

Installing Flow Meters on Dairies

Marsha Campbell Mathews
University of California Cooperative Extension

Note: These installation notes are not intended to substitute for the installation instructions in the product manual, nor are they a blueprint for specific installations. They are intended as a general overview.

Flow meters require proper placement in order to read accurately. Occasionally a suitable existing location for a meter can be found on a dairy but, more often, the flow meter is installed in a newly constructed metering run. Before constructing a metering run or making any other modifications to the liquid manure transfer system, the proposed nitrogen budget and nutrient application infrastructure should be reviewed. The correct size for pumps and pipelines is determined by the flow rates that are needed to provide the amounts of nitrogen specified in the nutrient management plan. Because the concentration of nitrogen in the pond may fluctuate throughout the year, it is important to be aware of the range of concentrations expected and the impact this will have on the required flow rates. If possible, obtain an estimate of existing pump output before installing a flow meter and making modifications to the system so that the metering run installed will be appropriate for the size of pump and throttling valve that will eventually be needed.



A correctly installed flow meter is an indispensable tool for managing and recording applications of lagoon nutrients. *Photo: Eric Swenson*

Because the fluid in a pressurized pipeline moves as a continuous column, the volume of water moving through the pipeline is constant along the entire length of the pipeline. A correctly installed meter positioned at any location along the pipe between the pump intake and the first discharge should give the same reading. Also, the change in flow rate from turning on or off the pump or adjusting a throttling valve will take effect at the same time at all points along the length of the entire pipeline. Flow meters can be sited anywhere along the pipeline that is most convenient providing their placement requirements are met.

It can be desirable, however, to locate the meter in a smaller diameter section of pipe nearer to the pump because smaller diameter tube style meters are less expensive and also some meters perform better when the fluid is moving at a faster velocity. A smaller diameter pipe has similar advantages for

the throttling valve since there may be a cost savings for a smaller valve and a higher velocity can help prevent the throttling valve from plugging. Any change in pipeline diameter must always be from a smaller to a larger size, and never from a larger diameter to a smaller one to reduce the risk of plugging and damage to the pipe. The smaller diameter pipe is generally used at the pipe discharge, and the pipe diameter is not increased to its final size until the after the meter.

When choosing a location for a flow meter consider:

- Safety of personnel who will be reading the meter and adjusting flow rates in the dark
- Security from theft and tampering
- Available power supply
- Convenience of access by irrigators
- Likelihood of being damaged by vehicles and equipment

The placement of the flow meter is critical to obtaining accurate flow readings. For a flow meter to perform properly there must be:

- A full pipe at all times, and
- A uniform water velocity across the cross section of the pipe, especially if using an insertion style electromagnetic meter.

Ensuring a full pipe

If a pipe is not full, the flow meter will give inaccurate results because the meter measures velocity of the liquid as it passes through a specific area. If the sensor is always completely submerged but the pipe is not full, the meter will still calculate flow based on the area of the full pipe, resulting in a flow reading that is too high.

To assure the pipe is always full, the flow meter must be situated in a location where the pipeline beyond the meter is at least 1 pipe diameter above the level of the section of pipe where the meter is situated. The easiest way to do this is to install the meter on a vertical section of pipe.



The upturn at the outlet helps to keep the pipe full so that this insertion style meter will read accurately. *Photo: Mace USA LLC*

If the pipe downstream of the meter is horizontal or tilted so that the flow is going downhill, the pipe must be modified so that a rise of at least one pipe diameter is downstream of the meter, with a continuous acting air vent placed immediately upstream of the meter or at the highest point close to the meter, to prevent air pockets from building up in the vicinity of the meter.



Mounting the meter on a section of vertical pipe is one way to assure that the pipe will always be completely full. *Photo: Eric Swenson*

Having a pump intake or gravity flow outlet on the bottom of a pond does not guarantee a pipe will run full. Air has been found in pipes coming off the bottom of a pond where the lift pump sucked air into the pipeline when running at less than full capacity. A gravity pipe will not be full if air remains from when the pipe was empty and there is not a good way for that air to escape. Pond gasses may come out of solution once released from the pressure of the bottom of a deep pond. Wherever the gas or air is coming from, if it displaces water in a pipe that is assumed to be full, it will interfere with flow measurements. Where it is not possible to tell if a pipe is completely full, consider installing a wetted Doppler insertion meter. The software with these meters can indicate if the pipe is not full or if there is a significant silt accumulation in the bottom.

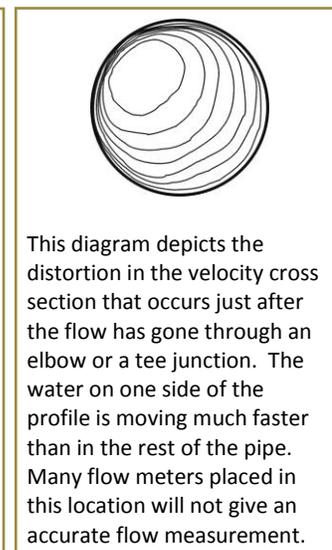
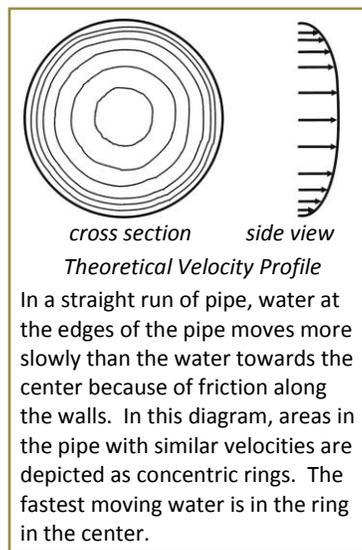


The sweeps on this metering run are designed to keep the pipe full. Although sweeps are preferred over elbows to minimize loss of head pressure and pump efficiency, the turn in this metering run is unnecessarily high and tight. A sloped pipe with an continuous acting air vent ahead of the meter would have been sufficient to ensure that the pipe is full.

Even if a pipe generally runs full, the flow may be underestimated if the sensor is placed where it is not completely submerged in the water, such as when pockets of trapped air are moving past the sensor. Insertion style meters should be placed 45° to 90° off of vertical to avoid interference from entrained air bubbles. Do not mount a wetted Doppler or insertion magmeter at the 12 o'clock position on the pipe unless you are absolutely certain the pipe is full. Do not mount a spool-type magmeter so that the sensors are in a vertical plane.

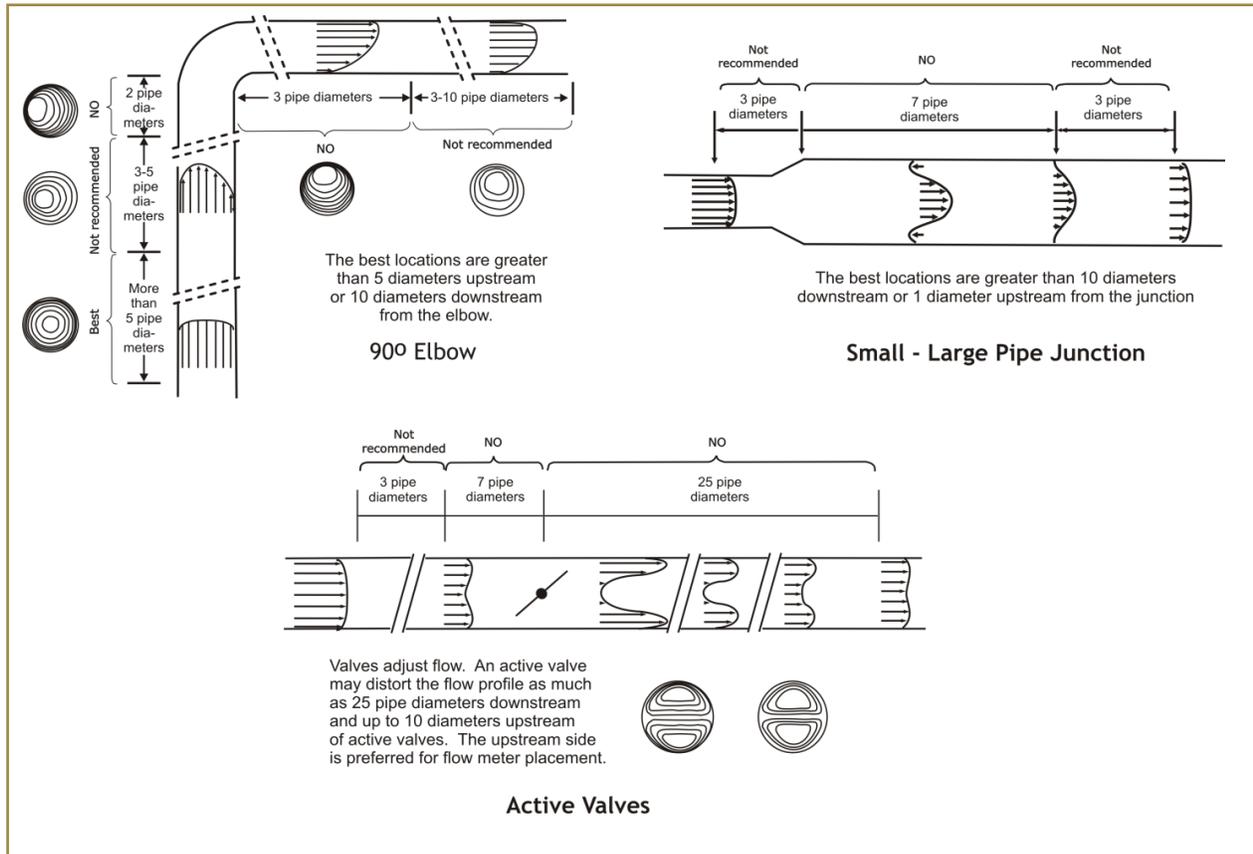
Ensuring a uniform velocity profile

When water flows around a bend, the water on the outside of the bend flows faster than the water on the inside. Because flow meters measure the velocity of water, it is important that the velocity be uniform across the entire cross section of the pipe in the location of the sensor. Flow patterns will be distorted both downstream and upstream of any disturbance. As a general rule, most meters perform well when placed 10 pipe diameters downstream or 5 pipe diameters upstream of any elbow, tee, junction or change in pipe diameter. When 5 pipe diameters of length downstream from the meter are not available, the accuracy sacrificed by positioning the meter closer to the minimum of 3 diameters may be acceptable. Wetted Doppler meters and some tube style meters may be sometimes be placed even closer than 3 pipe diameters and still maintain sufficient accuracy.



A valve will distort a flow pattern for a much greater distance than an elbow or tee, so a greater distance between the meter and the valve is required. Recommendations are for the meter to be at least 25 pipe

diameters downstream or 10 diameters upstream of an active throttling or check valves. It is always best to place the flow meter ahead of, not after, a valve. This is especially important in the case of throttling valves because water jetting through a small opening will distort the flow profile for a long distance downstream. It at all possible, place an elbow between the valve and the meter to help dampen the flow pattern distortion effects of a nearly closed valve.



Externally mounted Doppler meters which clamp on to the outside of a pipe are sensitive to sound in addition to flow pattern so additional distance – 40 pipe diameters or more - from pumps, partially closed valves and open discharges is required.

Because there are variations in the amount of flow profile disturbance that different meters can tolerate without loss of accuracy, check the instructions for your particular meter and don't hesitate to call the manufactures' technical support with questions.

Metering runs

The key elements to choosing a location for a flow meter are ensuring a full pipe and providing a straight run of pipe. With new construction, an ideal location for a flow meter can be designed into the system. In existing plumbing, it is sometimes possible to find an ideal location to place a flow meter that requires only minimal modification to existing plumbing. Examples of these locations are a vertical section of pipe where the manure pipeline discharges into an elevated box or a floating pump pipeline with a long straight upslope as it exits the pond.



This horizontal metering run has a full bore (tube style) flow meter. The pump and meter are between two adjacent retention ponds and can draw from either. There is a shunt installed ahead of the meter that can direct some of the flow back to the pond when necessary to avoid damage to the pump when applying very low flow rates.

If an appropriate location for a meter is not available, the usual remedy is to construct a metering run to provide ideal conditions for the flow meter, and also to accommodate the throttling valve, sampling spigot, air vents and sometimes a pump bypass. Even though some meters will perform well with shorter distances from flow disturbances, a standard metering run should be constructed if possible because this will assure optimal performance of any meter and provides flexibility if changes need to be made in the future.

Horizontal metering runs are ideal for situations where the pipe to the application fields is immediately downstream of a vertical stand pump. Some operators like this configuration because all the piping is visible and accessible. These metering runs are often constructed of metal pipe which is more durable than PVC but it is also more costly. If constructed of PVC, painting the exposed pipe a light color to protect it from deterioration from sunlight is recommended. The interior of drained black metal pipe can be extremely hot and has led to failures of some meters.

If the flow meter is on a section of pipe that is connected to a floating pump or far enough away from a vertical turbine style pump that the flow pattern is not disrupted, placing the straight section of the metering run on an incline can reduce the cost of installation.

Meter Installation Tips

Use two 45s instead of one 90 degree elbow on lagoon water pipelines to avoid eddies where solids can settle out. Or, use a sweep style elbow.

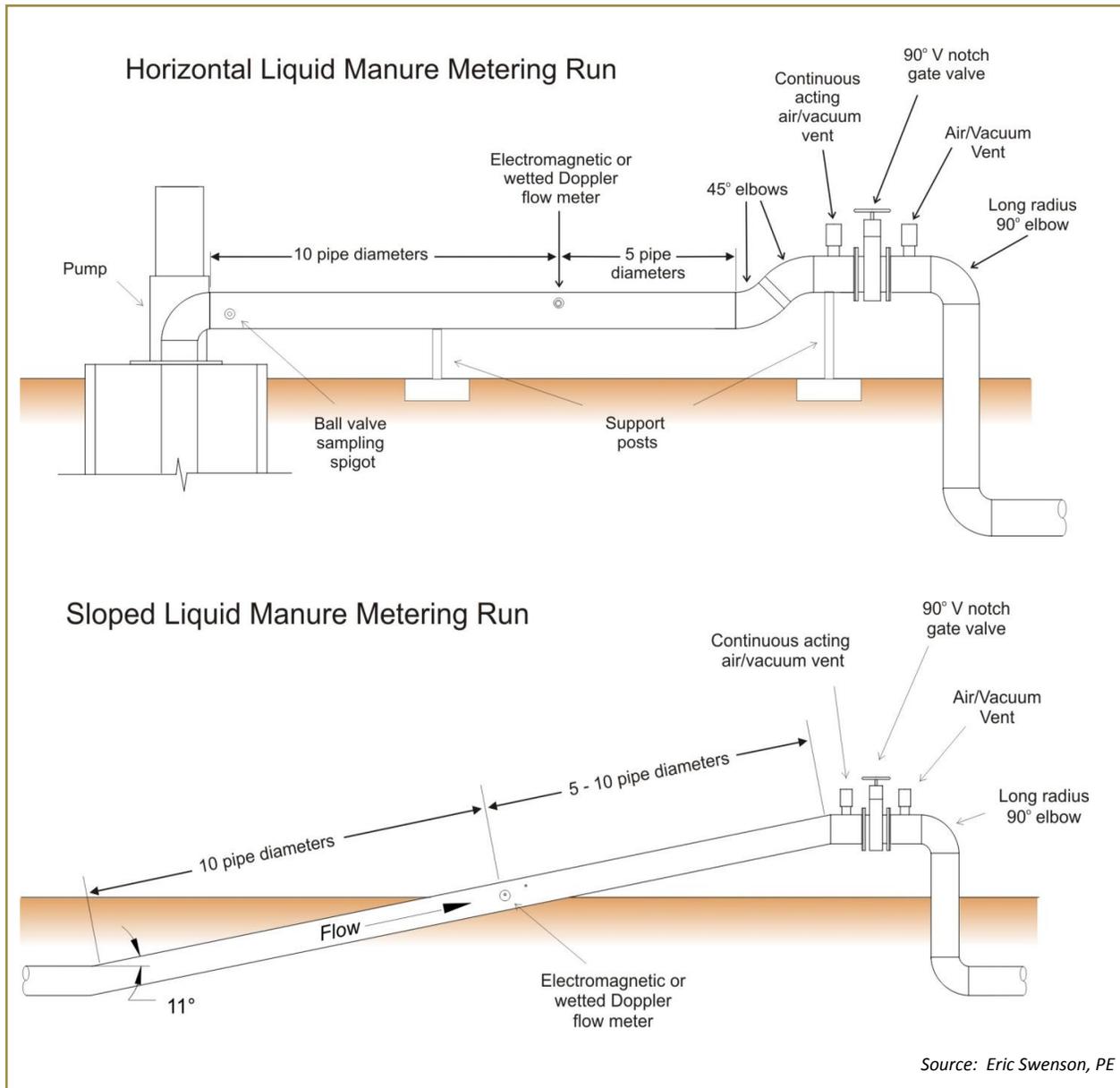
Never decrease the diameter of the pipeline in the direction of flow.

Meters should be installed upstream of throttling valves and check valves.

Larger lagoon water solid particles may tend to settle at velocities less than 2 feet per second. To avoid plugging, size pipeline to maintain fluid velocity above 2 to 2.5 feet per second.



This sloped metering run with probe style meter is economical to construct. The flow runs from left to right. The V-notch throttling valve is positioned downstream of the meter. *Photo: Eric Swenson*



Throttling valves

Flow meters are most useful for nutrient management when they are used in conjunction with a throttling valve. A throttling valve allows the operator to apply a desired nutrient application rate by adjusting the amount of lagoon water that is being mixed with the fresh irrigation water. Most metering runs should be designed to accommodate some method of controlling the flow rate. Most commonly this will be a throttling valve. For smaller diameter pipes and low flow rates, a variable frequency drive controller on the pump can also be an option for adjusting the pump output. A third option is to install a bypass controlled with a valve that directs a portion of the flow back into the lagoon. Both of these latter methods avoid putting back pressure on the pump. Most low head manure pumps can tolerate some degree of throttling without damage, but always check to be certain beforehand because there are some types which cannot be safely throttled. The more common concern with any method of flow control is that the velocity of the fluid in the pipeline is reduced as flow rate is cut back. If the velocity

becomes too low, solids begin to settle out, clogging the pipeline. You are very likely to be limited on how much you can throttle back without plugging the line, especially when pumping high solids sludge. Additional information, on preventing pipeline plugging is available in [Designing Liquid Manure Transfer Systems](#), in this series.

Valves vary in their suitability for throttling flow, especially of water carrying debris. Most of the flow reduction does not occur until the valve is mostly closed. When using butterfly and gate valves for throttling, the narrow opening that results from even moderate reduction in flow are prone to clogging and subject to increased wear from abrasion. A V-notch gate valve is recommended for throttling liquid manure. For a discussion of valve selection, see [Controlling Liquid Manure Flow Rates](#), in this series.

The valve should be positioned so that it can be operated while viewing the flow meter display. If the valve controller is high, a metal step will make access easier.

Valves should always be positioned after the flow meter because they will disrupt the flow profile for a considerable distance downstream of the valve. It is also good practice to position a bend in the pipe between the valve and the flow meter since the disruption in flow pattern for a bend is less than for a mostly closed valve.

Position shut off valves as close as possible to a junction, especially if one of the lines will be used infrequently. Solids may settle out and pack the lesser used segment between the junction and the valve. Install cleanouts in locations where this is a possibility.



A V-notch throttling valve is more suited for controlling liquid manure application rates than other types of valves because the opening is large enough to pass debris even when mostly closed. It is also much easier to “fine tune” the lowest flow rates.



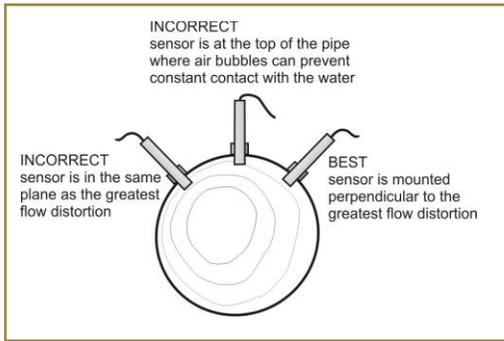
Install valves close to junctions to avoid leaving sections of pipe that may pack with solids when not in use. A cleanout in these locations is a good idea.

Installing probe style meters

Probe style meters are more complicated to install than tube style meters which are usually just inserted in the pipeline. Most probe style meters currently being used on dairies are inserted through a threaded 2 inch nipple. A pre-formed saddle with the correct size opening is available for PVC installations. The glued saddle is typically supplemented with hose clamps. A similar saddle strap is available for metal pipe. Since one of the advantages of a probe style meter is that the sensor can be removed for cleaning or storage, some operators mount a meter that will be removed periodically using bayonet style quick connectors. Make alignment marks on the quick connectors to assure that the meter is pointing in the right direction when inserted into the pipe. The hole in the pipe can be closed with a ball valve, cap or both.



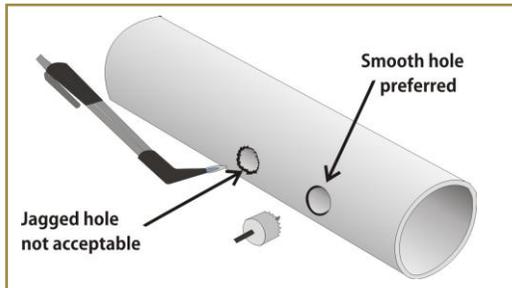
Pre-formed nipples for both PVC and metal pipe are available for mounting insertion meters.



Meter sensors should never be mounted at the top of the pipe where air bubbles can prevent continuous contact with the water. A probe style meter should



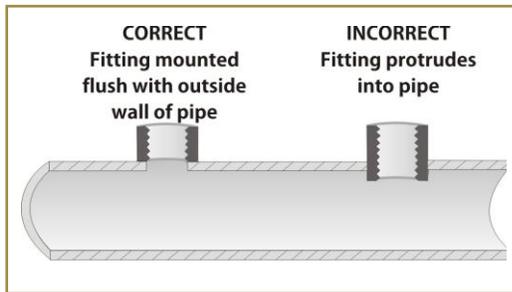
be positioned so that the sensor is perpendicular to the greatest flow distortion in the pipe velocity profile.



The hole in the pipeline through which the sensor shaft is inserted should be cut as close as possible to the diameter of the sensor shaft to prevent a gap between the sensor shaft and



Probe style may be mounted with quick connectors for easy installation and removal while maintaining an exact insertion depth into the pipe. The hole is capped while the sensor is removed for cleaning or secure storage



the edge of the hole in the pipe. Cut the hole with a hole saw to assure a smooth edge. Gaps, burrs and irregularities may trap stringy debris or create swirls and eddies which can affect the velocity reading of an electromagnetic meter especially if the sensor tip is very close to the wall of the pipe.

Additional instructions for installing probe style electromagnetic meters

Probe style electromagnetic meters have additional placement requirements that require that the sensor be inserted a precise distance into the pipe depending on the pipe diameter. Any deviation from this position, however small, will result in erroneous readings so it is critical that a mechanism be in place to assure that the sensor be inserted to the proper position in the pipe each time it is reinserted after being moved. This is because these meters measure the velocity of the liquid in an area about the size of a golf ball regardless of the diameter of the pipe. The speed of the water is greatly affected by the friction on the walls, so the water closest to the walls moves more slowly than the water at the center. The velocity reading from this location must be related to the velocity across the entire cross section of the pipe by a factor (k factor). Once a relationship between the sensor tip and the rest of the pipe has been established, it is critical that the sensor be inserted to the exact same depth each time it is reinserted after removal.

This sensor tip is usually placed near the wall to avoid blocking the flow and collecting debris. In a uniform flow profile, a velocity reading at 1/8 the diameter of the pipe represents the average velocity in the pipe and this is the recommended insertion depth for some meters. This is equivalent to 1¼ inches in a 10 inch pipe, and experience with sensors that protrude no more than this into the pipe have had minimal problems thus far in dairy situations.

The exact inside diameter of the pipeline must be known in order to properly calibrate an electromagnetic insertion meter. Because there may be small differences in pipe inside diameter (ID) even on the same size pipe, recording the exact pipe ID and wall thickness of the pipeline during construction will facilitate obtaining the best accuracy from the meter when it is installed.

If an electromagnetic insertion meter will be used in more than one location, it will be necessary to change the pipe diameter and possibly also the profile factor in the controller box electronics each time the meter is moved unless the pipeline diameters and insertion depths are identical. This requires some negotiation through the electronic menus in the controller box but is usually not difficult.

Maintaining an exact insertion depth is not as critical for a wetted Doppler insertion meter so long as the entire sensor tip is completely inside the pipe. The tip should not be put in too deep, however, to avoid obstructing the flow or accumulating debris.

Venting

Air vents are an essential component of the metering run. A continuous acting air vent is placed at the highest point in the run, usually just before the throttling valve. This vent prevents air from building up in the line and forming an air pocket which will prevent the pipe at the meter from being completely full.

Preventing air from displacing water in the pipe also assures optimal flow of fluid through the pipe.

A second air vent placed after the throttling valve is needed to prevent the the smaller volume of larger diameter pipeline, also keep water from siphoning back into the pond when the pump is shut off.

An air vent that is designed to introduce air into the line can cause considerable foaming at the pipe discharge. If this is an issue, the discharge may need to be completely enclosed or a mechanism installed to recapture the foamy overflow.

Air vents that are designed to release air can also spit out manure water onto operators and sensitive electronic equipment, resulting in unpleasant, muddy conditions around the metering run. It is best to install a shunt that will divert the manure water from the vent back to the pond. At a minimum, the vents should be positioned so that they point away from the operator and equipment.



Lagoon water can spray out of air vents resulting in unpleasant and possibly unsafe conditions. Consider installing a shunt to return to spray back to the pond



collapse of a pipe as gravity pulls water down into an equal or forming a vacuum. This vent will



Cables

It is always preferable to put the cable from the meter to the read-out box in a conduit; however there are many instances where exposed cable has been performing well for several years. Check with the manufacturer to confirm the resistance of the cable to exposure.

Some meters have cables that cannot be repaired, spliced or shortened without affecting the accuracy of the meter. On these meters, the cable and meter will likely need to be sent to the factory for recalibration of the sensor or replacement of the cable if the cable is damaged or is the wrong length.

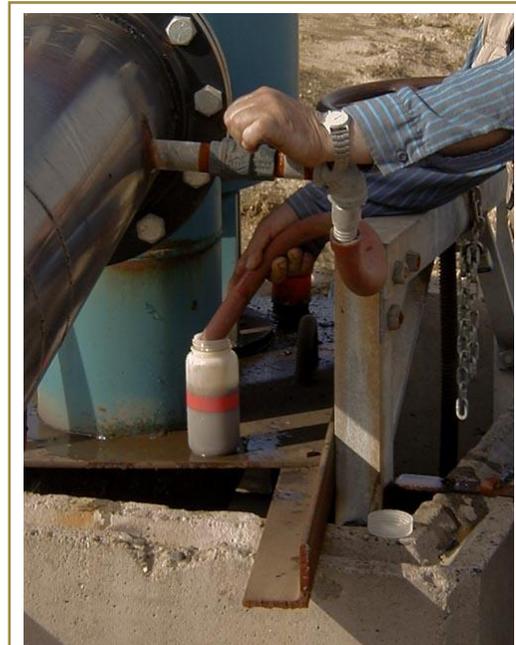
Sampling ports

Make provision for a convenient way to obtain a sample of the same lagoon water as is being measured by the flow meter and applied to the field.

The ideal sampling spigot has a place to set the sample bottle, and also a place nearby to place the cap. A short length of hose attached to a 1 inch ball valve makes it easy to fill the bottle without packing in a disproportionate amount of solids by overfilling the container. Because the liquid manure must be run long enough to clear the hose of existing material before filling the bottle, and because sampling protocols may require that the sample bottle be rinsed with the material that will be sampled prior to taking the sample, there needs to be a place for the liquid manure to drain back to the pond without making the sampling area muddy or eroding the bank of the lagoon. Mounting the sampling spigot on the pump discharge housing of a stand pump so that it drains back into the pump box has been a popular and effective location to place a sampling spigot. Floating pumps are more problematic, and a bucket or shunt to direct the excess lagoon water back to the pond may be the easiest solution. Consider installing a PVC pipe or channel to prevent erosion of the pond bank.

If there is not a convenient location to install a sampling port near the pump, it is sometimes possible for a sample to be taken from the pipe discharge.

Do not make the opening too small or it may become plugged with solids especially when pumping from the bottom of the lagoon. The sampling port should be installed on the side of the pipe and never on the bottom. A drain valve on the bottom of the pipe cannot double as a sampling port because it is prone to plugging from solids settling in the pipe. An accurate sample can only be obtained if the sample is



The ideal sampling port has a ball valve, a short length of hose, a way to return excess liquid manure to the pond or field, and a place to set the bottle and the lid.



Where it is not possible to install the sampling spigot or hose so that it points back into the pump box, consider installing a shunt to prevent making the ground muddy or eroding the pond bank.

captured in mid-stream after having run for long enough to clear out accumulated solids.

Electrical power

Often only 220 V power associated with the lagoon pump is readily available at locations where meters are installed. Some meters can utilize 220 volts, but most that need external power will need a source of 110 AC. Usually, a small portion of the 220 power is tapped into to supply 110 VAC for the meter. However, power surges and low power can, and frequently does, destroy flow meters. Meters that rely on 110 AC current should have power supplies that have over-current (typically fused) protection, ground fault protection (GFI), an uninterruptible power supply (UPS) and a cutoff to turn off the meter if the power supply drops below the operating minimum. Grounding is especially important with some tube style meters. Be sure to check installation requirements and install the specific type of grounding that is specified.

When setting up a 110 V AC plug for the meter, install a small light for irrigators to use when recording data or making adjustments to the meter at night.

Reliable solar powered meters and extended life battery powered meters are becoming available. These eliminate the need for installing a new power supply and avoid the problems with power surges and voltage drops associated with high voltage sources which serve large motors. Although newer models have a battery which can run for an extended period, a feature that shuts off the meter when voltage drops below the minimum will protect the meter from damage if this should occur. A solar powered meter should have a backup battery that will last long enough to continue operating and maintain stored data until a damaged solar panel can be discovered and repaired. These self-powered units provide great flexibility in the kinds of situations that can be economically metered.

Twelve volt meters are available but the models that have been tried so far have had too short a battery life to be practical for most purposes and were prone to failure due to low supply power voltage.



A small light will make reading the meter, adjusting flow rates and recording data much easier at night, especially if the meter readout is not backlit.

Heat Protection

Some flow meters have ratings that are limited to about 150°F. The interior of steel piping exposed to full sun and drained of water probably exceeds this temperature and has resulted in sensor failures. Meters installed in steel pipes should be shaded to protect sensors from direct sun. Pipes should be painted light colors to reflect solar radiation. Electromagnetic flow sensors should be turned off when not in use.



Sensors in steel pipe have failed by cracking due to overheating in unshaded drained black steel pipeline

Placement of Meter Readouts

Nearly all flow meters consist of two main sections, the meter itself and a controller box which interprets the signal received from the meter sensor(s) and displays the velocity or gpm on a readout. Most flow meters have the option of having the controller box separated from the meter itself via a cable. This is preferable in most cases because it allows the display to be



This shelter keeps sun off the meter and cables and also provides a protected place for the operator to record data.

close to the control valve, and because the controller box can be mounted in another enclosed box to protect it from sun, rain, dust etc. The controller box itself must be well sealed to prevent entry of moisture, pond gasses and dust. The enclosure for the controller should have some ventilation to avoid condensation.

Meter readouts that are in the sun can darken and become unreadable. Provide shade for the readout, or make certain that the readout is covered or replaceable. Also, some displays have no backlight. Even with a flashlight, these have proven hard to read at night. Consider installing a light in a shelter to facilitate reading the meter at night to adjust the flow rate.



Position the meter readout so that it can be easily read when operating the throttling valve. Steps make it easy to reach and turn the valve.

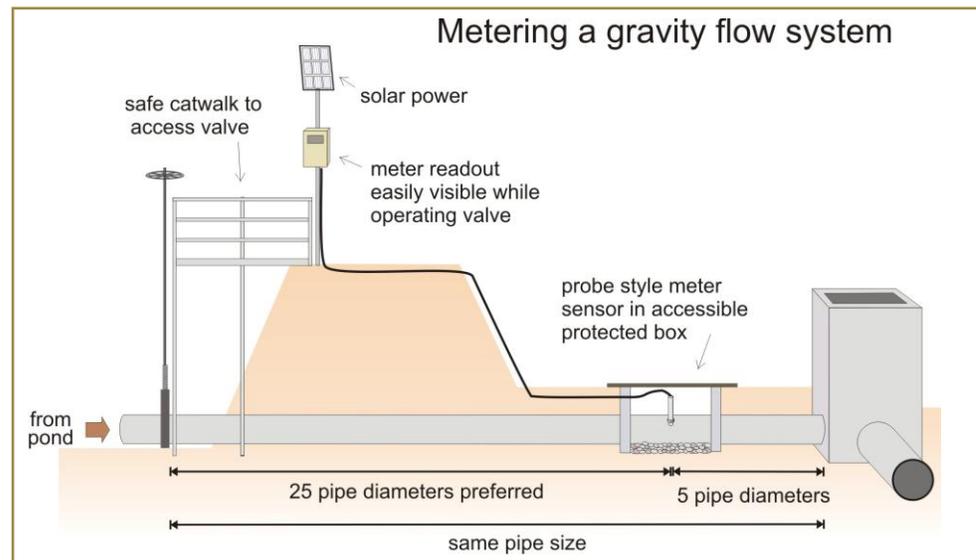
Installing meters in gravity systems

Flow meters can be successfully installed in gravity systems, however these are seldom as straightforward as installations on pressurized pipe. Often the pond must be empty or nearly so when accessing plumbing safely, especially if it is old, so the work needs to be done at a time when it is appropriate to apply the lagoon water to cropland and there will be a short time frame in which to complete the metering system installation. With old systems, consider using the opportunity to replace the existing valves and also install a secondary backup valve on each outlet to prevent a catastrophic lagoon discharge.

Underground pipelines from the bottom of the lagoon are usually large, making the probe style meter more economical than the tube style meter. In addition, a probe style meter is easier to install on existing underground pipelines and is easier to replace should the meter fail. Because the pipeline exiting the pond usually goes in a straight line from the outlet valve to the underground discharge to the buried pipeline, it may not be possible to obtain an ideal flow profile. A wetted Doppler insertion meter measures across the entire profile, rather than just the velocity at a single point on the edge of the pipe, so this type of meter may give a more accurate reading under less than ideal conditions than an

insertion style electromagnetic meter. Also, a technician may be able to identify if there are unexpected issues with the installation, such as a pipe that is not full.

A solar or battery powered meter will eliminate the need to bring in electrical power.



An accessible box should be constructed around the pipe to provide access and to protect the meter sensor. Never bury a flow meter without protection, even if the manufacturer states this is acceptable.

Mount the meter controller box where it can be easily read by the irrigator when operating the valve from the pond. If access to the pond valve is via a catwalk over the pond, make sure it is safe even in the dark.

A valve on the outlet of a gravity pond provides the capability to moderate the flow rate to more closely apply a desired amount. However, most existing valves in these systems are standard side gates which, when nearly closed, form a narrow, crescent shaped opening. This is easily plugged with solids, and there may be difficulty maintaining a constant output. Also, the velocity in the pipeline downstream of the valve may not be fast enough to prevent solids from settling and plugging the pipe. Determine the minimum flow rate that will provide protection from plugging the pipeline and instruct irrigators not to close the valve so that the gpm falls below that value.

Sampling a gravity lagoon

When considering a metering system for a gravity flow system, planning for a safe and representative sampling location is an essential part of the installation. If possible, the sample of the undiluted liquid manure should be taken from an irrigation control box prior to being mixed with the irrigation water. The sample should be taken from the middle of the stream to avoid floating debris. This can be done by securing a narrow-mouth collection bottle to a pole using a radiator hose-type clamp bolted to the bottom of a pole long enough to reach into the main part of the flow in the bottom of the box. Attach a line to a cork that fits into the mouth of the bottle. Lower the bottle until you can feel that it is in the main part of the flow, pull out the cork with the line, and allow the bottle to fill. Lift up the pole and bottle quickly and cap the bottle.

An alternative sampling location could be off the end of a catwalk, in the flow near the outlet pipe on the lagoon. A corked bottle on a pole or similar device would be an appropriate sampling device in this situation.

A secure place on the catwalk, and a lifeline, are minimal safety features. Consider additional safety measures for personnel who may need to take a sample or adjust a valve on a catwalk in the lagoon at night. Be sure to observe appropriate safety precautions when obtaining samples from an irrigation box.

