Flow Meters for Measuring Dairy Liquid Manure Applications

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What a Flow Meter Can Do for a Dairy Operator

While there are many ways of measuring the amount of irrigation or lagoon water applied, an accurate flow meter is by far the easiest and most versatile method.

An appropriate flow meter correctly installed will tell the amount of lagoon water that was applied on each field, greatly simplifying calculations and recordkeeping compared to other methods of estimating the volume applied. Along with an accurate sample of the lagoon water, this information is used to calculate the amount of nitrogen and other nutrients applied to crops. The meter will also tell the total amount of lagoon water discharged from the lagoon. Having this information is useful when making pond capacity decisions and also for developing farm nitrogen budgets.

A flow meter on dairy lagoon discharge not only simplifies recordkeeping but enables the operator to accurately apply a predetermined rate of nutrients when used along with a flow control device such as a throttling valve.

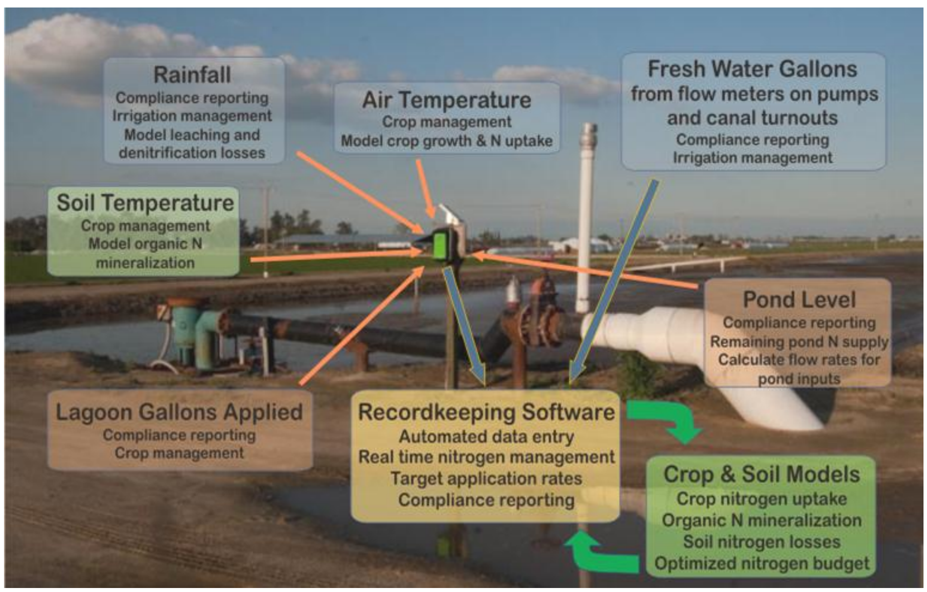
If lagoon nutrients are to be the primary fertilizer for crops, accurate application information is essential. Each of the other common methods of measuring the amount of lagoon water applied can result in large errors The flow rate (gallons per minute or gpm) over time method can be inaccurate for both pumped and gravity systems because the depth of water in the pond and the pumping distance will influence the pond discharge flow rate, and the lagoon pump output can be reduced by half when lagoon water is very thick. The pond drop method is rarely accurate because of many difficulties and is especially unreliable if other unmeasured pond outputs and inputs are occurring at the same time as the irrigation. Even methods that use a portable or temporary flow meter can be unreliable if the flow meter does not have a datalogger and too few readings are taken while measuring a fluctuating flow rate. Only an installed flow meter can provide a consistently accurate measurement of the amount of lagoon water that is being applied.

In addition to the benefit of supplying accurate application information when measuring what was applied, an installed flow meter provides the ability to confidently apply precise amounts of nutrients to a particular area when used in conjunction with a valve or other throttling device. Without this capability, meeting crop nitrogen needs and maintaining production while staying within regulatory nitrogen application limits becomes very difficult.

When a lower flow rate is desired, a flow meter will help the operator avoid plugging pipelines with solids or damaging pumps with too much backpressure. Irrigators can be instructed to not allow the pump to operate at a flow rate or pipeline fluid velocity that is less than the pump or pipeline can tolerate without issues.

Measuring more than flow

All flow meters will display both the flow rate (gallons per minute) and the total gallons (usually set to read in either 1000 gallons or 100 gallons) that have passed through the meter. To determine how many gallons have gone to each field, the reading from the totalized gallon readout must be recorded at the beginning and end of each irrigation for each field. This usually involves an irrigator returning to the meter location to write down a long string of numbers each time the water is moved from one field to another. Many operators report that these numbers are often wrong or illegible, and the data for each field may not be accurate if the reading was not recorded at the same time as the change was made. Both of these issues can be eliminated by ordering a meter with a data logger that records the totalizer value at set intervals, usually every minute, along with the date and time. The irrigator then only needs to record the time that the change was made and the totalizer reading for that time can be looked up on the datalogger trace. The data can also be automatically accessed by recordkeeping software that minimizes tedious and error-prone manual data entry for long strings of numbers.



The amount of lagoon water applied is only one type of information that is useful for managing nutrients. Some flow meter controllers will also log data from other types of sensors. Software is being developed that will automatically upload and use this information to support real-time nutrient management decisions.

Meters can be configured to have data from the meter transmitted to the farm office in real time so that applications can be remotely monitored. In addition to accommodating more than one flow meter, some meter controllers can support data logging and transmission for a variety of other types of sensors such as lagoon water level, soil temperature and weather data. Software is currently being developed by UC that can use this information to model crop nitrogen uptake in comparison to the amount of soil nitrogen projected to be available to the crop in addition to automated tracking and recording of nutrient applications. In the future more data collection will probably become automated. When choosing a flow meter, consider all the ways that the flow meter information will be used and select a meter that has the capabilities that may be needed in the future, such as the ability to accept other types of sensors in addition to the flow sensor. Because technology is constantly improving, upgrading or replacing metering equipment should be a planned expense over the long term.

Do You Need More Than One Meter?

In many situations, more than one meter will be necessary in order to accurately measure and manage nutrients on a dairy. More than one meter is needed if:

- There is more than one pond or more than one outlet on the same pond.
- More than one field is being irrigated with lagoon water at a the same time.


In this installation, separate metering runs allow lagoon water to be accurately applied on three locations simultaneously. A kiosk provides a lit, sheltered location to post target flow rates and record data.

If multiple ponds or multiple outlets from the same pond are used for irrigation, a separate meter will be needed for each one. Depending on the meter and location of the outlets, it may be possible to have several sensors share the same controller box. It may also be possible to select a meter that can be moved to cut down on the number of meters that must be installed. This solution may be best for sources that are rarely utilized since most operators find that moving meters, although not difficult, is inconvenient if done often. If the same meter is used in more than one location, having identical inside pipeline diameters and meter mount dimensions for each site will make moving the meter much easier.

When lagoon nutrients are applied to more than one field at the same time, a single meter installed on the lagoon water source flow will tell how much was applied to all of the fields, but rarely will it be possible to say with certainty how much of the diluted lagoon water was portioned out to each field. Even if a reasonably accurate estimate of the application rates can be made, without the capacity to meter and throttle each field separately, it will be difficult to apply targeted amounts to an individual field. Ideally, a separate flow meter should be installed on each of the streams and provision should be made to throttle each of the streams separately. The number of flow meters needed can be minimized by grouping fields that will not usually be irrigated simultaneously so that they share the same lagoon water transfer line and meter.

Considerations for Choosing a Flow Meter

There are many methods of measuring flow of fluids and many types of flow meters. Most are inappropriate for use in lagoon water because of concerns of plugging or fouling due to particles, sludge or stringy debris. Scum build-up or mineral deposits may coat sensors or other measuring apparatus and degrade their function. Others may restrict flow, resulting in an unacceptably large drop in water pressure. Many methods are impractical because there is no way to install them in most common lagoon water system designs and many others are too fragile or too expensive to be used on a dairy.

When selecting a flow meter consider accuracy and suitability for your situation. Only a very few of the many styles of flow meters can be adapted for measuring lagoon water. These vary in price, accuracy, susceptibility to fouling, placement requirements, portability, ease of installation, ease of cleaning and maintenance, and ease of use. Flow meters have long been used in municipal wastewater systems and other industrial applications, but their use with dairy lagoon water poses unique challenges such as power supply fluctuations or extreme temperatures in drained pipelines on exposed pond banks. Most meters designed for other situations have initially failed when used on a dairy. Some of these have been re-engineered and now perform satisfactorily.

Meters have failed in dairy situations for the following reasons:

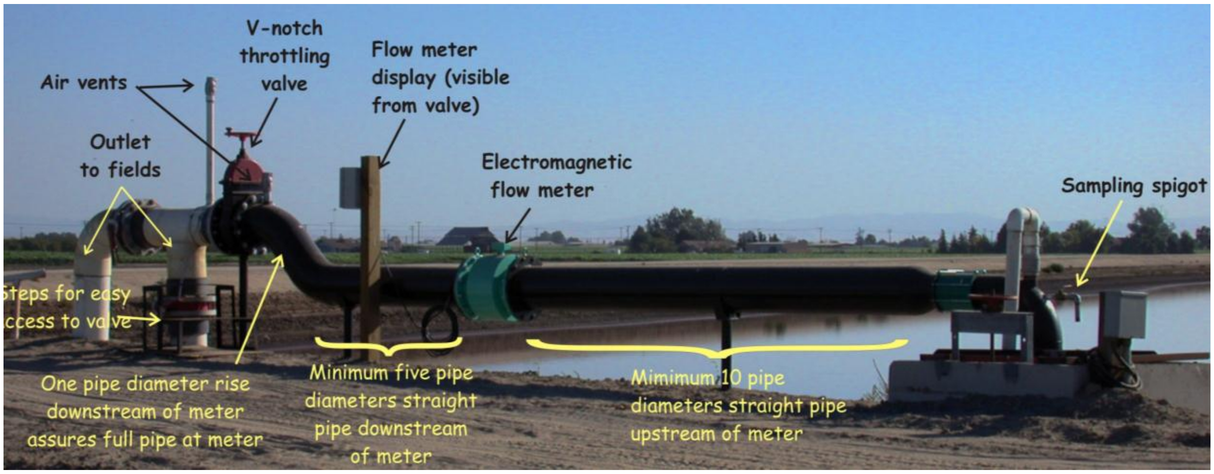
- Voltage spikes damaging sensitive electronics
- Low voltage damage to power supply
- High temperatures inside drained pipes causing sensors to crack
- Sensors with prongs that collect debris
- Seals leaking due to corrosion or high temperature on the inside of the pipe, allowing liquid to come into contact with electrical components
- Failure of electronic parts not rated for high temperatures
- Controller boxes not weather tight
- Unable to find a suitable location

Be certain that the meter you choose has a history of successful use in an application similar to yours and that it

- Has a good warranty
- Is from a well-established company willing and able to make changes to the meter design if necessary
- Has a local and responsive customer service representative.

Most flow meters consist of two main sections, the meter itself and a controller box. The box contains the electronics that interpret the signal received from the meter sensor(s) and calculate the flow velocity, which is then displayed as flow rate expressed as gallons per minute. Some flow meters have the option of having the controller box separated from the meter itself via a cable. This is usually preferable because it allows the display to be mounted where it can be easily read when operating the throttling valve. Also, a separate controller box can be mounted inside a weatherproof box or kiosk to protect it and the operator from sun, rain, dust etc. Make certain that the meter controller box itself is well sealed against moisture and insects. If the sealed controller box is mounted inside a weatherproof box, allow for some ventilation to avoid condensation. Some readout displays do not have a backlight and are difficult to read at night even with a flashlight. A controller box mounted in a kiosk with a light is one solution but most operators prefer to select a meter that comes with a backlight.

Some meters use cables that cannot be repaired or shortened without affecting the calibration of the meter, others are more forgiving. For the first mentioned type, the proper cable length will need to be determined before the meter is ordered.
For a flow meter to give accurate readings, it must be properly installed. Any pressurized pipe flow



A constructed metering run provides conditions that result in optimum performance of any type of meter.

meter must have a full pipe in order to read accurately. To accomplish this, situate the flow meter at a point where the pipe will always be full. The only way to ensure that the pipe is full is for the pipeline downstream of the meter to be at least one pipe diameter higher than the level of the meter. Sometimes a suitable section of vertical pipe already exists but often a metering run needs to be constructed. It is also important to situate the flow meter in a straight length of pipe. A rule of thumb is that the meter be located no less than 3 - 5 pipe diameters upstream and 8 - 10 diameters downstream of a bend or change in the pipe size. Additionally, the flow meter should usually be placed ahead of, not after, a valve. Valves will distort a flow pattern for as many as 25 pipe diameters downstream of the valve. Some types of meters require less than these distances while other types of flow meters have additional placement requirements; always consult the manufacturer's manual. Determine the location where the flow meter will be placed and be sure that it will provide suitable conditions for the type of flow meter you select. For more information on meter installation requirements, see "Installing Flow Meters".

What are pipe diameters?
A pipe diameter is the inside diameter (ID) of a pipe. If a pipe ID is 8 inches, 10 pipe diameters would be 80 inches (10 x 8 inches)

When choosing a meter for a particular location, keep in mind that the meter by itself will only provide information on the amount of liquid that passed by the meter. In order to determine the amount of nutrients applied, you must also know the concentration of those constituents in the liquid, so the ability to obtain and analyze a representative sample of the same material that the meter sees needs to be considered. Lagoon water should be measured and sampled before dilution with fresh irrigation water if at all possible, and California regulations require reporting of the undiluted liquid manure lab analysis data. A sampling spigot should be installed in the pipeline to facilitate collection of a representative sample of lagoon water. Sampling the undiluted flow also allows for easy adjustment of the nutrient application rate if this information is used in conjunction with a flow meter and throttling valve or variable frequency drive (VFD) on the lagoon pump. To apply a specific amount of lagoon water nitrogen, a target gpm is calculated based on the nitrogen concentration in the lagoon water, and the estimated amount of time it will take to irrigate a given acreage. The valve or VFD is adjusted until the flow meter reads the target gpm.

Overview of Meter Types

The main flow meter technologies used to measure liquids on dairies are

Electromagnetic (Magmeters)
Ultrasonic (Doppler)
Mechanical (Propeller meters)

Each of these meter technologies are available as either

full bore (also called tube or spool) type, or
insertion (or probe) style sensor housings.

The sensor housing style impacts how each meter technology functions so that the same meter technology that works well for a particular application in a tube style may not perform as well in an insertion style and vice versa. Both the meter type and sensor housing style must be considered when choosing a meter for a particular application. In general, both tube style and insertion meters provide sufficient accuracy – within 5% - for dairy applications when properly installed.


This photo shows an electromagnetic meter that replaces a section of pipe. The terms "spool type," " tube style" and "full bore" are used interchangeably for this type of meter.

Tube style meters, also called spool type or full bore meters, replace a section of pipe and are sized to a match the pipe diameter. The price of full bore meters goes up dramatically as the pipe size increases, and may be uneconomical for pipes over 12 inches in diameter.

The most common type of full bore meters are flanged spool types that bolt into flanges on the pipe. Another type is a straight tube without flanges which uses compression fittings to squeeze the meter between flanges on the pipeline with long bolts. A third type, a wafer-style spool magmeter, slips between existing flanges and does not require cutting out a section of pipe. Spool-type meters are not portable, but they are always "ready to go" and therefore more likely to be used regularly than a meter that requires insertion each time it is used.


This probe style meter sensor is screwed into a threaded nipple mounted on a PVC saddle. The rise in the pipe beyond the meter assures that the pipe is full.

Tube style meters usually require no calibration or other adjustments, and can be often be installed with little difficulty by users with only minimal technical expertise. A major disadvantage is that they are not easily moved and most must be removed entirely from the pipeline if they require inspection or cleaning. If the meter is heavy, repairs may need to be done in place. If the meter must be removed for repair, the pipeline cannot be used until the meter is reinstalled or a new section of pipe is fabricated. If a meter needs to be replaced, the new meter may not be the same length as the old meter and the pipeline may need modification. If the old broken meter is left in place to keep the pipeline intact, it may prevent placing the new meter in the best location on the metering run.


This insertion style meter has quick couplers for the power supply and cam locks on the sensor probe so that it is easily packed up and stored in the office to protect from damage and theft. The meter box hangs on the bracket on the pole when it is in use and the power supply is connected to the yellow coupler.

Insertion style flow meters have a sensor at the end of a rod or tube mounted in a housing that is screwed into a (usually) two inch threaded nipple in the pipe wall. The sensors themselves are mounted in a cylindrical, slanted, or bullet shaped tip that protrudes a short ways into the pipe. They can easily be removed from the pipe for secure storage when not in use. They can also be used on a variety of pipe diameters, in multiple locations, or with very large pipe sizes.

When the probe is removed from the pipe, either a simple cap or a shutoff valve is used to close the hole. A ball valve is less prone to plugging than a gate valve. If desired, a quick coupler can be installed to make it even easier to clean the meter or move it from site to site. Using quick couplers, it takes only a few minutes to move and reprogram a meter. Many users, however, prefer to leave the meter in place throughout the irrigation season. If there is potential for theft, look for a meter that can accept a lock.

Because insertion meters are portable, they can be used in situations where there is more than one pond or on lagoons with multiple outlets, assuming only one field is being irrigated at a time. It is also useful for temporary installations to get an idea of how a system is performing. There is a big difference between manufacturers in how easy it is to initially calibrate the meter for each location, ranging from a few seconds to hours. Once the calibration for each site is established, it is not difficult to reprogram the meter from one site to another, although some are easier than others.


Clamp on Doppler meters do not require cutting into the pipe making them ideal for temporary installations. Their stringent placement requirements limit their use on dairies.

Because the meter sensor can be easily taken in and out of the pipe, this style is easily cleaned, which is advantageous for situations where buildup of deposits or solids is expected. The price of this style of meter is the same for most sizes of pipe, making this the most cost-effective style for pipes over 12 inches in diameter.

When selecting a meter, consider if there is the possibility that phased installation of infrastructure such as pipelines and pumps will take place. Proper pipeline size is largely determined by pond concentration and irrigation run times. Until this information is developed, or if either of these factors change, or may change, a probe style flow meter that can be installed in a variety of pipe sizes may be a more appropriate choice than a tube style meter that fits only one size pipe.

Clamp on meters are available for either temporary or permanent installations. These avoid having to modify pipelines. However, the placement requirements are stringent and they cannot be used on some types of pipe.

Spool Type Electromagnetic Flow Meters (Magmeters)

Electromagnetic flow meters operate on a principle based on Faradays law of electromagnetic induction. The meter generates an electromagnetic field in the pipeline and measures the amount of voltage created by charged particles in the water as they move through the magnetic field. The faster the velocity of the water, the greater the voltage generated. All electromagnetic meters have at least two electrodes in direct contact with the water that pick up the electromagnetic signal. The sensor picks up the generated voltage, amplifies it and calculates the velocity of the water based on the signal strength.

Most conventional spool (or tube or full bore) type magmeters generate a magnetic curtain that extends over the entire cross section of the pipe. Sensors on opposite sides of the inside of the spool pick up the voltage generated across the whole inside diameter of the pipe, making them very accurate. Other types of spool-type magmeters work on the same principle but rather than generating one large magnetic field, multiple smaller fields are generated and the velocity is measured in several different places around the perimeter of the pipe. Accuracy is increased according to how many areas are measured.

Most meters automatically convert this velocity measurement to display flow, however there are some specialty meters which display only the velocity and the conversion to flow must be made manually.

Electromagnetic meters rely on charged particles in the water to carry a signal. Variations in the conductivity of the irrigation water do not affect performance. As long as the conductivity of the liquid is at least 5 μs/cm the meter will operate to specifications. Accuracy of electromagnetic meters may decline somewhat when suspended solids are over 12-15% because the signal strength becomes weak. This will rarely be an issue except when pumping very thick sludge. If it is known that the lagoon water will frequently be thick, ensure that the signal strength and power supply to support it will be adequate.


All electromagnetic meters have sensors that must be in contact with the fluid.

All spool type magmeters have sensors in the interior of the pipe. If these become coated with deposits or scum, the ability of the magmeter to pick up the voltage signal may be hindered. Some magmeters have a way to check signal strength if this is a concern. Some electromagnetic flow meters claim to have self-cleaning electrodes that "burn off" deposits with concentrated electrical discharges.

Spool type electromagnetic flow meters require a minimum velocity of water in order to read accurately, usually over 0.3 ft/sec. Most dairy operations generate velocities far greater than this (for example, 0.3 ft/sec is 100 gpm in a 12 inch pipe) so only rarely would it be necessary to use a smaller pipe diameter to increase the velocity for the sake of the meter. Decreasing the diameter of the pipe may be desirable, however to reduce the expense of installing a larger size meter since spool-type magmeters increase dramatically in price as the diameter of the pipe increases. In general, spool type meters are rarely used for on pipelines larger than 12 inches. Small diameter meters may be priced reasonably enough to justify installing more than one meter in situations where multiple meters are advantageous.

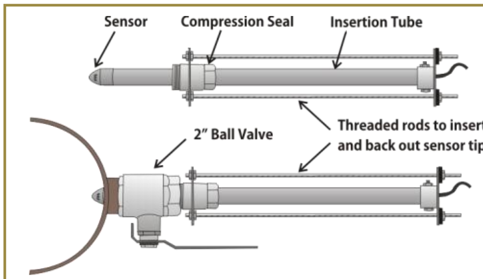
A spool type magmeter requires excellent grounding for best accuracy and special grounding techniques are sometimes needed. Check the installation manual for any specific requirements.

A tube style magmeter, properly installed, is one of the most accurate of the flow meters available for lagoon water because there is no potential for errors in measuring the inside diameter of the pipe or the depth of insertion of the sensor, and most of them measure all or much of the entire cross section of pipe.

Insertion Style Electromagnetic Meters

Electromagnetic insertion meter with an integrated readout.

An insertion style magmeter measures velocity using the same electromagnetic principle as tube style magmeters, but the magnetic field extends only a few inches from a single point near the wall of the pipe. The velocity measured at the wall is then related to the velocity across the entire pipe cross section with a ratio factor. They are very sensitive to insertion depth, because small differences in the depth they are inserted will affect the relationship between the slower moving fluid near the wall to the average velocity in the pipeline cross section. Some must also point exactly the right direction in relation to the flow direction. If the sensor is to be taken in and out of the pipeline, a mechanism is needed for replacing it in exactly the same position to which it is calibrated.



This sensor is mounted on threaded rods that allow precise positioning of the tip inside the pipe. With the 2" ball valve in place, the rods are long enough to allow the meter to be removed from a pressurized pipeline without shutting off the pump. The longer rods aren't needed in a dairy situation and sensors are usually mounted in a more compact housing that is less prone to cause or receive damage.

Because electromagnetic insertion meters measure the velocity of the water at a single point in the pipe and then adjust this value to reflect the assumed velocity in the whole cross section of the pipe, it is especially important that these meters be properly positioned in a long straight stretch of pipe, well away from flow disturbances such as elbows or valves, to ensure a uniform velocity profile within the pipe.

A robust signal strength is also important for an insertion meter especially when thicker streams are being measured. Probes should have a smooth, preferably debris-shedding tip design. Probes with protruding spike-style electrodes have fouled quickly. Another issue is temperature resistance of the probes. Polycarbonate sensors left in drained pipes in the sun have split open after one or two seasons of use.

Wetted Doppler Insertion Meters

A wetted Doppler is another type of insertion meter but unlike the electromagnetic insertion meters, it measures the velocity of the fluid across the entire cross section of the pipe and also up- and down-stream for a short distance. This feature makes placement requirements less exacting than electromagnetic insertion meters, and allows for placement in pipes from 4 to 100 inches in diameter.

Like a conventional externally mounted Doppler meter, a wetted Doppler measures velocity by transmitting a sound that is bounced off of particles or bubbles suspended in the water and picked up by a receiver. The wavelength of the reflected sound is altered depending on how fast the particles in the water are moving and the velocity of the fluid is calculated by comparing the original sound with the reflected sound. Because the wetted insertion Doppler transmitter and receiving sensors are inside the pipe in direct contact with the fluid, it is not as sensitive to interference from other sources of sound compared to conventional Doppler meters that clamp to the outside of the pipe. Unlike a probe-style electromagnetic meter which measures the velocity in a small area, a wetted Doppler measures the sound reflected back from all particles throughout the entire cross section of the pipe and also up or downstream a short ways. During a fixed period of time there will be more particles passing through the faster areas of the pipe than through the slower regions and the reflected signal received is a composite of the fast moving particles towards the center of the pipe and the slower moving ones nearer the walls, in correct proportions to the velocity of the water. A wetted Doppler insertion meter requires much less straight pipe for accurate measurement than does an electromagnetic insertion meter. The probe style sensor can be used in pipelines from 4 to 100 inches in diameter although a flush mount sensor that can be attached to the inside wall of the pipe is more commonly used on accessible pipelines over 30 inches across.


Wetted insertion Doppler meter sensor

Another advantage of these meters is that they have the capability of providing some indication to an experienced technician if there is a problem that would prevent an accurate reading. Pockets of trapped air, silt on the bottom, or debris in the pipe will show up as an irregularity on the meter output when accessed by the computer software. This feature is especially useful in situations such as underground pipelines for gravity discharge from lagoons where it is not possible to confirm that the pipe is completely full before the meter is installed. When the pipe is not full, accurate flow measurement is still possible by recording the depth of water using a depth sensor along with the velocity.

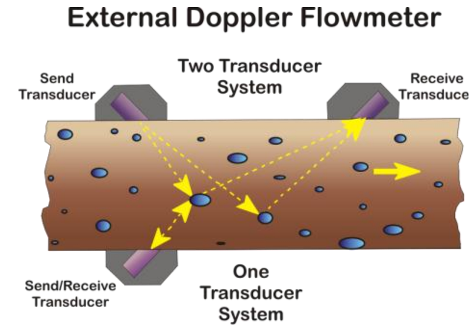
Most wetted Doppler insertion meters currently being installed are solar powered units with data logging capabilities that accommodate not only the flow meter but also several additional meters or other types of sensors, such as temperature or pond level using the same controller box. This type of meter can be used not only for lagoon flows in pipes but also to measure open channel flows such as freshwater applications or tailwater runoff.

Doppler meters cannot be used in situations where there are no particles or bubbles in the water. This is generally not a limitation on dairies but may be an issue for some clean water applications.

External Mount Doppler Meters

A traditional external Doppler is another style of meter that is sometimes used to measure dairy lagoon water. It works on the same principle as the wetted Doppler only this type is clamped onto the outside of the pipe and does not require that the pipeline be cut or modified. The placement requirements are especially stringent and this kind of meter can give false readings under many common dairy conditions. It is recommended that an external Doppler meter reading be confirmed using another type of meter.

External Doppler meters have the advantage of not requiring any modifications to the irrigation system in order to obtain a reading. Some are easily portable, with an internal rechargeable battery and may also have the capacity to store flow data. Doppler meters that are not portable can be less expensive.



Doppler meters measure velocity by generating a sound and measuring how much the sound waves have been altered after it is reflected back from particles or bubbles moving with the water.

Like other meters, external Doppler meters are most accurate when there are at least 5 to 10 pipe diameters of straight pipe upstream and 5 downstream of the meter. However, sonic, mechanical and electrical noise can interfere with the signal and meters vary in their ability to compensate for these types of interferences. Mounting too close to a pump or throttling valve will result in the Doppler signal traveling to the pump or valve and getting echoes back from high velocity or cavitation. External Doppler meter sensors, in addition to having an adequate length of straight pipe, must also be more than 30 pipe diameters from a pump, partially closed valve or open discharge. Because of the stringent requirements, it may be difficult to find an appropriate length of exposed pipe in which to install a Doppler meter.


External Doppler meters do not require alterations to the pipe but must be positioned far from other sources of sound, such as pumps or elbows.

If the inside of the pipeline becomes coated with an insulating scum or mineral deposit, it can interfere with the ability of the meter to pick up the reflected sound causing an erroneously low reading due to poor signal strength. flow rates can also be underestimated when there are too many particles in the water (>10% solids) because more of the signal is reflected back from the slower moving outer water rather than the faster moving water at the interior of the pipe. Doppler meters will not work on concrete or asbestos pipe, or on pipe with certain types of liners.

Experience using external Doppler meters to measure lagoon water flow has been inconsistent. They have performed very well in many circumstances. In one trial, where the flow meters were installed on a metal pipe that was separated from a floating pump by a flexible pipe, an external Doppler meter gave readings similar to other types of flow meters. In another trial where an external Doppler was attached to a metal pipeline coming directly from a large pump, readings were inaccurate likely due to too much noise and vibration from the pump as it was being throttled down. In a third trial, where an external Doppler was on a metal pipe in a situation similar to the previous trial, it tracked well with an insertion-style magmeter until about 1700 gpm in a 10.25 inch diameter pipe, above which it no longer continued to track the increased flow rate.

Propeller Meters

Propeller meters are the most common and least expensive kind of flow meter used in agriculture. They consist of a propeller inserted into the pipe that spins on bearings. The speed of the spinning is relative to the speed of the water in the pipeline. Flow is determined by the speed of the water and the cross sectional area of the pipe. In clean water, propeller meters can be quite accurate especially if the


Propeller Meter

impellor blade spans a relatively large cross section of the pipe. Propeller meters are most accurate if they are installed in a straight section of pipe. Probe style propeller meters have similar placement requirements as electromagnetic insertion meters since they also measure velocity at one location in the pipe.

Since they are mechanical, propeller meters do not usually need a power supply.

Propeller meters are best suited for clean water applications only and are NOT recommended for use in waters containing manure. They are very susceptible to fouling and also cannot be used in situations where there is any chance of weeds, straw, plastic, twine, etc. entering the meter. If the meter fouls, the entire pipeline can clog and the meter may be damaged. Even if the shaft does not clog or stop, cow hair and or other fine particles can get caught between the shaft and the bearings and keep the shaft from spinning freely. This can give erroneous readings that may be difficult to detect. Sand in the water is also very hard on this type of meter. Propeller meters have had a history of failure in dairy wastewater applications but work well for most pumped freshwater situation.


Inexpensive propeller meters are well suited for measuring pumped groundwater or clean district water but can easily foul if debris is present.

Power Supply

Many flow meters require 120 v AC power. Since flow meters are often located near electric pumps, it is common to split off a small amount of power from the pump power supply to accommodate the meter and perhaps a low wattage light bulb. There is some risk with this arrangement because the high voltage lines have had problems with fluctuating voltages which can damage the meters.

Battery operated meters are now available with a battery life of at least two years, much longer thatn previous batteries.

Operators who have used 12 v DC meters running off a 12 volt deep cycle battery have found it cumbersome to keep the battery charged and even a fully charged battery was insufficient to keep the meter operational for an entire irrigation event. If converting 120 volt AC to 12 volt DC for a meter that only runs off of DC power, a high quality industrial grade constant voltage power supply must be used since they are very


A good quality solar powered meter can eliminate most of the difficulties frequently encountered with 120V or battery operated models.

sensitive to voltage irregularities.

Solar powered units have the advantage of not needing to run a separate power supply, and are not subject to damage from voltage irregularities from lines shared by heavy equipment. Check that the solar powered unit you are considering has a good track record, since there have been both excellent and poor results with solar powered meters in dairy situations.

Coatings and Deposits

Most types of meters have sensors that are in contact with the liquid in the pipeline. These sensors can become covered with scum or deposits and meters vary in their ability to obtain an accurate reading when these coatings or deposits are present. If it is known that a pipeline is subject to these deposits, be sure that the meter selected has sufficient signal strength to read accurately despite the coating, or choose a meter that is easy to take out and clean. All sensors can be cleaned with soap and water and fine steel wool can be used on some sensors if necessary. Always check with the manufacturer if in doubt.

Coatings of scum from dried lagoon solids may interfere with the readings until they scour off.

There is concern that a coating of scum may give erroneous values or no reading, especially in situations where the pipeline is drained and allowed to dry after an irrigation with lagoon water containing heavy solids. There is some indication that electrodes protruding into the pipe will be scoured clean when the pump is turned back on. If this is the case, then the meter will need to be run for some time before the readings can be trusted.

Flushing the meter with clean water after pumping high solids material would prevent scum deposition but this may be impractical unless special provision is made to accommodate this. Another option may be to locate the meter in a low portion of the pipeline that always is full of water so the solids do not have an opportunity to dry on the sensor.

Some lagoon water systems are subject to deposits of either hard water precipitated salts or a crystalline magnesium ammonium phosphate compound called struvite. This material tends to form in systems that have high concentrations of magnesium, phosphorus and ammonium coupled with high pH water. Deposits of struvite can become so thick that they reduce the diameter of the pipeline. Reduced pipe diameters will affect the flow calculations for all types of meters and therefore impair accuracy. If the electrode becomes coated on spool-type magmeters additional inaccuracies occur. Depending on the thickness of the coating, the accuracy of external Doppler meters will degrade because of poor signal penetration. An insertion style meter or spool type with removable sensors that can be easily taken out and cleaned would be an alternative in this situation. If a non-removable spool style flow meter is installed and acid or other materials are used to clean the pipeline, be certain that the flow meter liner and electrodes will tolerate whatever method of cleaning is used.

A crystalline deposit called struvite can form thick coatings on the inside of some lagoon pipelines. These will interfere with sensors that cannot be easily cleaned, and may be thick enough to change the diameter of the pipeline.

Some manure pipelines have deposits that build up so much that the diameter of the pipeline is reduced. In addition to making sure that the sensor is clean, it will also be necessary to change the factor in the meter controller so that the volume applied is not overestimated.

Meters for Large Pipelines, Non-Pressurized Pipelines and Open Ditches

In most cases, installing a flow meter in a pressurized lagoon water pipe is the simplest way to measure the amount of lagoon water applied. However, sometimes it is necessary to measure the blended fresh and lagoon water in open ditches or in large concrete pipelines which may or may not run full.. Electromagnetic or wetted Doppler meters are available which are designed to work in these situations.


Insertion meter sensors can be mounted into large pipes through the pipe wall, using a tight fitting band, or bolted directly onto the interior wall. *Photo: Mace USA LLC*

Wetted Doppler, and certain types of electromagnetic smeters can be used for large pipelines. Usually a streamlined sensor is mounted to the inside of the pipe using a close-fitting expandable band or, on larger pipes, a mounting plate affixed to inside of the pipe wall. The sensor cable is threaded out through a vent or other opening to the meter controller box. If the pipeline runs full enough, the preferred location for the sensor is at approximately the 2 o'clock position. This avoids trapped air at the top of the pipe and debris and silt at the bottom. Like pressurized pipes, a straight run is especially essential for an electromagnetic meter which only measures velocity of the water in a small radius immediately surrounding the sensor. A wetted Doppler meter can evaluate the velocity in the entire cross section of pipes up to 100 inches in diameter.

If the pipeline does not run full, both the velocity of the water and the level of fluid in the pipe will need to be simultaneously measured.

The water level in the pipe is measured using either a pressure sensitive sensor on the same housing as the velocity sensor or a separate ultrasonic device that is mounted at the top of the pipe and measures the distance between it and the water below without coming in contact with the water.


Solar or battery powered datalogging meters that measure both velocity and depth of water make measuring open channel flows a relatively simple operation even in remote locations. *Photo: Mace USA LLC*

The same methods work for measuring flows in open channels. Both the velocity and level are measured in an area of the channel with a known cross section. For non-uniform channels such as earthen ditches, inserting a weir, flume or short section of pipe can provide an accurate cross section in which to position the sensor. Battery or solar powered units that log both level and velocity make it possible to obtain accurate information on the amount of water applied to or running off most any field.

Be certain that the meter chosen to use in these situations is supported by software that will easily allow you to make adjustments for the changing cross sectional area of the pipe or channel to account for silt on the bottom of the pipe and air space on the top.

If the ultimate goal of the measurement is to determine the amount of nutrients or salts applied to or running off a field, a sample of the same water that is measured by the meter will also be necessary. For liquid manure, regulatory requirements dictate that an undiluted sample be submitted. If the material in the pipeline measured consists of blended fresh and lagoon water, the undiluted lagoon water sample results cannot be used to determine nutrient application rates to fields unless an accurate flow rate for the fresh water can be obtained at the same time. In this case, the freshwater flow rate is subtracted from the blended water flow rate to determine the flow rate of the lagoon water alone. If the fresh water flow rate is not known, a sample of the blended water must be taken in addition to the undiluted lagoon water sample in order to calculate nutrients applied.

Portable Meters for Open Ditches and Pipelines

Stand pipes, vents, some types of valves or other pipeline flow access points are opportunities for flow measurement in irrigation pipelines using a hand-held meter, as are open ditches and canals.

Hand held flow meters are used to spot check flow at one point in time in a non-pressurized open pipeline system. These meters have the advantage of being completely portable, and do not generally require system alterations. They are sometimes used by consultants and researchers when other methods of flow measurements are not possible. In some circumstances, they can also be used to estimate the output of a lagoon water pump.

The hand held meter is usually on a pole which is inserted down a standpipe or vent into the flow of an underground pipeline. Once pipeline dimensions have been established, it generally takes less than 15 minutes to determine flow. How often measurements need to be made depends on the amount of fluctuation in flow rate and the accuracy desired. This type of meter reads out in velocity only (feet per second) and the user will need to calculate flow (gallons per minute or cubic feet per second) from the velocity readings and the cross sectional area of the pipeline or canal. The velocity of the water will vary across the pipe, so readings need to be taken along the entire cross section of the pipe, guided by ruler marks on the pole, if using a sensor that reads the velocity of the water in a small area. The flow rate in gpm or cfs is calculated from the weighted average of the velocity readings.

A hand held meter mounted on a rod works well for measuring flow velocity at a single point in time. The velocity should be measured at several points across the transect of the pipe if using an electromagnetic or propeller meter.

Selection of an appropriate vent or standpipe is critical to the accuracy of the measurement. The section of pipeline to be measured must have uniform flow. To simplify calculations, the pipeline should be flowing full with no accumulation of sediment on the bottom. It should not be immediately downstream of a box, near a change in pipe direction or pipe diameter, or subject to other conditions which could make the water too turbulent for accurate velocity readings. Chunks of concrete and other debris in the pipeline will also interfere with accuracy. A clean, uniform, straight stretch of pipeline without turbulence will produce the most accurate results. If there is no standpipe or vent access to underground pipelines, this type of meter cannot be used.

Hand held electromagnetic velocity meters have performed well for this purpose except where stringy debris rapidly catches on and covers the sensor. Hand held propeller type meters are available but are only suitable for use in very clean freshwater. Some operators have adapted a wetted Doppler insertion meter to use as a portable meter. Since this technology reads the velocity across the entire pipe, it eliminates the need for taking multiple readings to establish the velocity profile. When using this type of meter, there is the possibility that the zero velocity of the still water column in the vent above the main flow will be included in the reading unless the sensor can be inserted some distance into the pipeline ahead of the vent. The preferred method for using a wetted Doppler insertion meter as a portable meter would be to install an access port with quick couplers on each pipeline that is to be measured.