motor cools down. DO NOT work on the pump or motor without first disconnecting and locking out the power supply.
- Enter tanks or pits with extreme caution and only after an instrument check of the pit/tank has been completed to verify the absence of dangerous gases and the presence of safe levels of oxygen. Never enter a tank or pit without a safety harness and lifeline, and an air pack. Never enter the pit without rescue personnel standing by. Follow all national and local requirements for confined space entry.
- Keep all pit openings covered when not in use. In addition to the injuries from falling, pits may contain poisonous gases or liquids.
- The pump and nozzle assemblies are to always be lifted using adequate crane and sling capacity. All applicable safe hoisting practices should be employed. When doing so, rig the load to prevent flipping. Do not use the motor lifting eyes to lift the assembled pump. Use the motor lifting eyes to lift the detached motor only. Cast-in lifting eyes are designed for lifting individual pump components or sub-assemblies, not the entire pump. Only base-mounted lifting eyes may be used to lift a pump and drive assembly.
- Lift submersible pump and motor by pump lifting bail only. Lifting by any other parts of this equipment is dangerous and may damage equipment. Inspect the lifting bail to be sure it is not damaged. Replace immediately if the bail is weakened in any way.
- Do not allow people under the pump or nozzle assembly while it is being lifted.
- Pump and nozzle components can be heavy. Proper methods of lifting must be employed to avoid physical injury and/or equipment damage. Steel toed shoes should be worn at all times.
- Do not allow liquid to be trapped in pump or piping between two closed valves. Always drain or vent the piping/pump between two closed valves. Failure to vent or drain could allow dangerous pressures to build causing rupture damage resulting in injury, death, and equipment damage.

- Never operate a pump with closed or blocked discharge valves. This will destroy the pump and could be dangerous to personnel.
- Safety apparel to be worn when working on or making adjustments to pumps should include:
  Heavy work gloves when handling parts with sharp edges, especially impellers.
  Safety glasses (with side shields) for eye protection
  Steel-toed shoes for foot protection when handling parts, heavy tools, etc.
  Other personal protective equipment to protect against hazardous/toxic fluids and gases.
- Do not operate this equipment unless safety guards or devices are in place and properly adjusted.
- Let the pump cool to ambient temperature before beginning work on it. A warm pump can contain compartments of pressurized fluid, which may vent violently during disassembly.
- Never apply heat to remove parts unless specifically directed to do so in overhaul instructions. Use of heat may cause an explosion due to trapped fluid, resulting in severe physical injury and property damage.
- Pressure may build up in the standard mechanical seals used in Vaughan pumps. Whenever checking or maintaining the oil in the Vaughan Cartridge Seal, or the welded metal bellows seal with seal oil chamber, make sure the pump and seal are cool to the touch. Use care when removing the oil chamber plugs and pressure relief valve, in case any residual pressure exists. If pressure exists, the plug could become a projectile and/or contaminated oil could spray.
- As it is possible to run Vaughan Chopper and Screw pumps dry, for quality assurance or troubleshooting reasons, it is extremely important to ensure suction and discharge connections are always properly guarded to prevent anything (i.e. foreign objects or pump parts) from being thrown from the pump as a projectile. All pumps must be run with suction and discharge piping in place, or blind flanges installed on suction and discharge connections. Blind flanges should be vented to avoid pressure build-up. Note that cast rotating parts could break if metal to metal contact occurs while the pump is running dry.
- Shut pump off when adjusting fittings to avoid being sprayed with pumpage. Pumped materials may be hot, corrosive, poisonous, infectious, or otherwise dangerous to personnel.
- Pump motors are connected to high voltage. Allow only qualified electricians to service this electrical equipment only in accordance with the latest revision of the National Electrical Code and other applicable requirements.
- Make certain all personnel are clear of equipment before operating.
- This equipment may not meet explosion proof requirements for hazardous environments unless specifically ordered for this purpose. Introducing non-explosion proof equipment into a hazardous environment as defined by the National Electrical Code can cause a dangerous explosion.
- This pump uses oil which, if spilled, can cause a slipping hazard and danger to personnel.
- Keep hands, feet and clothing away from moving machinery.
- Never clean, oil, adjust, or repair machinery while in motion.
- Keep electrical control panel area clear to avoid to avoid hazard to personnel. If a person should trip and fall into an open panel enclosure, serious electrical burns can result.
- Keep electrical control panel doors closed except to make adjustments or repairs by a qualified electrician.
- Overheated pumps can cause severe burns and injury. If overheating of pump casing occurs:
  1) Shut down pump immediately.
  2) Wait for pump to cool to air temperature.
  3) Slowly and cautiously vent pump at drain plug.
  4) Trouble shoot cause of overheating.

If there are any questions regarding the safe and proper methods for operating or servicing this pump, please contact Vaughan Company for assistance.

SECTION 2: DESCRIPTION OF THE VAUGHAN ROTAMIX™ SYSTEM

The Vaughan Rotamix™ system is a proprietary (patent 7,025,492) mixing system designed to mix cylindrical, egg-shaped, or rectangular sludge storage tanks or digesters with greater mixing efficiency and lower power requirements than some other systems that have been traditionally used.

The Rotamix™ system consists of one or more Vaughan chopper pumps pumping through a customer-supplied piping system to one or more Vaughan-supplied nozzle assemblies.
The glass-lined ductile iron nozzle assemblies are typically floor-mounted, dual-nozzle systems, but can also be single nozzle systems (generally in rectangular tanks). In a cylindrical storage tank and with dual nozzle assemblies, the lower nozzle is aimed more toward the center of the tank, while the upper nozzle is aimed to create more tangential rotation. *Nozzle aiming must be done per Vaughan instructions once nozzle assembly installation is complete but before the storage tank is closed up.* Please contact your local representative for aiming the nozzles. Nozzles normally cannot be aimed remotely on floor-mounted systems.

A layout drawing of the Rotamix™ system (showing nozzle location and nozzle angles within the tank) is included in your custom Installation, Operation and Maintenance Manual package for your particular project.

SECTION 3: INSTALLATION INSTRUCTIONS

A. RECEIPT INSPECTION

Description of pump receipt inspection is described in the IO&M Manual for the Vaughan chopper pump. You should also inspect the nozzle assemblies received for the Rotamix™ system to make sure they have arrived undamaged. Your best indication of potential shipping damage to equipment is the condition of the crating. If the crating is damaged, look for cracked fittings and clamps or damaged paint, **report damage to your carrier.** Vaughan Co. can also work with you to provide replacement fittings as needed.

B. STORAGE CONSIDERATIONS

The epoxy paint on the nozzle assembly is susceptible to damage from prolonged UV exposure. If nozzle assemblies are to be stored for more than two weeks prior to installation they must be either stored indoors or covered. If nozzle assemblies will be exposed to sunlight for more than two weeks after installation they should be covered.

C. INSTALLATION

The Vaughan chopper pump is to be installed as described in the pump IO&M Manual. Note however, that the Rotamix™ system reason for being is to achieve improved efficiency over your previous mixing systems. Therefore the Rotamix™ system piping design should minimize friction losses through the suction and discharge piping. This means using suction and discharge piping dimensions as shown on your system outline drawing.

For best results choose piping size so that velocity is around 3-5 ft/sec. for suction piping and no more than 8 ft/sec for discharge piping. This is fast enough to avoid particle settling in the piping, but slow enough to minimize friction losses. Vaughan Co. will help you with your system design. Please consult us to be sure your system works as intended.

NOTICE
Use of smaller diameter piping than recommended results in higher velocities, increased friction loss, and less effective tank mixing.

Smaller diameter piping may lead to troublesome gas-binding problems in the mix pump because of decreased pressure at the pump suction that tends to liberate volatile gases from the pumped fluid. Gas binding in the pump can result in complete loss of flow and low motor amps. If the pump is gas bound, even though the pump is turning, no mixing will be taking place. To restore flow stop the pump and vent all the trapped gas out of the pump casing before restarting the pump.

Total Rotamix™ flow is determined in consultation with Vaughan Co. Sales Engineering. The total flow is calculated based on your storage tank (or digester) volume and consideration of your tank geometry. Once you know total system flow, you can determine best sizing for suction and discharge piping. Vaughan Co. will help you with piping sizing recommendations.

Nozzle sizing for the nozzle assemblies is also determined at the beginning of the Rotamix™ project in consultation with Vaughan Co. Proper sizing for the nozzles is critically important in making the system work efficiently.

⚠WARNING

Follow all confined space entry procedures when entering an enclosed tank.

Nozzle aiming is performed once nozzle assembly installation is complete but before the storage or digester tank is closed up. Proper nozzle aiming is critically important and is performed by your Vaughan Co. representative. Please contact your representative to schedule this very important operation before closing the digester or storage tank.

Finally, location of the nozzle assemblies within the digester is determined in consultation with Vaughan Co. In a cylindrical tank (such as a digester) the floor-mounted nozzles are typically mounted on a circle whose diameter is defined by Vaughan Co. based on the diameter of your storage tank. Also, the nozzle angles are determined by Vaughan Co. The positioning and angles of the nozzles in your digester or storage tank are defined on a Rotamix Nozzle Location Plan drawing specific to your project. This drawing will always be included in the custom Installation, Operation and Maintenance Manual for your particular Rotamix system.

Vaughan Foambuster:

The Vaughan Foambuster is a patented nozzle and splash plate combination that sprays sludge droplets over a large area at the upper surface of a digester to break down and suppress foam. In some cases, digester mixing systems are purchased with the addition of the Foambuster because of the risk of foaming, particularly in activated sludge plants. The Foambuster nozzle must be mounted above liquid level. Only a few inches of distance is enough to allow the Foambuster to work. Also, the Foambuster needs about 4 ft. of headroom above the height of the nozzle to allow the spray to cover as much of the tank surface as possible. The Foambuster works best with a fixed cover. Finally, the Foambuster is designed to be aimed radially inward toward the center if the Foambuster if located near the outer walls, or aimed radially outward toward the outer walls if the Foambuster is located at the tank center. When the Foambuster is used with the Rotamix system, Rotamix rotates the liquid in the tank below the Foambuster. In this way, one Foambuster can cover all the surface area of the tank as it rotates below the Foambuster.

Vaughan Co. recommends that the Foambuster operates whenever the Rotamix system operates. By taking this approach, if foaming should occur, the Foambuster will always be operating to keep the level of foam broken down and under control. If foaming is allowed to take place when the Foambuster is not operating, foam may adhere to the tank walls, preventing the surface from rotating. If the upper surface does not rotate, the Foambuster will not be effective at controlling foam over the entire upper surface.

System Venting:

⚠DANGER

Explosions can kill or injure! Mixing may liberate gases of decomposition which are highly flammable or explosive. Do not use an open flame or non-explosion-proof equipment in areas where gas is present. Follow all plant safety procedures for hazardous areas.

Sludge pumping systems are likely to generate gases of decomposition and these gases are likely to collect in either the suction piping or in the chopper pump casing. Should this occur, the pump would not work properly when started, since the impeller, when rotating, will collect gas and not be able to fill with the sludge to be pumped. So gas buildup in the system may keep your pump and Rotamix system from working properly. This can be particularly troublesome if your system operates intermittently. Gas binding is also much more common if your pump has other than a top discharge on the pump casing.

That is, side-discharge orientations of the pump casing flange tend to trap more gas in the pump casing. Gas binding problems can keep your mixing system from working properly so this issue must be addressed.

To avoid gas binding problems, you should consider designing in an automatic venting system. Failure to properly vent the pump before each startup can result in a mixing system that doesn't work. *Note that you cannot vent the pump of gas or air when the pump is running.* (The pump casing can be vented through the pressure tap on the casing flange if the pump has a top discharge, or through the vent on the side of the casing if the pump uses a side discharge configuration.)

There are several ways to successfully vent the pump:

1. You can install an automatic venting system to the pump casing vent in a couple of ways:
    a. You can use a suitable automatic air release valve (ARV) of 2" size available from various manufacturers. (Vaughan Co. has available an air release valve from Val-Matic.) Run the discharge piping to either a drain or back to the digester or tank to be mixed. An automatic air release valve will continually and automatically vent gas or air from the pump casing any time the valve senses that the presence of gas or air at the valve. We feel the ARV is the best approach.
    b. You can use a solenoid-controlled valve (2" is best) controlled by a timer in your control panel, which would open this valve prior to each startup of the pump. Based on experimentation, you can determine how long it takes to vent the gas from the system to completely fill the pump casing before the pump starts. You can then set the timer to this setting. Again, run the piping either to a drain or back to the tank you are mixing.

Note also that pumps and piping located outdoors and exposed to the sun are more likely to cause more gas generation in an idle pump and system. Shading the system from the sun can be very helpful to minimizing gas problems.

E. NOZZLE AIMING

To perform this procedure, you will need the Vaughan nozzle aiming kit, Part# V108-205. This kit includes the aiming protractor, mounting bungee, and the plumb bob. You will also need two 15/16", and two 1-1/8" wrenches or sockets and a ladder tall enough to reach the top nozzles.

NOTICE
This procedure must be done before filling the tank,.

STEP 1

Check nozzle assembly location against the Vaughan supplied layout drawing. Check both the radial and tangential measurements.

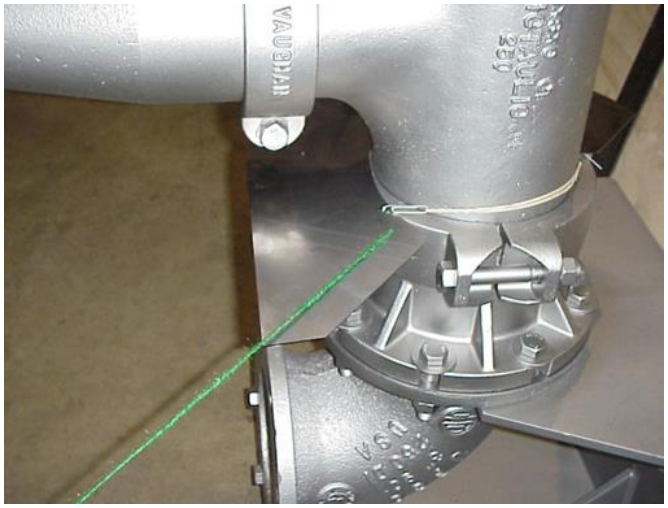
To aim the nozzles, loosen the clamp on the vertical pipe just below the lower nozzle and spread it so that it will allow the pipe to rotate without being so loose that it will allow the nozzle assembly to fall.

Once the clamp is loose, place the Vaughan protractor on top of it.

There is provision for an elastic tie around the back side of the protractor to hold it in place.

STEP 2

Tie a string to the protractor at the zero point hole, and attach the other end of this string to the center of the tank in some manner. This will align the protractor so that the nozzles can be properly aimed relative to the center of the tank.



STEP 3

Once the protractor is properly aligned with the tank, you can proceed to aim the nozzles.

Aim the lower nozzle by aligning the center of the lower nozzle clamp with the specified degree mark on the protractor.

See your Nozzle Layout drawing for the proper angles to set your nozzles.

Moving the lower nozzle will tend to move the protractor also. Be sure to recheck the zero point before tightening the lower nozzle clamp.

STEP 4

To aim the upper nozzle, tie the plumb bob string to the bolt on the nozzle clamp as shown. Make sure that it hangs from the the center of the nozzle.

Loosen the clamp on the vertical pipe below the nozzle, and spread it slightly so that the elbow can rotate, but not so much that the nozzle could fall.

The picture shows a sling holding the nozzle for security. If a crane is not available, just make sure that the nozzle can't fall.

STEP 5

The plumb bob will hang directly over the protractor scale. Rotate the upper nozzle until the bob hangs over the degree mark specified for the upper nozzles on your nozzle location plan view drawing.

Tighten all clamps, remove the plumb bob and the protractor, and the job is complete.

SECTION 4: STARTUP INSTRUCTIONS

See the pump IO&M Manual for pump startup and operating instructions.

Before starting the Rotamix™ system, check all piping connections to be sure they are tight and are not stressing up the pump or other equipment. Proper piping alignment and support is critically important to good equipment life. Also, as discussed above, venting all air from the system at initial and all startups is critical to allowing the mixing system to work to its normal capacity. Poor gas venting can often result in poor mixing or no mixing at allSee the pump IO&M Manual for pump startup and operating instructions.

Vaughan Co. requires the Startup & Certification Checklist pages, with the job –specific Vaughan Rotamix tank drawing marked up with nozzle locations, nozzle angles, nozzle elevations, and confirmation of all bolt torques, to be sent to Vaughan Engineering. If the job-specific tank drawing is not available please contact Vaughan Engineering prior to performing Start-Up to have the correct drawing supplied.

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STARTUP AND CERTIFICATION CHECKLIST

DATE:_____

Pump S/N: _____

Equipment ID/Tag#:_____

Nozzle S/N's _____

Project Name: _____

Project Location: _____

Startup Performed By: _____

Customer Contact Info_____

Contractor Contact Info _____

Engineer Contact Info _____

Vaughan Co. requires the Startup & Certification Checklist pages, with the job specific Vaughan Rotamix tank drawing marked up with nozzle locations, nozzle angles, nozzle elevations, and confirmation of all bolt torques, to be sent to Vaughan Engineering. All verified dimensions should be indicated by a circle or check mark on that dimension.

Rotamix Drawing No._____

Is drawing attached? Yes ____ No ____

Is drawing marked up to show each verified nozzle location? Yes ____ No ____

Is drawing marked up to show each verified nozzle angle? Yes ____ No ____

SYSTEM DATA

Tank Geometry: _____

Type of process being mixed: _____

%Solids: _____ Tank Type: New:_____ Retrofit:_____

If Retrofit, previous system? _____

Sloped Floor: Yes _____ No _____ If sloped, slope = _____ degrees/depth

NOZZLE ASSEMBLY DATA

Contractor's piping is properly installed and supported? Yes ____ No ____

Is Contractor's piping properly aligned and bolted to assembly? Yes ____ No ____

Flange bolts are properly torqued? Yes ____ No ____

Couplings have been checked and torqued to 80 ft/lb after nozzle adjustment? Yes ____ No ____

Grouting complete and Assembly Base set level? Yes ____ No ____

Anchor bolts are installed and properly torqued? Yes ____ No ____

COMMENTS: _____

SECTION 5: NORMAL OPERATION

Operation of the Rotamix™ system involves operation of the Vaughan pump(s). The objective in Rotamix™ operation is achieving effective mixing in your storage tank or digester. This may or may not require operation of the Rotamix™ system on a 100% duty cycle. Many times this system may be operated on a timer, on a duty cycle less than 100%. As a general rule, a Rotamix system requires 30-60 minutes to reach steady state mixing, and it may require several days of mixing after that to achieve a homogeneous slurry in the tank. Note however, that if the Rotamix™ system is operated intermittently, there may be more of a challenge in properly venting the pump of gas prior to each pump startup, and so an automatic venting system should be considered during design. This gas venting issue is discussed above in the Installation section.

Digester Mixing:

Vaughan Co. as well as most consulting engineering firms have concluded in recent years that the use of a variable frequency drive (VFD), also called a variable speed drive (VSD), is the best method for mixing a digester. The VFD provides a way to cut power usage significantly, often cutting power expenses in half over time, while also providing a way to continue low speed mixing during foaming or rapid volume expansion events.

- **Mixing during foaming or rapid volume expansion (RVE):**

Intermittent mixing (that is, turning the mixing pump on and off over various periods of time) leaves pockets of undigested feed sludge in the digester to suddenly erupt in gas generation as soon as mixing is restarted. Because of this effect, intermittent mixing can exacerbate both foaming or rapid volume expansion problems. The better approach has proven to be the use of the VFD controller to maintain continuous mixing while reducing mixing pump speed when necessary. During foaming or RVE disruptions mixing can (and should) continue at lower mixing pump speeds, typically at about 75% of full speed, which is about 42% of full power. Mixing pump speeds below about 75% of full speed is not recommended because very low speed operation risks plugging nozzles as pump pressure falls off rapidly. The value of maintaining continuous mixing during foaming or RVE events is that pockets of feed sludge are continuously mixed with the rest of the digestate, spreading out gas generation over a maximum time period to minimize sudden bursts of liberated gas. By maintaining continuous mixing at lower speeds, the gas generation and therefore the foam generation, is kept more under control.

- **Reduced energy mixing for power savings:**

Many mixing systems tend to be slightly overdesigned to allow for variations in sludge concentrations and viscosities and to pass the startup mixing tests. However, many Rotamix systems can be operated quite effectively for about 22 hours/day at 75% of full speed and for 2 hours/day at 100% if full speed, resulting in savings of about 50% of the full-speed electrical costs. Consult with Vaughan Co. as to whether your mixing system can be used in this way.

- **Intermittent Rotamix system operation:**

Vaughan Co. recommends against the use of intermittent Rotamix system operation of digester mixing because of the problems of controlling foaming or RVE events. However, some users for various reasons opt not to use a VFD controller for mixing pump speed control and instead opt to use intermittent mixing. Intermittent mixing works best in digesters where foaming does not occur. Experience has shown that the majority of gas generation in a digester occurs while new sludge is being added, and so the Rotamix system should be run during this time. Therefore, if intermittent mixing is going to be used, the Rotamix system should be started about 60 minutes before adding new sludge and should be shut down about 60 minutes after stopping the addition of new sludge. This mode of operation generally amounts to about a 35% to 50% duty cycle and saves a considerable amount of electricity. Vaughan Co. encourages experimentation so that you get the best possible mixing using the lowest possible energy requirements for your system. Generally, the mixing system should be run for at least 3–4 hours at a time, then perhaps the pump can be shut off for an equal amount of time, say 4 hours on, 4 hours off. Operation of the mixing system for short periods of time, such as less than 60 minutes will not provide any useful mixing. Again, most tanks must be run for 30–60 minutes just to reach full mixing velocity in the tank; active digester mixing occurs *only* after reaching full mixing velocity.

SECTION 6: SHUTDOWN INSTRUCTIONS

Shutdown of the Rotamix™ system involves stopping the pump(s). Again, see the pump IO&M Manual.

Note also that if you are mixing a sludge storage tank that heavy, lime-stabilized sludge should not be permitted to sit stagnant in the system piping. The piping should be flushed with light sludge or water before securing the system. Especially with an open-top storage tank where the sun can heat the piping, the sludge can dry out and ultimately cause plugging of the mixing nozzle(s).

SECTION 7: MAINTENANCE

A. ROUTINE MAINTENANCE

No routine maintenance is required for Rotamix™ floor-mounted nozzle assemblies as these units have a standard 10-year warranty, are made of ductile cast iron and are completely glass-lined. If you have occasion to enter your digester or storage tank, you will want to inspect the nozzle assemblies and piping to make sure the equipment is in good working order and that the nozzles are still properly aimed. Whenever you check the nozzle system, inspect the nozzle opening to make sure that the glass coating is still intact. If the glass coating and ductile iron metal is worn away, replace the nozzle. For polyurethane nozzles, measure the discharge diameter to make sure that it is no more than 15 % larger than it was when new. (For example, a new 2.00” dia. nozzle should not be larger than 2.3”. If it is larger than 2.3”, replace it.) Nozzle exit diameters are defined in the PARTS section of your custom Installation, Operation and Maintenance Manual for your Rotamix system.

Venting systems may require yearly inspections to make sure they are working properly and staying clear of debris. Vaughan always supplies the flushing option with the air release valves we supply.

B. CORRECTIVE MAINTENANCE

Replacement of any Rotamix™ nozzle assembly components is self-explanatory. Fittings are attached to each other on the assembly by clamps. Contact Vaughan Co. for pricing on replacement components. The parts list for the nozzle assembly is included in your Rotamix™ system I,O&M Manual Parts Section.

SECTION 8: TROUBLESHOOTING

Most Rotamix systems work extremely well, but once in a while we run into trouble. Historically the biggest troubleshooting problems we have encountered with Rotamix installations have been: (a) foaming and rapid volume expansion (RVE) events, (b) problems relating to gas binding in the mixing pump that can negatively affect mixing, and finally, (c) a few problems with nozzle plugging. Trouble can show up: (1) in the pump, (2) in one or more nozzles, (3) in the mixing.

1. Troubleshooting the pump:
    A. See the associated Vaughan pump IO&M manual for the applicable troubleshooting chart. Anything that could cause trouble for a pump in any other system could cause similar problems for a pump in a Rotamix system. To head off future problems, a careful pump startup is important. Verify correct pump rotation and take and record suction and discharge pressure readings and motor amperage readings to compare against future readings.
    B. Pump cavitation may be evident from the Rotamix™ system mixing pump when mixing your tank at abnormally low levels. Mixing at very low levels can cause vortexing in your tank, which results in drawing large amounts of air into the mixing pump. Low-liquid-level mixing can also cause the nozzle to discharge above liquid level, a situation that can cause aeration of the fluid in the tank. Either of these situations can cause pump cavitation and vibration, which if allowed to continue will shorten the life of your pump(s). To stop vortexing, Variable Frequency Drive (VFD) motor control systems can be used. By using a VFD, you can slow the pump (and pump motor) down as tank level decreases and thus reduce pumping power going into the system, thereby avoiding some types of vortexing and cavitation problems. However, Vaughan Co. recommends that the slowest VFD speed used be no slower than 75% of normal pump speed. For example, if 100% speed is at 60 Hz. on your VFD, do not run the VFD at less than 45 Hz. Too slow of a speed reduces pump and system pressure and can result in nozzle plugging.
2. Troubleshooting the nozzles:
    A. Historically about ½ of 1% of Rotamix systems experience a plugged nozzle, so while blockage can occur, it's not a common problem. Nozzle blockage may show up as reduced mixing within your digester or storage tank. Other symptoms of nozzle plugging would be reduced pump electric motor power requirements (lower mixing pump motor amps), and higher pump discharge pressure than normal (which is typically about 15-17 psi differential pressure across the pump).
        a. Nozzle blockage can happen at startup because of debris left in the tank. Careful tank inspection by Vaughan Co. or Vaughan's authorized representative before closing the tank for filling and startup is required and can help avoid this problem.
        b. Older systems can eventually experience nozzle plugging problems if the mixing pump is not properly maintained to keep pump parts sharp and cutting clearances close. Routine pump maintenance per the pump and Rotamix I,O&M manuals can help avoid this problem. Pump cutting parts are designed for long life (3-5 years of continuous use), so that such an event should not occur on a new system unless construction debris has gotten into the system piping. Annual inspection of the pump as required in our pump IO&M manuals should help prevent nozzle plugging because of loss of chopping ability.
        c. Some systems, which allow large amounts of rags into the tank to be mixed may only be able to use Rotamix with only a few nozzles and with very large nozzle exit diameters. Even with effective chopping and reduced particle size, very high rag and fiber content in the slurry may create a slurry that is so hard to shear that the slurry shape will not deform to fit through any nozzle size.
        d. Fermenter tanks in some treatment plants have the potential to cause nozzle blockage because fermenter tanks tend to have high fiber content in the sludge, which can lead to

reweaving and the creation of large rags. Therefore, careful nozzle sizing is required for fermenter tanks.

e. Tanks downstream of influent screens with insufficient capacity for all possible flows (for example, a rain storm) may experience nozzle blockage problems if too many unscreened rags overflow the screen(s) and get into the downstream tank.

f. Coarse influent screens can allow large amounts of fiber to enter a tank. This fiber can then reweave to create large rags, which then may cause nozzle blockage problems under some conditions. Fine influent screens (1/4" (6mm) or so) are best.

g. Any tank where influent screenings are dumped are not suitable for nozzle mixing systems like Rotamix.

h. Corrective action to resolve nozzle blockage issues is to first consult with Vaughan Co. or Vaughan's Authorized Representative for help. The use of larger nozzle openings may help, or in some cases, the nozzle system may have to be revised to use fewer and much larger nozzles. Sometimes modifying the mixing pump to add finer chopper capability may also be an option.

B. Nozzles need to be placed correctly in the tank as described by Vaughan Co. Rotamix nozzle plan drawings for the project. The nozzles also must be aimed correctly in accordance with Vaughan drawings. A proper evaluation of the nozzle installation prior to closing the tank by Vaughan personnel or by trained Vaughan sales representatives is required and can head off problems with an improper nozzle installation or nozzle aiming.

C. In multiple tank Rotamix systems, sometimes nozzle size from one tank to another are different sizes. If nozzles are mixed up so that incorrect (too large or too small) nozzles are used, a particular tank mixing system may not mix as well as expected. Again, a proper evaluation of the nozzle installation prior to closing the tank by Vaughan personnel or by trained Vaughan sales representatives is required and can head off problems with installation of incorrect nozzle size.

D. A worn nozzle may show up as increased mixing within your digester or storage tank. Other symptoms of a worn nozzle could be higher than normal mixing pump electric motor power requirements (higher amps), and lower pump discharge pressure compared to your recorded readings at startup. You may also hear pump cavitation noise, a crackling sound, similar to the noise of pumping gravel. Many people incorrectly interpret cavitation as a pump bearing problem. Nozzles on Vaughan Rotamix™ systems are made of glass-lined ductile cast iron (and sometimes made of abrasion-resistant polyurethane). So nozzle wear should take many years to achieve.

E. Operating a digester mixing pump on a Variable Frequency Drive or VFD can be very helpful to reduce digester reaction rates to help control foaming or Rapid Volume Expansion (RVE) events. However, operating the mixing pump at speeds slower than about 75% of full speed increases the risk of nozzle plugging since flow and pressure generated by the mixing pump is also reduced by lower speed pump operation. Too little flow and pressure through a nozzle may not keep the nozzle clear of debris. Vaughan recommends a minimum mixing pump of 75% of full speed.

F. Reduced speed mixing is not recommended for sludge blend tanks or sludge storage tanks.

3. Troubleshooting mixing:

A. Poor mixing performance from the Rotamix™ system may be caused by air or gas binding in the mixing pump(s). Proper venting and filling of the pump casing at each startup is required for the pump to work to its normal capacity. If the pump is partially full of air, it will not generate normal pressure or flow, and therefore the flow through the nozzles will be inadequate. Mixing increases Volatile Solids Reduction or VSR and this means that more gases of decomposition – methane and carbon dioxide – are generated. So, more gas generation in a digester can also increase the risk of gas binding. The plant operator may not know that gas binding is occurring. This is a problem because while he is operating the mixing

pump he is going to assume that mixing is taking place, but if the pump is gas bound, there may be little or no mixing occurring. The best way for the operator to know if the mixing system is not gas bound and operating normally is to check regularly on the differential pressure across the pump and on the motor amperage to make sure they are normal. During gas binding, pump differential pressure falls, sometimes to zero, and motor amperage also falls, since the pump will be doing less flow work. If the system is allowed to run too long with the mixing pump gas bound, big scum or sludge layers can build up in the tank during poor or non-existent mixing. Also, equipment life may be reduced and/or risk of nozzle plugging increased.

a. Vaughan Co. recommends the installation of a suitable air/gas release valve (ARV) for each mixing pump. Note that an ARV cannot vent gas from a gas-bound, operating pump. The rotation of the pump traps air at the impeller center. To vent air or gas from a pump, it must be shut down. Some operators will resist the installation of ARVs because these devices may need to be backflushed periodically, but the problems from loss of mixing can be much more troublesome than periodically cleaning an ARV.
b. To properly vent air or gas from the pump by an ARV, the ARV must be mounted close to and above the pump and not isolated by a valve or check valve that might close. Any check valve, if used, should be located downstream of the ARV and pump.

B. Poor mixing performance from the Rotamix™ system may be caused by plugged or blocked nozzles as discussed in 2A above.

C. Foaming and Rapid Volume Expansion (RVE) problems in a digester are one of the most common problems facing an operator of a modern anaerobic digester. Mixing increases Volatile Solids Reduction or VSR and this means that more gases of decomposition – methane and carbon dioxide – are generated. We want high VSR for better digestion, and we want more gas for cogeneration of electricity. However, generating too much gas in a digester over too little time can lead to foaming, RVE issues, and possible digester overflows. Digester overflow means bad odors, a big cleanup, and complaints from residential neighbors.

a. Troubleshooting foaming or RVE problems can be difficult because the causes of these problems are complex.
b. Many of the causes of foaming and RVE are out of Vaughan Co.'s control, such as:
    i. Feeding a digester in slugs rather than continuously. The best way to avoid foaming is to spread out the feeding of new sludge over as much time as possible.
    ii. High grease content. The feeding of grease or other high strength waste into a digester generates a lot of gas and must be metered into the digester at a slow enough rate to avoid upsetting the digester.
    iii. The presence of Nocardia or Microthrix Parvicella from the secondary (aeration) plant. When these bacteria from aerobic digestion are broken down in an anaerobic digester, more gas is generated.
    iv. High levels of WAS in feed sludge. WAS is Waste Activated Sludge from the aerobic digestion, secondary side of the plant. WAS usually has some amount of Nocardia or Microthrix Parvicella as well as undigested sludge. As the bacteria and sludge are digested further, they will generate more gas.
    v. Excessive alkalinity & CO_2 content in digester gas. More CO_2 gas can generate more foam or cause RVE events.
    vi. Volatile Fatty Acids (VFA), which can be caused by primary sludge fermentation prior to feeding. This situation can lead to more rapid release of gases of decomposition.
    vii. Feeding chemical sludge to digester, which could be the result of coagulant use upstream of digestion. When these chemicals break down in the digester they release more gas.
    viii. Polymer overdose during dewatering. Again, when these polymers break down in the digester they release more gas.

ix. The release of surfactants as intermediates during the degradation process. When surfactants are digested anaerobically, they generate more gas.

x. Inadequate mixing, start-up conditions, shock/inconsistent loading rates. Again, any time digestion and generation of the gases of decomposition are not spread out evenly over time, the risk of foaming and RVE events is higher.

c. What are the causes of foaming that are within our control?

i. We can reduce mixing so that the digestion rate slows, generating less gas, thus producing less foam while still maintaining mixing.

ii. The best method of reducing mixing in a digester is with Variable Frequency Drive (VFD); 75% of full speed is the recommended lower limit, as we have discussed earlier.

iii. Intermittent mixing is not the best method for reducing foaming and RVE problems because it leaves pockets of undigested feed sludge in the digester, which then can rapidly turn to gas on resumption of mixing.

d. To suppress foaming, we recommend Vaughan's Foambuster. Pumping digester sludge through a nozzle and over a splashplate by use of the Foambuster generates thousands of droplets, which are spread over the digester surface to break foam bubbles and reduce foam levels. The Foambuster can be fed sludge by the main mixing pump or by a separate pump to provide independent foam suppression control. The best approach is to install the Foambuster with the Rotamix system so that there is a way to control foaming right from the start. If foaming occurs after startup of the mixing system and a Foambuster has not been installed with the system, the recovery costs for installing a Foambuster are much higher.

D. Poor mixing can result if the viscosity of the mixed sludge is too high. This situation can occur when mixing very thick TWAS (thickened waste activated sludge). Once TWAS gets up to the range of 6-7% solids, mixing may be difficult to achieve. When TWAS concentrations are higher than 6-7% solids, it is generally not possible to effectively mix this fluid.

a. The use of CFD (Computational Fluid Dynamics) in evaluating mixing systems in ultra-viscous sludges has been extremely helpful. Vaughan Co. has significant CFD capabilities and a great deal of experience with this method of analysis.

E. When mixing straw, grass and other materials that float, the mixing system often needs a combination of Rotamix and propeller mixers to drive the floating material down into the slurry to be hydrolyzed. Hydrolysis is the chemical breakdown of a compound due to reaction with water.

F. Some Rotamix systems depend on two pumps pumping at the same time to send enough flow through the nozzles to mix a very large volume tank. On systems like this it's not uncommon for the plant operator to misunderstand that operation of only one pump is not effective and may be operating the single pump in high flow cavitation. Cavitation can shorten pump life and the life of the mechanical seal, in particular. The use of a VFD controller on each pump motor as both pumps are operated is the correct way to reduce overall system flow, when required. Alternatively, consider piping the system such that each pump independently feeds half the mixing nozzles.

VAUGHAN CO., INC. WARRANTY
GLASS LINED DUCTILE IRON NOZZLE ASSEMBLY
FOR MUNICIPAL SLUDGE SERVICE

Vaughan Co., Inc. warrants the Rotamix glass lined ductile iron mixing nozzle assembly manufactured by Vaughan Co. to be free from defects in workmanship or material for a period of ten (10) years from date of shipment from Vaughan Co. If during said warranty period, any components of the mixing assembly wear or corrode through the walls of any of the nozzles or fittings under normal use in biological sludge mixing service, Vaughan Co. will provide a replacement for the worn part free of charge. Vaughan Co. shall not be responsible for the cost of nozzle removal and/or re-installation.

All warranty claims must be submitted in writing to Vaughan Co. not later than thirty (30) days after warranty breach occurrence. The original warranty length shall not be extended with respect to nozzle assemblies repaired or replaced by Vaughan Co. under this Warranty. This Warranty may be voided if nozzle or nozzle parts are repaired or replaced by anyone other than Vaughan Co. or its duly authorized representatives.

Vaughan Co. assumes no liability for consequential damages of any kind and the purchaser by acceptance of delivery assumes all liability for the consequences of the use or misuse of Vaughan Co. products by the purchaser, its employees or others. Vaughan Co. will not be held responsible for travel expenses, rented equipment, outside contractor's fees, or unauthorized repair service or parts.

This warranty shall not apply to any product or part of product which has been subjected to misuse, accident, negligence, used in a manner contrary to Vaughan's printed instructions or damaged due to faulty installation or repair.

THIS IS VAUGHAN CO.'S SOLE WARRANTY AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, WHICH ARE HEREBY EXCLUDED INCLUDING IN PARTICULAR ALL WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

Vaughan Co. neither assumes, nor authorizes any person or company to assume for it, any other obligation in connection with the sale of its equipment. Any other enlargement or modification of this warranty by a representative or other selling agent shall become their exclusive responsibility.