Understanding Important Characteristics of Vortex Grit Removal Systems

As municipal wastewater treatment plants around the world become increasingly more mechanized, greater consideration must be given to equipment protection. One emerging treatment process step that accomplishes this function is grit removal. "Grit" consists of a variety of particles including sand, gravel and other heavy inorganic materials. Removing grit from wastewater streams at the start of the wastewater treatment process significantly protects downstream mechanical equipment from abrasion and abnormal wear. It also reduces plugging in pipes caused by the grit settling out in these, particularly where the piping changes direction. Grit can also settle out in aeration tanks, making it necessary to take these tanks offline, pump them down, and manually remove the buildup of grit.

Other costly problems that can arise from not removing grit include gravity rake arm failures, plugged heat exchangers in digesters, and unpleasant odors. If the grit removal process is removed from the pretreatment section of the plant, the initial capital cost may be lowered; however, the operation and maintenance cost will be larger within a few years.

Without grit removal in the headworks, grit is usually removed in primary clarifiers, or, if the plant lacks primary treatment, in aeration basins and secondary clarifiers. Because the sludge from these process tanks is often stored in digesters on-site, sizing consideration for the digesters must include the grit load, if the grit removal process is not included. Although clarifiers are usually designed for a given retention time, the formulas often fail to take into account the volume lost due to grit accumulation. The same is true of aeration tanks with loading rates based upon volume available.

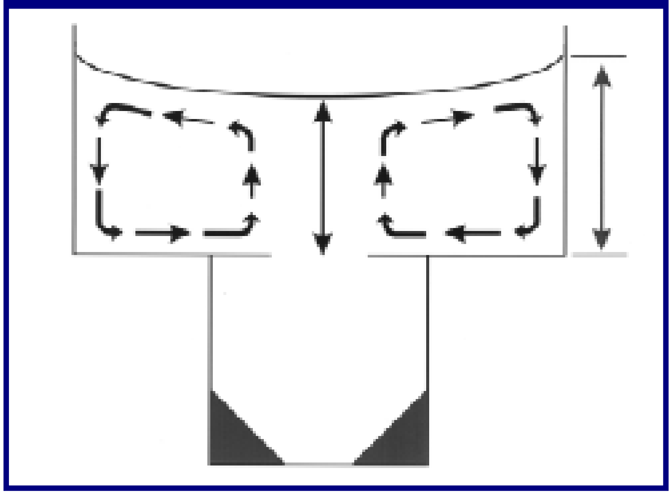
In addition, the more grit there is in the sludge, the more the related cost of handling this material will be. This extends all the way from dewatering, if included at the plant, through the actual hauling costs for ultimate disposal. Grit removal is critical for protection of sludge dewatering centrifuges, as well as high-pressure progressive cavity and diaphragm pumps, since all can be easily damaged by grit. Loss of volume in digesters because of grit settling out and "cementing" is another example of why grit removal should be implemented as a process step.

Grit Removal Systems

The prevailing grit removal mechanism in the U.S. and globally is the circular or "vortex" grit chamber. There are several features to consider when comparing vortex flow grit removal chambers. The most important features include the degree of liquid rotation, 270 degrees versus 360 degrees, and the shape of the grit removal chambers floor, flat bottom versus and sloped bottom.

It's important to understand that the vortex grit chamber has two distinct designs – flat bottom and sloped bottom. The flat bottom model has a flat-bottomed grit removal chamber, while the hopper bottom has a 45-degree cone-shaped bottom. The flat bottom and sloped bottom units were developed and patented concurrently by different companies, the sloped bottom units originally in Switzerland and the flat bottom **PISTA®** unit by Smith & Loveless. Both types of systems rely on the greater specific gravity of grit to separate it out from the lighter organic material – but they differ in how the grit is actually removed.

Figure 1: PISTA® Grit Chamber



The measure by which grit system performance is evaluated – can be greatly enhanced in vortex systems by having a long, straight entering flume where the flow can become as laminar as possible. This allows the grit to settle instead of being agitated by the turbulence caused by bends, etc. The entering flow has a steady tangential direction, so it is more efficient in creating rotational flow. The chamber's effluent should go out a flat floor for a distance of at least 6 feet to reduce weir effect and establish flow levels. Turbulent flows entrain air. Flows dropping into vertical pipes vortex and can cause large air pockets to pass down the pipe. This is especially undesirable if the flow passes into a primary settling basin.

While sloped-bottom units are considered "vortex" units because of their circular similarity to flat-bottom units, they actually rely on particle settling rather than hydraulic removal. Sloped bottom units are designed to provide a long flow path around the perimeter of the chamber. The desired long flow path must achieve sufficient retention time to allow for grit to settle. Settled grit on the sloped-bottom floor subsides on the slope – much like a clarifier – and collects in the hopper below the basin. If the retention time is not long enough for particular sized grit particles to settle, less removal efficiency is the result, translating into larger problems downstream.

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continued from front side

The flat-bottom **PISTA**® Grit Chamber (Figure 1, Page 1) works on the principle of a forced vortex. The incoming flow is straightened in the inlet flume to minimize turbulence at the inlet of the chamber. At the end of the inlet flume is a ramp that produces a Coanda effect, which causes grit that may already be on the flume bottom to follow the ramp to the floor of the chamber and be captured. In addition, at the end of the flume is the inlet baffle. This inlet baffle is positioned such that the flow entering the chamber and the flow inside the chamber impinge. At the center of the chamber are rotating paddles, which maintain the proper circulation in the chamber at all flow rates. This combination of paddles, inlet baffle and inlet flow produces a toroidal flow pattern, which is key for creating hydraulic removal ability.

PISTA® Grit Chamber flat bottom grit basins, by the nature of their operation, avoid the problems inherent to hopper bottom grit basins. In the flat bottom grit chamber, the forced vortex turns the upper area of entering flow and rotates it to the chamber floor where the grit finally passes along the floor. The grit becomes attached to the floor. This is accomplished by centrifugal force of the rotating tank contents causing the surface of the vessel at the perimeter to be at a higher elevation as shown in the figure. The surface level at the center is lower. The surface of the vessel is a parabola. The secondary induced flow, shown by the arrows, goes down the outside wall, across the floor where the grit is deposited, back up the center core and across the surface. The blades on the center propeller are above the floor, increasing the flow along the floor and directing it up the center core from below the impeller to the surface.

Most importantly, the flow path is not around the perimeter, as in the sloped bottom, settling-type unit. Instead as the basin contents rotate, the flow moves across the floor to the center of the basin. This movement is accomplished in one full rotation of the tank contents. The flow up the center core to the surface and across the surface is accomplished in the next rotation. The flow path is not simply the distance of the grit basin, but two revolutions of the grit chamber's paddles. The result is a substantially longer grit flow path and thus a higher removal efficiency.

The removed grit on the floor of the flat bottom basin is moved along the floor by the hydraulic current to the center. At the center, the propeller above the floor aids this flow by pumping the hydraulic flow, which increases flow and velocity. The grit moving on the floor falls into the hole at the center, and drops into the grit storage chamber to settle quiescently.

The toroidal flow pattern maximizes the number of times a grit particle can be subjected to hitting the chamber floor and be captured. Once captured on the flat floor of the chamber, the grit is moved along the floor toward the center by the bottom velocity created by the toroidal flow pattern. A flat chamber bottom is essential to maintaining the toroidal flow pattern at its maximum efficiency. A sloping bottom would decrease the intensity of the toroidal flow pattern, reducing the grit capture efficient and increasing the amount of organics that will be captured and contained in the grit.

As the solids are moved along the flat floor of the chamber toward the center, the rotating paddles maintain a velocity such that the lighter organic materials are lifted and returned to the flow passing through the grit chamber. The grit then moves toward the center and drops into the bottom storage chamber through a small opening between the paddle drive shaft and the steel cover plate. All grit passes under the paddles to remove organic materials before being allowed to fall into the storage chamber. In terms of removal efficiency, the flat-bottom grit chamber is capable of removing the following at the specified hydraulic peak flow rate: 95% of the grit greater than 50 mesh in size, 85% of the grit greater than 70 but less than 50 mesh in size, 65% of the grit greater than 100 but less than 70 mesh in size.

When sufficient grit has accumulated in the storage chamber, the grit is then removed from the chamber and transferred to dewatering devices. In vortex grit chambers, removed grit collects in the storage hopper below the chamber floor. Superior grit chamber units will offer a fluidizing option in the storage hopper to prevent grit from compacting and cementing.

Once removed from the main wastewater flow stream, grit is conveyed out of the storage hopper by various means, most notably airlifts and turbo grit pumps. Airlifts can be useful – typically on small flow applications – but will plug more often and prevent the use of a vortex separator component (i.e. grit concentrator or cyclone) in the grit dewatering phase. Airlifts represent conventional technology that has been replaced with heavy-duty grit pumps, particularly in large flow applications (12 MGD and larger).

Grit pumps employed in these applications are centrifugal, and the superior ones feature a Ni-hard construction. They can be remote-mounted, using gravity flow or be top-mounted on the grit chamber using vacuum-priming. Top mounted designs offer unique advantages including a self-draining capability, which minimizes the potential for clogging. The suction pipe is a vertical rise where the grit can flow back into the storage hopper. Remote mounted units require additional suction piping where material can accumulate and increase the potential for clogging. In addition, top-mounted grit pumps minimize space and construction cost because they don't require additional dry wells; instead they simply reside on top of the grit chamber.

Conclusion

Grit removal has become an important stage in the wastewater treatment process for protecting down stream equipment and operating efficiency. As the removal technology advances with time, it has become important to understand the dynamics of grit chamber operation to properly implement an effective removal system. The latest market trend shows that grit chamber installations are using more and more vortex grit chamber features, including flat bottom chambers, top mounted grit pumps (non-airlifts), and 360 degree rotations.

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