

Liquid Flowmeters – A Guide for Selecting a Flowmeter for Pressurized Systems

Selecting a meter requires a first-rate technical assessment of the pressurized system and a thorough evaluation of the capabilities and needs of the operator. Technical knowledge required for metering ranges from very basic ability to read a meter and write down the rates of diversion and total use to a high level of technical ability for automated systems that enable a user to operate/control a system from almost any location (see discussion on Supervisory Control and Data Acquisition, also called SCADA).

Selecting a meter for pressurized pipe systems

Experts claim that over 75 percent of the flow meters installed are not performing satisfactorily, and improper selection accounts for 90 percent of problems users have with meters. Selecting a meter for pressurized systems can be confusing because of the different types and styles available on the market. **A meter must be matched to the system, and the water user has to tell the meter dealer the following basic information to make sure a meter matches the system. If not, readings and recordings will be inaccurate, and inaccuracies will not likely favor the water right holder.**

- Know the range of flow under which the system operates. Range of flow is the lowest rate of pumping to the highest rate of pumping of a system needed for the operator. For instance, a system may need to pump as little as 20 gallons per minute for the smallest set of water to as much as 120 gallons per minute for the largest set. The lower rate may eliminate some types of meters because the low flow may be outside the range the meter can measure. In some cases, a meter that will measure the lowest rate for a system may not be able to measure the highest rate used in that system.
- A meter must be able to measure the instantaneous quantity (Q_i) and record the total quantity of water used over time (Q_a). Q_i is the rate at which water is pumped, such as 20 gallons per minute, 550 gallons per minute, and so forth. The total quantity pumped over time may be recorded as gallons, tens of gallons, hundreds of gallons, or thousands of gallons. Totalizing use in gallons is standard for meters. If recording Q_a in acre-feet is desired, the user must order that requirement. **For most uses in agriculture, recording Q_a in acre-feet is best. If totalizing Q_a in acre-feet is not available, then order a meter that records in thousands of gallons, or 10 thousand gallons, if possible.** Once installed, be sure the dealer explains how to read the meter and record the readings.
- The size of the pipe is very important. Some systems have pipe installed where the diameter of the pipe is larger than necessary. In those cases, it is not likely that a meter of reasonable cost for the system will be available. It is best to place a smaller diameter pipe in the system and install a meter in the smaller diameter section that will measure small flows.
- Be sure that there is enough straight pipe before and after the meter. **Read the instructions for installation.** Not all meters have the same requirements. The required lengths are a function of the diameter of the pipe. If, for example, a meter requires 5 times the diameter of straight pipe before the meter and 2 times the diameter after the meter, a 6-inch pipe would need 30 inches of straight pipe before the meter and 12 inches of straight pipe after the meter.
- If the required length of straight pipe is not available, particularly before the meter, then straightening vanes would be required or the system redesigned near the outlet of the pump to install a meter properly.
- Be sure the accuracy of the meter is within prescribed limits, which are plus or minus 5% of the amount actually being pumped. Most, if not all, meters are calibrated at the factory and operate well within $\pm 5\%$.
- All meters should be inspected periodically as part of a scheduled maintenance program, especially meters that have moving parts. Generally, meters are checked for two reasons: to confirm that it's still operating or to assess its accuracy.

What type of meter to install

It is just as important to know what a flowmeter cannot do as well as what it can do when selecting a meter. Each type and style has advantages and disadvantages, and the degree of satisfactory performance is directly related to how well the capabilities and shortcomings of an instrument is matched to the requirements of the application. Users often expect performance from a meter that is not consistent with what the supplier has provided. Most suppliers want to make sure the right flowmeter is installed and used for a particular system. Many provide questionnaires, checklists, and specification sheets designed to obtain the critical information necessary to match the correct flowmeter to the job. Contact your local conservation district administering cost-share funding to see if they have a checklist to use.

Technological improvements of flowmeters must also be considered. A common mistake is to select a design that was most popular for a given application some years ago and to assume that it is still the best instrument for the job. Many changes and innovations may have occurred in recent years in the development of flowmeters for that particular application, making the choice much broader.

A recent development is the availability of computer programs to perform the tedious calculations often necessary for selecting flowmeters. Calculations that used to take an hour can be performed in a matter of seconds.

Considerations of Cost

There are a wide range of prices for flowmeters. Prices range from approximately \$50 to over \$10,000. Generally, meters for large systems will cost more than those for small systems. Specific designs for an individual system can be even higher. However, total system costs must always be considered when selecting flowmeters. For example, a meter for a 6" pipeline may cost around \$1200 plus installation. Adding a data logger may cost an additional \$200 to \$400, and telemetry and installation would add to the cost. Users should balance added cost with the efficiencies of having automatic recordings of date, telemetry, and so forth with labor savings over time.

As with many products, users generally get what they pay for when purchasing a flowmeter. The satisfaction received with the product will depend on the care used in selecting and installing the instrument. That, again, involves knowing the process, the products, and the flow-metering requirements. "Overbuying" is not uncommon. Users need not buy a flowmeter more capable or complicated than they need, but neither should a meter be purchased that will not or can not satisfy future needs, such as adding telemetry.

WORKING WITH FLOWMETERS

Although suppliers are ready to install meters, around 75 percent of the users install their own equipment. Mistakes when installing are not uncommon. One of the most common is not allowing sufficient upstream and downstream straight-run piping for the flowmeter.

Every design has some tolerance to variable velocity conditions in the pipe, but all units require a certain amount of straight pipe to provide a normal flow pattern for the device. Without it, accuracy and performance are will not be correct.

With electrical components, safety is an important consideration in hazardous areas. Stray magnetic fields may exist, particularly when other electrical equipment is operating nearby. Power lines, relays, solenoids, transformers, motors, and generators all contribute their share of interference. Be sure that the flowmeter selected is immune to such interference. Problems occur primarily with the electronic components in secondary elements, which must be protected. Most flowmeter suppliers offer designs for such uses, and strict adherence to the manufacturers recommended installation practices will usually prevent such problems.

Reading a meter

One of the biggest sources of confusion with metering is knowing how to read a meter to determine what the meter is recording. Figure 1 is an example of what some readouts look like. All meters read and record the same designated units, but the displays may be different, as Figure 1

shows. Readouts usually are in gallons, 10s of gallons, 100s of gallons, 1,000s of gallons, 10,000s of gallons, and acre-feet. Always select a meter that displays in as large a number as possible, and preferably in acre-feet if available.

What does the readout on a meter head look like?

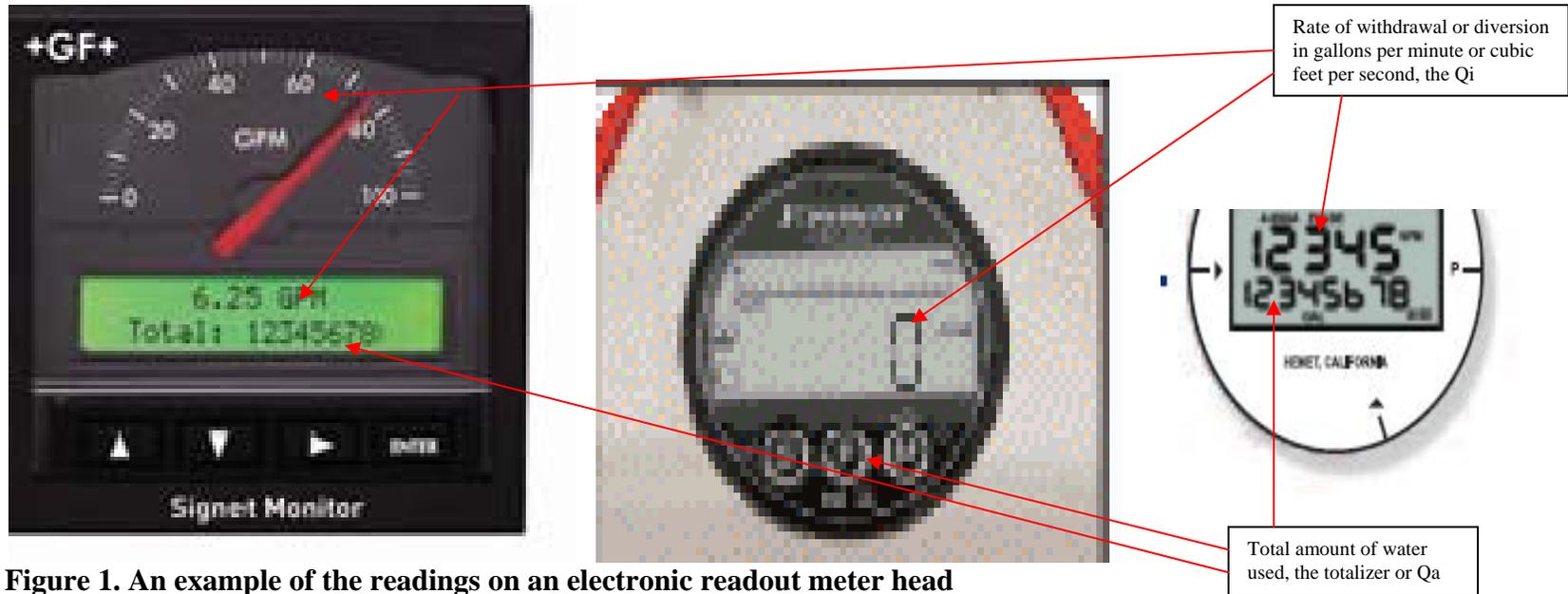


Figure 1. An example of the readings on an electronic readout meter head

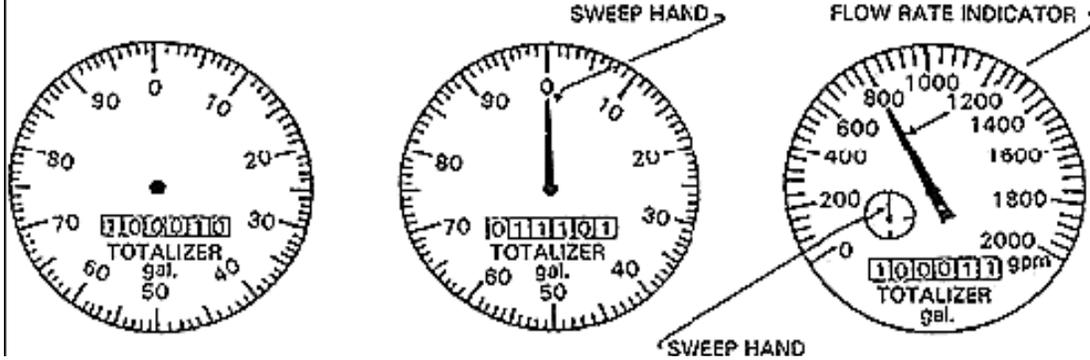


Figure 2. What a mechanical meter head might look like and what readings are provided. For agricultural applications, totalizing in acre-feet is best.

Calibration

All flowmeters require an initial calibration. Most manufacturers calibrate a meter for the specified service conditions. If qualified personnel are available, the user can either perform their own calibrations or hire an outside consultant. If telemetry equipment is in place and a user uses wireless internet, for example, a user can often contact the manufacturer or other qualified people to conduct a diagnostic on the equipment over the internet and corrections made that way.

The need to recalibrate usually depends on how well the meter fits the application. Some liquids passing through flowmeters tend to be abrasive, erosive, or corrosive. In time, portions of the device will deteriorate sufficiently to affect performance. Some designs are more susceptible to damage than others. For example, wear of individual turbine blades will cause performance changes. In other cases, recalibration may not be necessary for years because nothing that could change the meter's performance has occurred. Most manufacturers will recalibrate a meter in their plant or in the user's facility.

Maintenance

A number of factors influence maintenance requirements and the life expectancy of flowmeters. The major factor, of course, is matching the right instrument to the particular application. Poorly selected devices invariably will cause problems and/or fail at an early date. While flowmeters with no moving parts usually will require less attention than units with moving parts, all flowmeters eventually require some kind of maintenance.

Flowmeters with moving parts require periodic internal inspection for wear and tear, especially if water contains sediments. Installing filters ahead of such units will help minimize fouling and wear. Meters with no moving parts, such as ultrasonic or electromagnetic meters, may develop problems with their secondary element's electronic components. Pressure sensors associated with secondary elements should be periodically removed and inspected.

Applications where coatings such as calcium or iron may occur are potential problems. If the coating is insulating, the operation of magnetic flowmeters will be impaired if the coating insulates the electrodes from the flow of water. Periodic cleaning would be necessary to remove any buildup of coatings on the electrodes. With ultrasonic flowmeters, refraction angles may change and the sonic energy absorbed by the coating will cause the meter to become inoperative. In that case the inside of the pipe wall would have to be cleaned.

The chart below is a general guide only. There are several other types of meters available; the chart discusses meters most commonly used in agriculture for large to small irrigation systems.

General Guide for Selecting Among the More Common Types of Pressurized Pipe Flow Meters Used in Agricultural Applications

Type of Flowmeter	Conditions of water suited	Pipe sizes	Pressure loss	Typical accuracy in percent	Required length of straight pipe upstream of meter	Required length of straight pipe downstream of meter	Cost
Electromagnetic full pipe meter	Few limitations	4", 6", 8", larger sizes available by order	None	±0.5 % of rate	5 or less. Consult dealer and specification sheet	2 or less. Consult dealer and specification sheet	Depends on brand and size of pipe (increases with pipe size)
Electromagnetic insertion meter	Few limitations	3" to 48"	None	±1 % of full scale	10 times the diameter of the pipe	5 times the diameter of the pipe	Low to medium
Ultrasonic (time-of-travel)	Clean water with some particles or air bubbles	1" to 60" or more	None	±2 % of full scale	10 times the inside diameter of the pipe	5 times the inside diameter of the pipe	Medium to high, depending on configuration needed and diameter of pipe
Propeller	Clean, relatively free of sediments preferred	2" to 96"	Low	±2 % of reading	5 to 10 diameters	1 to 2 diameters	Low to high, depending on pipe size
Positive displacement	Clean	5/8" to 2"	High	±1.5 to 2 %	Minimal	Minimal	Low
Vortex	Clean to dirty	2" to 20"	Low to medium	±1 % of full scale	10 times the diameter of the pipe	5 times the diameter of the pipe	Low to medium

With most pressurized pipe flow meters, the flow rate (instantaneous quantity, or Q_i) is determined by measuring the velocity of the liquid flowing in the pipe. Velocity depends on the pressure forcing the liquid through a pipe or conduit. Because the pipe's cross-sectional area is known and remains constant, the average velocity is an indication of the flow rate. Factors that affect the rate of flow include the liquid's viscosity and density, and the friction of the liquid in contact with the pipe.

Flow through a pipe is described generally in Figure 1. A characteristic of laminar flow is the parabolic shape of its velocity profile, Fig. 1. Uniform laminar flow provides the most accurate measurement. Turbulent flow is caused by bends, valves, restrictions, and so forth in the pipe and provides the least accurate measurement. Each style of meter will require a certain amount of straight pipe before and after the meter to ensure laminar flow. In some applications, the piping system may have to be redesigned to make sure that both laminar flows are ensured by having the recommended length of straight pipe before and after a meter to reduce if not eliminate turbulent and non-laminar flow.

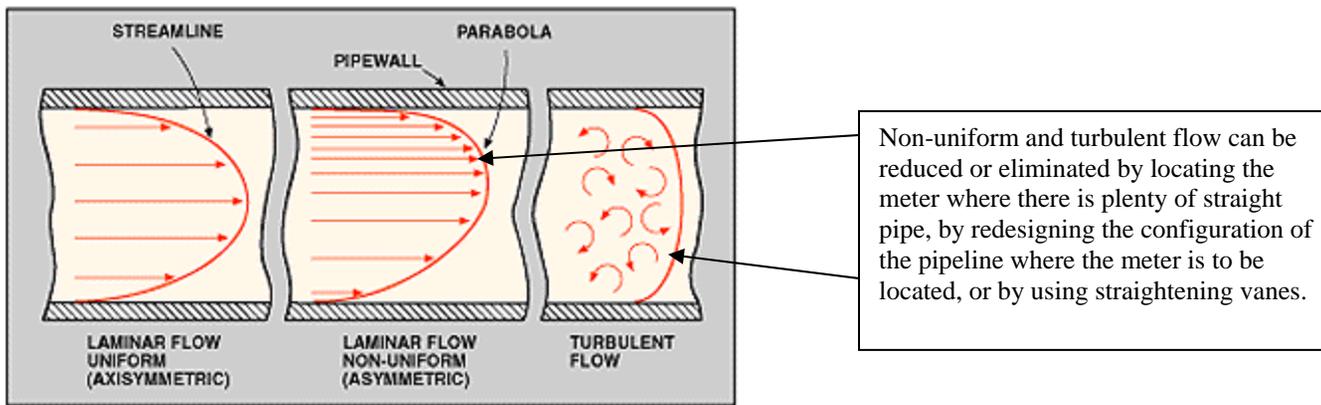


Figure 3. Laminar and turbulent flow.

Straightening Vanes

A meter should not be placed in pipe where turbulence exists because turbulence causes the meter to read the amount of water incorrectly. The error likely will not be in favor of the water right holder. Meters should be placed where turbulence is reduced or eliminated. Some meters require more length of straight pipe than others. Look at the directions for installing the meter and make sure that the minimum length of straight pipe, both before and after the meter, is available to ensure accuracy (see the table above). The length of straight pipe needed ahead of the meter is more than that required the meter.

If the required amount of straight pipe is not available, straightening vanes are an option to reduce turbulence and improve accuracy for the end user. Straightening vanes need to meet requirements and standards of the American Petroleum Institute. Straightening vanes may be necessary for any meter, depending on the length of straight pipe ahead of a meter. Look at the instructions for the meter, and ask the meter installer about the need for straightening vanes.

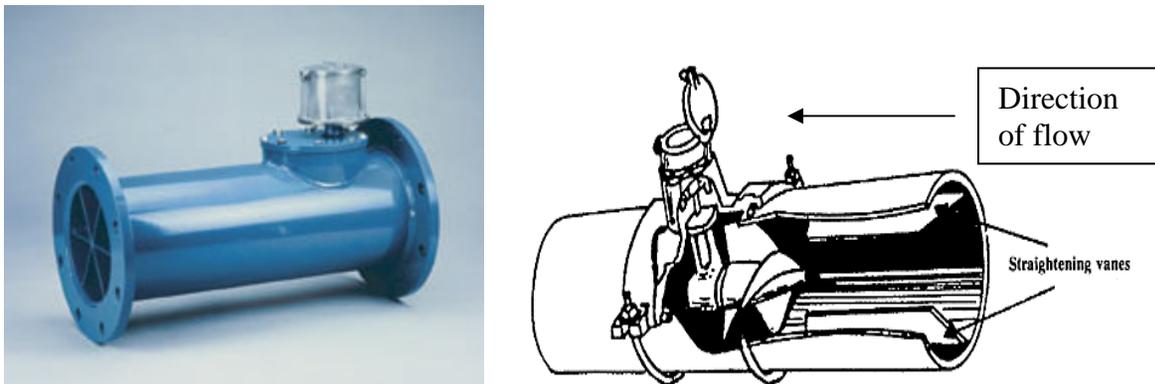


Figure 4. Meter with straightening vanes **ahead** of the meter.

Installing a Meter on the Pipe

There are a number of ways to install a meter on a pipe. The usual methods are:

Threaded pipe fitting: involves cutting a hole in the pipe, welding on a threaded pipe fitting, and screwing the meter into the pipe fitting. This type of installation is usually for insertion-type meters where the meter is inserted into the pipe (insertion means that a part of the metering system has an element of the meter inserted into the pipe flow), such as with paddle wheel meters, vortex meters, and some types of magnetic meters.

Saddle mount: involves cutting a hole in the pipe and installing a saddle mounted meter. This type of installation can be used for propeller meters, paddle wheel meters, vortex meters, and some types of magnetic meters.



Figure 5. Typical saddle mounts for installing a meter in a pipe



Figure 6. Example of a propeller meter on a saddle mount

Flanged meter: involves cutting a section of the existing pipe out of the system, installing flanges on both ends, and placing the flanged meter in place of the cut out section. Often used when straightening vanes are required.



Figure 7. Example of a typical flanged meter with straightening vanes.

TYPES OF PRESSURIZED PIPE FLOW METERS

Many types of flowmeters are available for pressurized-pipe systems. In general, meters for most water systems are positive displacement or velocity meters. Positive displacement meters include piston, oval-gear, nutating-disk, and rotary-vane types. Velocity meters consist of turbine, vortex shedding, electromagnetic, and sonic designs.

Mechanical Flow Meters

Mechanical meters are probably the most used type of meter for pressurized systems. There are several types of mechanical flow meters available over a range of costs. The following is not to be considered an all-inclusive list of mechanical flow meters. There are others; this discussion only provides a brief overview of meters commonly used in many applications.

Propeller meters

Propeller meters are the most common type of meter in use for measuring water at the source in pressurized water delivery systems. The basic unit consists of a rotating propeller mounted in the pipe with a meter for measuring the rate of pumping and the volume of water pumped. The revolutions of the propeller are counted and the rate and volume measured. The rotational speed is a direct function of flow rate and can be sensed by magnetic pick-up, photoelectric cell, or gears. Propeller meters are relatively accurate and meet the needs of many users. The readout on the meter provides Q_a and Q_i , and does not require power to operate unless equipped with an electronic readout for Q_i and Q_a .

Major concerns with propeller meters are wear on the bearings and turbidity in water causing excessive wear on the propellers or plugging of bearings with sediment. Propeller meters are not recommended when water is dirty and contains abrasive material such as sand. A rule of thumb is that if the impellers on a pump have to be replaced often (for example, every two years or so), then propeller meters are probably not the best choice due to abrasive wear on the meter propeller. Propeller meters can be equipped with electronics for SCADA (see SCADA webpage).



Figure 8. Flanged propeller meter with straightening vanes



Figure 9. Saddle mount propeller meter

Positive-Displacement Meters are mechanical meters that separate liquids into accurately measured increments representing a discrete volume. Each segment is counted by a connecting register. Positive-displacement units work well for small pipe systems 2" or smaller and where a simple mechanical meter system satisfies requirements. With all positive-displacement meters, variations in viscosity below a given threshold will affect measuring accuracies (viscosity is the resistance to flow, honey is more viscous than water). Many sizes and capacities of positive-displacement meters are available.



Figure 10. Example of a positive displacement meter.

Vortex meters make use of a natural phenomenon that occurs when a liquid flows around a bluff object. Eddies or vortices are shed alternately downstream of the object, much like a flag flapping in the breeze. The faster the wind blows, the more the flag flaps. The "flapping" in liquid flows is called "shedding." The frequency of the shedding is directly proportional to the velocity of the liquid flowing through the meter. The more frequent the "shedding," the higher the rate of flow of water.



Figure 11. Example of vortex meters

The three major components of the flowmeter are a bluff body strut-mounted across the bore of the flowmeter, a sensor to detect of the vortex and generate an electrical impulse, and signal amplification and conditioning transmitter whose output is proportional to the rate of flow. The meter is equally suitable for rate of flow or for totalizing flow measurements. Use for slurries or high viscosity liquids is not recommended.

Electromagnetic meters can handle most liquids and slurries, providing that the material being metered is can conduct electricity. Major components are the flow tube (primary element). The flow tube mounts directly in the pipe. Pressure drop across the meter is the same as it is

through an equivalent length of pipe because there are no moving parts or obstructions to the flow. The voltmeter can be attached directly to the flow tube or can be mounted remotely and connected to it by a shielded cable.



Figure 12. Examples of full pipe size mag meters with readout/datalogger capabilities

Electromagnetic flowmeters operate on Faraday's law of electromagnetic induction that states that a voltage will be induced when a conductor moves through a magnetic field. The liquid serves as the conductor; the magnetic field is created by energized coils outside the flow tube. The amount of voltage produced is directly proportional to the rate of flow. Two electrodes mounted in the pipe wall detect the voltage, which is measured by the secondary element.

Electromagnetic flowmeters have major advantages: they can measure difficult and corrosive liquids and slurries, and they can measure forward as well as reverse flow with equal accuracy. They also have no moving parts to wear.

Electromagnetic flowmeters are also available as insertion meters. Magnetic insertion meters use a probe inserted into the pipe, usually through a "hot tap" arrangement. Insertion meters have to be installed carefully as the diameter of the pipe affects the depth the probe has to extend into the pipe. Insertion meters work well when expensive major modifications would be required to install a full pipe meter.



Figure 13. Examples of two types of magnetic insertion meters

Ultrasonic flowmeters are Doppler meters and time-of-travel (or transit) meters. Doppler meters measure the frequency shifts caused by liquid flow. Two transducers are mounted in a case attached to one side of the pipe. A signal of known frequency is sent into the liquid to be measured. Solids, bubbles, or any discontinuity in the liquid, cause the pulse to be reflected to the receiver element. Because the liquid causing the reflection is moving, the frequency of the returned pulse is shifted. The frequency shift is proportional to the liquid's velocity.

A portable Doppler meter capable of being operated on AC power or from a rechargeable power pack is available. The sensing heads are clamped to the outside of the pipe, and the instrument is ready to be used. A set of 4 to 20 millampere output terminals permits the unit to be connected to a strip chart recorder or other remote device.



Figure 14. Example of ultrasonic meters installed on a pipe.

Time-of-travel meters have transducers mounted on each side of the pipe. The configuration is set so that the sound waves traveling between the devices are at a 45 deg. angle to the direction of liquid flow. The speed of the signal traveling between the transducers increases or decreases with the direction of transmission and the velocity of the liquid being measured. A time-differential relationship proportional to the flow can be obtained by transmitting the signal alternately in both directions. A limitation of time-of-travel meters is that the liquids being measured must be relatively free of entrained gas or solids to minimize signal scattering and absorption.