Designing Dairy Nutrient Management Systems

University of California Cooperative Extension
Stanislaus County

Controlling Liquid Manure Flow Rates

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In order to apply lagoon water at agronomically acceptable rates, the lagoon water delivery system must have the ability to apply controlled quantities of nutrients at timings that match the needs of the growing crop. In a surface irrigation system, applying the correct amount of lagoon nitrogen or other nutrient requires injecting the appropriate amount of liquid manure (lagoon water) into the fresh irrigation water. While a flow meter measures what is being applied, a means of adjusting the flow of lagoon water to meet desired application rates is also necessary. Having a method of adjusting the ratio of pond water to fresh water is essential to applying precise amounts of nutrients called for in management plans and is also important in preventing crop injury from excess salts.

The three main ways to adjust the liquid manure flow rate from a retention pond are to put a controller on the pump to control its speed, use valve on either the pump discharge or gravity outlet, or to divert a portion of the pump output back to the pond. Many lagoons already have valves or side gates installed that can be utilized, but how well they function for controlling application rates will depend on the type of valve and the degree to which the flow needs to be throttled back.

Any flow control device will change the pump output and will nearly always need to be used in conjunction with a flow meter in order to determine how much to throttle back the flow, and to have an accurate measurement of the amount of water and nutrients being applied.

A simple method of precisely controlling the flow rate of lagoon water makes applying the specific amount of nutrients that the crop needs an easy task.

When reducing the liquid manure flow rate on an existing system, be aware that the velocity of the water in the pipeline will be slower and may not be fast enough to keep manure solids in suspension. A minimum velocity of between 2 and 5 feet is the standard recommendation to prevent solids from settling but the velocity needed also depends on how large and dense the solids are, and the slope and roughness of the pipeline. If solids are allowed to settle in the pipeline, the pipeline may plug. In larger pipelines, the solids may build up in the pipe until the open area is small enough to maintain a velocity that will keep that area clear. However, effective diameter of the pipe is less and the capacity of the pipeline is diminished.

There are three main ways to adjust the flow rate from a lagoon pump:

- Variable frequency drive pump controllers
- Throttling valves
- By-pass on the pump

Variable Frequency Drive Pump Controllers

On pumped systems, one method for controlling the flow rate is to install a variable frequency drive controller on the pump motor.

A variable frequency drive (VFD) is a controller that sits between the power supply and the motor. It allows continuous and precise control over the output of a pump by regulating the speed of the pump motor. VFD pumps are becoming increasingly popular in industrial and municipal applications because they are more energy efficient in comparison to throttling valves. With a VFD, a pump can be gradually brought up to speed over a period of time, so there is the potential to reduce or eliminate the demand charges from utilities for the extra power needed to start up a pump motor in the usual way. A VFD also reduces power costs because power usage is proportional to the speed of the motor. If the pump output is reduced, the motor will draw less current because it is going slower. By reducing the speed of the motor, a VFD reduces the shaft horsepower of the pump. By using a VFD instead of a valve to adjust the flow rate, the pump's efficiency is maintained to a large extent, which can result in significant energy savings.

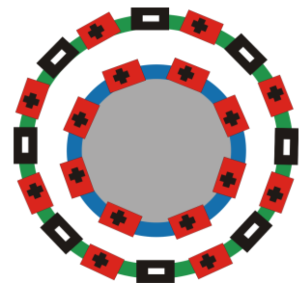
The two main drawbacks to a VFD over a valve are the cost and it's suitability to outdoor environments.

Sample VFD prices are about $4500 base price plus about $100 per horsepower, not including housing. When compared to the cost of a valve, this may not be cost effective for a 30 – 40 hp lagoon water pump motor, where the controller alone would be about $7500 - $9000. However, there is a wide range of efficiencies in pump types. It may take a 30 hp motor with a 25% efficient pump impeller to move the same amount of water as a 50% efficient pump with a 15 hp motor. The cost of the VFD on the smaller motor is less prohibitive and there is a continual advantage in power savings with the more efficient motor.

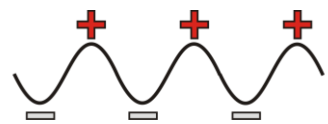
While efficiency is an important consideration when choosing a lagoon pump, resistance to clogging and price are

How a Variable Frequency Drive Works

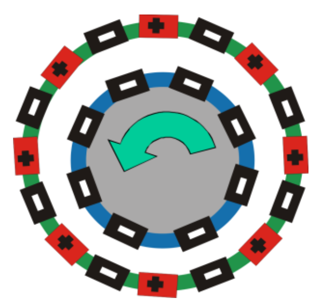
Opposite charges attract. Like charges repulse.



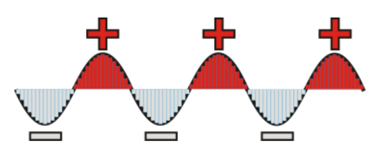
A motor works by lining up the positive charges on the interior shaft with positive charges on the surrounding stationary coil. The like charges repulse, moving the shaft so that it lines up with opposite charges.



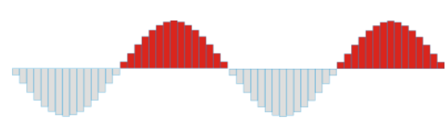
With AC (alternating current) electricity, the charge alternates between positive and negative.



When the polarity changes, the charges become the same, so the shaft has to move again. The speed of the rotation is determined by how quickly the current alternates in polarity.



A VFD generates signals that mimic the fluctuations of alternating current (AC) electricity.



Because the artificial fluctuations in the current are being manufactured by the VFD, the cycles can be lengthened by the microprocessor from 60 cycles per second to 1 cycle per second or anything in between, slowing the motor as desired.

usually the higher priorities. Where irrigation run times are as fast as 10 to 20 minutes per acre, lagoon pumps with the ability to apply 1000 gpm are often used to achieve the correct ratio of lagoon to fresh water for reasonable nitrogen application rates. VFDs on these pumps can be prohibitively expensive.

However, in areas where irrigation delivery flow rates are slow, much lower pump outputs are indicated, and in these situations, a VFD pump may be a viable option.

A VFD gives more precise adjustment of flows that many types of valves, especially at lower flow rates. However, a VFD may not provide enough range of adjustment in pump output than with a valve unless precautions are taken. A pump motor can be continuously operated at 60 to 70% of its normal speed without concern. At speeds less than that, the motor fans do not function properly and the motor may overheat. At slower speeds, it may be necessary to install a supplemental fan for the motor.

VFDs are sensitive electronic devices that must be protected from heat, cold, dust, condensation and other environmental extremes. Building an enclosure that to provide protection can be an additional installation expense.

Improperly installed, VFDs can shorten the life of the motor by inducing mechanical vibrations in the pump. Such problems can be avoided by proper installation and calibration.

A preexisting motor can be used if it has been wound with VFD duty magnet wire which will withstand spiking. Most new motors and newly rewound motors have this type of wire but older ones may not. It may cost as much to rewind a pump motor with upgraded wire as to buy a new pump.

Adjusting Pump Output With Valves

The most common method of adjusting the pump output is to install a throttling valve. While these are in common use for throttling purposes, it is possible for damage to the pump to occur is caution is not taken.

How backpressure can damage pumps

Most low head trash-type pumps commonly used to pump lagoon water can be throttled back considerably without damaging the pump. Using a valve to throttle back the output from axial flow or propeller pumps, however, may cause the motor to overheat and be damaged. If very small valve openings are anticipated, a return flow system can be installed which will return part of the flow to the pond if backpressure on the pump becomes too great. Installing a variable frequency drive on these types of pumps is another alternative when lower flow rates are needed.

Low head centrifugal lagoon pumps are the most common type of pump used for liquid manure. They can usually tolerate a fair degree of throttling without damage to the pump, but they should never be throttled back so far that the pump begins to cavitate from too much back pressure. As water exits the pump, new water is sucked into the place where the other water used to be. The water is “stretched” as it is pulled, allowing gases that are dissolved in the water to fill the voids and form bubbles. These bubbles form cavities where there is no water, so the pump output is reduced.

Cavitation damages a pump that is throttled back too much because the water in the pump bell is forced to recirculate because the pump impeller blades are still spinning at the same rate but the water has no place to go. The water pressure is so great that the cavitation bubbles are pressed against the impellor blade until they implode. Since the water is the source of the pressure the force released from the implosion of the bubble is directed into the surface of the impellor blade, causing pitting, flaking and premature wear on blade. The bubble collapses with a speed faster than sound, creating a sonic boom, which is why pumps that are cavitating are noisy.

Installing a pump bypass to divert some of the flow back to the pond is a simple method for protecting the pump when low flow rates are needed. However, the minimum flow rate for a pump should be established based on the both the pump characteristics and the velocity in the pipe that is needed to prevent solids from settling. The minimum gpm for a particular system should be posted so that irrigators will know not to set a flow rate that is lower than the minimum. If the minimum flow rate will result in too high an application rate, consider other options for reducing the application rate or designing a nitrogen budget that does not require applying low rates. Additional information is in Designing Liquid Manure Transfer Systems and Measuring Liquid Manure Applications, in this series.

General Considerations for Selecting and Installing Valves

The longevity of the valve can be an issue. Cast iron valves installed in a location that does not drain but has standing liquid manure in the pipeline have corroded and fallen apart in less than a year. Stainless steel v-notch valves in pipelines that drain have performed well for the past 10 years.

Cast iron valves in lagoon water pipelines that do not drain have corroded in less than a year.

Leaking valves can be a major contributor to groundwater contamination if not repaired promptly. When installing valves in the bottom of a lagoon, a second, backup valve should be installed to shut off the flow from the pond to allow in-season repairs to the primary valve. If the pond needs to be drained to access the valve, if may be difficult to find a place to put the water that will not result in excess applications to some fields, and then possibly not having those nutrients available for when they are needed.

When installing valves for throttling purposes, safety to users should always be a priority. Valves used for nutrient management will need frequent adjustments. Whenever possible, these valves should be located on the outside of the pond so that irrigators will not need to go out on a catwalk on the pond by themselves at night. If this situation is unavoidable, catwalks must be sturdy and have good guardrails.

When selecting a valve, consider if eventually the valve may be monitored and controlled remotely. This is a common practice in other industries and some dairy operators may want to adopt this technology.

There are many types of valves, but only a few, butterfly, slide gate and ball valves, are commonly used on dairies.

Butterfly Valves

The butterfly valve on the left is shown in the open position. If debris becomes wrapped around the axis, the valve may not shut completely. The valve on the right is shown in the position needed to achieve a targeted application rate. The opening was too small to prevent frequent plugging, and the valve was subject to excessive wear from scouring and wobbling.

Butterfly valves are most common and least expensive. They have a rotating plate inside a pipe that can be set at different positions. Butterfly valves have poor throttling characteristics even for clean water because most of the throttling happens in the first 20% of valve opening, making them very difficult to adjust, especially if it is necessary to operate the valve in a nearly closed position. They can also be prone to plugging if operated in a nearly closed position, further complicating flow control. Butterfly valves can be prone to plugging if flows contain debris. If long debris (straw, plastic, twine, weeds) wraps around the central plate, it may not be possible to close the valve. Sometimes the pressure of the water may cause the valve to wobble, especially as the valve becomes worn. This could interfere somewhat with flow measurement.

In our experience, a ratchet style controller on a butterfly valve does not give nearly enough flexibility in adjusting flow rates for nutrient application. If using a butterfly valve, an infinitely variable wheel type controller is strongly recommended.

Standard Line Gate Valves

When a standard line gate valve is used for throttling, narrow corners can trap debris, making the flow rate erratic and potentially clogging the valve.

A line gate valve, also called a knife gate valve, consists of a sliding plate which covers the pipe opening. This type of valve is less susceptible to fouling than a butterfly valve. Even if the valve does accumulate debris, the sliding plate has a better chance of slicing through and closing than a butterfly valve. This type of valve has poor throttling characteristics because the shape of the opening makes fine adjustments difficult, especially at lower flows. When throttling at lower flow rates, the tips of the crescent-shaped opening can alternately be plugged with solids or the solids can spontaneously break loose. This makes it difficult to maintain a uniform flow rate. If the valve is run at a high velocity when partially closed, there is potential for mechanical wear and the gate will no longer seal when closed.

V-notch Line Gate Valves

A V-notch valve is a gate valve with a 'V' shaped orifice, formed by inserting a notched plate in the opening of a standard gate valve. This specialized type of valve is designed for use with thick slurries, such as in the pulp paper industry. These valves have been performing very reliably on dairies to control flow rates even on very thick sludge. They are as easy to install as other valve types and, depending on the material they are made of, may not be much more expensive than a standard valve.

The v shape allows for flow throttling while providing a large opening for solids and debris to pass, even when nearly closed. Another advantage of the v-notch gate valve is that, the closer to fully closed the valve is, the more the wheel must be turned to make the opening smaller. This makes it much easier to accurately control the flow rate when nearly shut because as the opening becomes smaller, the more finely the valve can be adjusted.

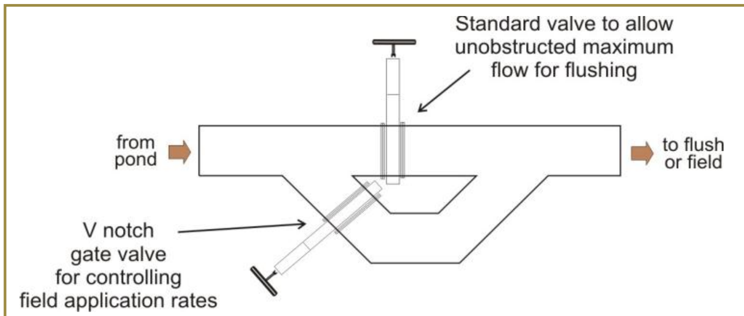
A V-notch gate valve maintains a relatively large opening for solids to pass through even when it is nearly closed, and it also makes it easier to make adjustments at lower flow rates.

Careful sizing is necessary to avoid restricting flow with this type of valve; a larger diameter valve is necessary to pass the same amount of water compared with a knife gate valve. A 60 degree v-notch is standard, but a 90 degree 'V' shaped orifice is available which has less full flow pressure drop while maintaining most of the resistance to plugging of the 60 degree type. A separate pump is recommended for the flush and irrigation systems. However, if the same pump must be used to operate both systems, do not put a v notch valve in the flush line because a v notch valve will constrict the flow even when it is fully open. This will result in too much loss of pump output for flushing. It may be necessary to install a bypass with a throttling valve on one arm and a standard valve on the arm used for flushing. When the pond is very dilute the option of using either valve to control pump output going to the field may be advantageous, especially if the pump is somewhat undersized. If the irrigation pump also operates the flush, place the irrigation valve as close as possible to the 'Y' to avoid the irrigation pipeline becoming packed with solids during the off season.

60° V notch gate valve

90° V notch gate valve

A 90° V notch gate valve has less pressure drop compared to a 60° V notch valve while still providing resistance to plugging.



Separate pumps for irrigation and flushing are preferred, but if the same pump must be used, do not install a v-notch throttling valve on flow that will be used for flushing since it will cause an unacceptable decrease in flow rate.

Controlling Application Rates in Gravity Systems

Many dairy lagoons have outlets where the lagoon water flows by gravity from an outlet near the bottom of the pond directly into an underground concrete irrigation pipeline. This configuration is especially common in the northern San Joaquin Valley where many ponds are mostly above ground. There is either a concrete box with a slidegate or a valve on the pond side of the underground pond outlet that controls the flow of the lagoon water from the pond. These valves have some potential for adjusting the amount of nutrients going out onto the field.

If the concentration of nitrogen in the pond is high, and the sidegate is large, the sidegate may need to be opened only a very small amount in order to achieve a reasonable application rate. In a 1998 UC study the opening of a 24 inch diameter side gate had to be between 1- 1/4 and 1-3/4 inches to obtain a 50 lb/A application of 350 ppm N lagoon water. Maintaining this small an opening can be difficult due to plugging, especially early in the spring after sludge has built up around the outlet. Even if the opening does not plug completely, portions of the opening may plug, resulting in an inconsistent flow rate.

Slide gate valves such as this irrigation turnout are often used on gravity outlets of lagoons.

It may not be practical to set the height of the side gate opening by the number of revolutions of the wheel if the amount of play in the wheel is greater than the entire desired opening. It is unlikely that the same number of revolutions will give the same opening each time. A better method is to measure the distance the threaded stem has moved. A consistent procedure should be followed each time the side gate opening is adjusted. For example, first raising the stem two inches above the target stem height before bringing it back to the desired opening will help clear the sludge from the sidegate opening while compensating for the play in the wheel.

Adjusting the rate from a pond with a gravity flow system can be easier if the valve is a line gate or butterfly valve instead of a slide gate because the diameter of the pipe and valve is usually smaller than is typical with a side gate and the amount of play in the wheel in many cases is less. However, since the pipe diameter is smaller, there may be some limitation on how low a flow rate can be maintained because too small an opening may result in plugging of the valve or outlet pipeline.

Although the flow rate of liquid manure from the pond can be adjusted by changing the degree of valve opening, when the water from the pond mixes with the freshwater in a gravity system, the backpressure from the freshwater in comparison to the level in the pond can greatly influence the lagoon flow rate that actually occurs. In a gravity system, some fields or checks of similar area may irrigate faster or slower than others because the pipeline diameter is different, the pipeline slope is flatter or steeper in that area, there are different number of valves open, or are not open the same amount, the fields are further away, or many other reasons. Irrigating the checks with the highest fresh water flow rate first, when the pond is fullest and the pond flow fastest will minimize the number of adjustments needed to achieve a uniform concentration of nutrients in the mixed water that will be applied to each field.

Valves in gravity systems are often accessed from a catwalk. If this valve is used for throttling, it will likely need frequent adjustments. Make certain that the valve can be accessed safely, especially in the dark. This pond has outlets at different depths in the pond, making it possible to adjust the amount of solids in the material being applied.

Adjusting Flow Using a Bypass on a Pressurized Pump

Some pumps cannot be throttled back to the degree needed for nutrient management without causing damage to the pump. Installing a bypass to divert some of the flow back to the pond will result in less flow going to the field without putting excess backpressure on the pump. While the pump bypass has the disadvantage of requiring energy to pump water that isn't needed, it may allow an existing pump to be used instead of installing a second, lower capacity pump to use when low flow rates are needed while maintaining the ability to apply higher rates with the original pump when needed. Be sure that the pipeline is sized correctly to accommodate the range of flows needed and that adequate measures have been taken to prevent pipeline plugging.

A single pump and metering run serves two adjacent ponds in this system. The pump bypass (red handles) relieves excess pressure on the pump by diverting a portion of the flow to either of two ponds, and can also serve as a way to adjust the application rate of the lagoon water.

A valve controls the amount of flow that is diverted to the pond. Ball valves are often used for this purpose, however other types may be preferred when higher flow rates are expected or there is a need for more accurate adjustments.

A pump bypass or other method of returning the pump output to the pond should be installed with a stand pump whether or not the bypass is used for throttling purposes. This will allow the operator to start up the pump prior to the irrigation and return the initial high solids material to the pond, and avoid sending slugs of sludge to the field. This thick material often contains several times the amount of nitrogen as the remainder of the pond, resulting in very high nitrogen rates on the first portion of the field irrigated, with high potential for groundwater contamination. The pump output from a stand pump should be returned to the pond, preferably at a different location than it was drawn from, until the product is more uniform.

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