ITS
INSTRUMENTATION
TECHNICAL SERVICES, INC.

LIQUID FLOWMETERS
Flow Reference Section

An overview of types and capabilities, plus guidelines on selection, installation, and maintenance

INTRODUCTION

Measuring the flow of liquids is a critical need in many industrial plants. In some operations, the ability to conduct accurate flow measurements is so important that it can make the difference between making a profit or taking a loss. In other cases, inaccurate flow measurements–or failure to take measurements–can cause serious (or even disastrous) results.

With most liquid flow measurement instruments, the flow rate is determined inferentially by measuring the liquid's velocity or the change in kinetic energy. Velocity depends on the pressure differential that is 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. The basic relationship for determining the liquid's flow rate in such cases is:

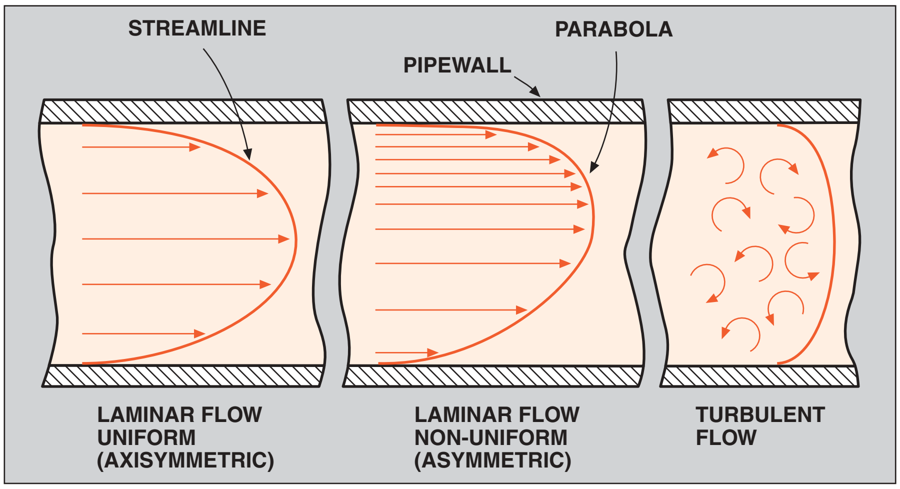
$$Q = V \times A$$

where:
Q = liquid flow through the pipe
V = average velocity of the flow
A = cross-sectional area of the pipe

Other factors that affect liquid flow rate include the liquid's viscosity and density, and the friction of the liquid in contact with the pipe. Direct measurement of liquid flows can be made with positive-displacement flowmeters. These units divide the liquid into specific increments and move it on. The total flow is an accumulation of the measured increments, which can be counted by mechanical or electronic techniques.

REYNOLDS NUMBERS

The performance of flowmeters is also influenced by a dimensionless unit called the Reynolds Number, defined as the ratio of the liquid's inertial forces to its drag forces.



The equation is:

$$R = \frac{3160 \times Q \times G_t}{D \times \mu}$$

where R =Reynolds number
Q = liquid's flow rate, gpm
G_t = liquid's specific gravity
D =inside pipe diameter, in.
μ = liquid's viscosity, cp

The flow rate and the specific gravity are inertial forces, and the pipe diameter and viscosity are drag forces. The pipe diameter and the specific gravity remain constant for most liquid applications. At very low velocities or high viscosities, R is low, and the liquid flows in smooth layers with the highest velocity at the center of the pipe and low velocities at the pipe wall where the viscous forces restrain it. This type of flow is called laminar flow. R values are below approximately 2000. A characteristic of laminar flow is the parabolic shape of its velocity profile (Fig. 1).

However, most applications involve turbulent flow, with R values above 3000. Turbulent flow occurs at high velocities or low viscosities. The flow breaks up into turbulent eddies that flow through the pipe with the same average velocity. Fluid velocity is less significant, and the velocity profile is much more uniform in shape. A transition zone exists between turbulent and laminar flows. Depending on the piping configuration and other installation conditions, the flow can be either turbulent or laminar in this zone.

FLOWMETER TYPES

Numerous types of flowmeters are available for closed-piping systems. In general, equipment can be classified as: differential pressure, positive displacement, velocity, or mass meters. Differential pressure devices (also known as head meters) include orifices, venturi tubes, flow tubes, flow nozzles, pitot tubes, elbow-tap meters, target meters, and variable-area meters (Fig. 2).

Positive displacement meters include piston, oval-gear, nutating-disk, and rotary-vane types. Velocity meters consist of turbine, vortex shedding, electromagnetic, and sonic designs. Mass meters include Coriolis and thermal types. The measurement of liquid flows in open channels generally involves weirs and flumes.

Space limitations prevent a detailed discussion of all the liquid flowmeters available today. However, summary characteristics of common devices are shown in Table 1. Brief descriptions follow.

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DIFFERENTIAL PRESSURE METERS

The use of differential pressure as an inferred measurement of a liquid's rate of flow is well known. Differential pressure flowmeters are, by far, the most common units in use today. Estimates are that over 50 percent of all liquid flow measurement applications use this type of unit.

The basic operating principle of differential pressure flowmeters is based on the premise that the pressure drop across the meter is proportional to the square of the flow rate. The flow rate is obtained by measuring the pressure differential and extracting the square root.

Differential pressure flowmeters, like most flowmeters, have a primary and secondary element. The primary element causes a change in kinetic energy, which creates the differential pressure in the pipe. The unit must be properly matched to the pipe size, flow conditions, and the liquid's properties, and the measurement accuracy of the element must be good over a reasonable range. The secondary element measures the differential pressure and provides the signal or read-out that is converted to the actual flow value.

Orifices are the most popular liquid flowmeters in use today. An orifice is simply a flat piece of metal with a specific-sized hole bored in it. Most orifices are of the concentric type, but eccentric, conical (quadrant), and segmental designs are also available.

In practice, the orifice plate is installed in the pipe between two flanges. Acting as the primary device, the orifice constricts the flow of liquid to produce a differential pressure across the plate. Pressure taps on either side of the plate are used to detect the difference. Major advantages of orifices are that they have no moving parts and their cost does not increase significantly with pipe size.

Conical and quadrant orifices are relatively new. The units were developed primarily to measure liquids with low Reynolds numbers. Essentially constant flow coefficients can be maintained at R values below 5000. Conical orifice plates have an upstream bevel, the depth and angle of which must be calculated and machined for each application.

The segmental wedge is a variation of the segmental orifice. It is a restriction orifice primarily designed to measure the flow of liquids containing solids. The unit has the ability to measure flows at low Reynolds numbers and still maintain the desired square-root relationship. Its design is simple, and there is only one critical dimension–the wedge gap. Pressure drop through the unit is only about half that of conventional orifices.

Integral wedge assemblies combine the wedge element and pressure taps into a one-piece pipe coupling bolted to a conventional pressure transmitter. No special piping or fittings are needed to install the device in a pipeline.

Metering accuracy of all orifice flowmeters depends on the installation conditions, the orifice area ratio, and the physical properties of the liquid being measured.

Venturi tubes have the advantage of being able to handle large flow volumes at low pressure drops. A venturi tube is essentially a section of pipe with a tapered entrance and a straight throat. As liquid passes through the throat, its velocity increases, causing a pressure differential between the inlet and outlet regions.

The flowmeters have no moving parts. They can be installed in large diameter pipes using flanged, welded or threaded-end fittings. Four or more pressure taps are usually installed with the unit to average the measured pressure. Venturi tubes can be used with most liquids, including those having a high solids content.

Flow tubes are somewhat similar to venturi tubes except that they do not have the entrance cone. They have a tapered throat, but the exit is elongated and smooth. The distance between the front face and the tip is approximately one-half the pipe diameter. Pressure taps are located about one-half pipe diameter downstream and one pipe diameter upstream.

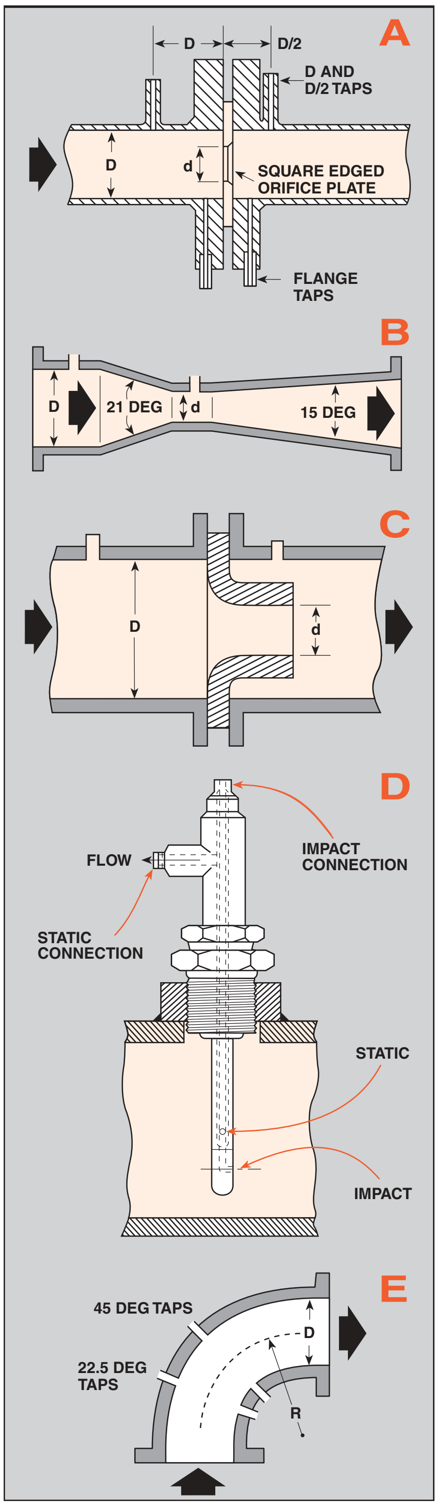

Figure 2: Common differential pressure flowmeters include the orifice (a), venturi tube (b), flow nozzle (c), pitot tube (d), and elbow-tap meter (e). All require secondary elements for measuring the differential pressure and for converting the data to flow values.

Table 1
Flowmeter Selection Guide

Flowmeter Element	Recommended Service	Rangeability[1]	Pressure Loss	Typical Accuracy, Percent	Required Upstream Pipe, Diameters	Viscosity Effect	Relative Cost
Orifice	Clean, dirty liquids; some slurries	4 to 1	Medium	±2 to ±4 of full scale[2]	10 to 30	High	Low
Wedge	Slurries and viscous liquids	3 to 1	Low to medium	±0.5 to ±2 of full scale	10 to 30	Low	High
Venturi Tube	Clean, dirty, and viscous liquids; some slurries	4 to 1	Low	±1 of full scale	5 to 20	High	Medium
Flow Nozzle	Clean and dirty liquids	4 to 1	Medium	±1 to ±2 of full scale	10 to 30	High	Medium
Pitot Tube	Clean liquids	3 to 1	Very Low	±3 to ±5 of full scale	20 to 30	Low	Low
Elbow Meter	Clean, dirty liquids some slurries	3 to 1	Very Low	±5 to ±10 of full scale	30	Low	Low
Target Meter	Clean, dirty, viscous liquids; some slurries	10 to 1	Medium	±1 to ±5 of full scale	10 to 30	Medium	Medium
Variable Area	Clean, dirty viscous liquids	10 to 1	Medium	±1 to ±10 of full scale	None	Medium	Low
Positive Displacement	Clean, viscous liquids	10 to 1	High	±0.5 of rate[3]	None	High	Medium
Turbine	Clean, viscous liquids	20 to 1	High	±0.25 of rate	5 to 10	High	High
Vortex	Clean, dirty liquids	10 to 1	Medium	±1 of rate	10 to 20	Medium	High
Electro-magnetic	Clean, dirty, viscous conductive liquids and slurries	40 to 1	None	±0.5 of rate	5	None	High
Ultrasonic (Doppler)	Dirty, viscous liquids and slurries	10 to 1	None	±5 of full scale	5 to 30	None	High
Ultrasonic (Time-of-travel)	Clean, viscous liquids	20 to 1	None	±1 to ±5 of full scale	5 to 30	None	High
Mass (Coriolis)	Clean, dirty, viscous liquids; some slurries	10 to 1	Low	±0.4 of rate	None	None	High
Mass (Thermal)	Clean, dirty, viscous liquids; some slurries	10 to 1	Low	±1 of full scale	None	None	High
Weir (V-notch)	Clean, dirty liquids	100 to 1	Very Low	±2 to ±5 of full scale	None	Very Low	Medium
Flume (Parshall)	Clean, dirty liquids	50 to 1	Very Low	±2 to ±5 of full scale	None	Very Low	Medium

[1] For given transmitter span setting. *[2] Percent of the flowmeter's full range.* *[3] Percent of liquid flow rate.*

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Flow nozzles, at high velocities, can handle approximately 60 percent greater liquid flow than orifice plates having the same pressure drop. Liquids with suspended solids can also be metered. However, use of the units is not recommended for highly viscous liquids or those containing large amounts of sticky solids.

Pitot tubes sense two pressures simultaneously, impact and static. The impact unit consists of a tube with one end bent at right angles toward the flow direction. The static tube's end is closed, but a small slot is located in the side of the unit. The tubes can be mounted separately in a pipe or combined in a single casing.

In operation, single-tube units detect the difference between the impact pressure and the static pressure at the wall of the pipe. Pressure taps connect the tube to a manometer where the pressure differential is indicated. The double-tube configuration consists of one tube mounted within the other. The inner tube senses the impact pressure while the annular space between the tubes transmits the static pressure.

Pitot tubes are generally installed by welding a coupling on a pipe and inserting the probe through the coupling. Use of most pitot tubes is limited to single point measurements. The units are susceptible to plugging by foreign material in the liquid. Advantages of pitot tubes are low cost, absence of moving parts, easy installation, and minimum pressure drop.

Elbow meters operate on the principle that, when liquid travels in a circular path, centrifugal force is exerted along the outer edges. Thus, when liquid flows through a pipe elbow, the force on the elbow's interior surface is proportional to the density of the liquid times the square of its velocity. In addition, the force is inversely proportional to the elbow's radius.

Any 90° pipe elbow can serve as a liquid flowmeter. All that is required is the placement of two small holes in the elbow's midpoint (45° point) for piezometer taps. Pressure-sensing lines can be attached to the taps by using any convenient method.

Target meters sense and measure forces caused by liquid impacting on a target or drag-disk suspended in the liquid stream. A direct indication of the liquid flow rate is achieved by measuring the force exerted on the target. In its simplest form, the meter consists only of a hinged, swinging plate that moves outward, along with the liquid stream. In such cases, the device serves as a flow indicator.

A more sophisticated version uses a precision, low-level force transducer sensing element. The force on the target caused by the liquid flow is sensed by a strain gage. The output signal from the gage is indicative of the flow rate. Target meters are useful for measuring flows of dirty or corrosive liquids.

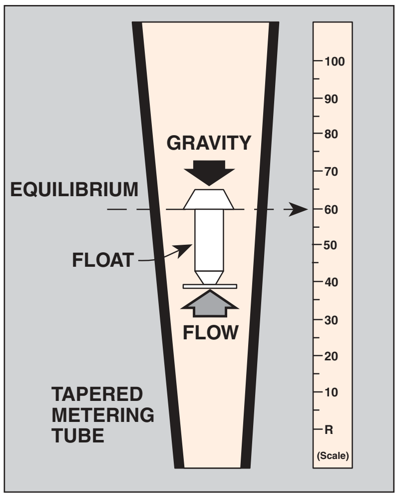


Figure 3: Variable-area flowmeter, also called a rotameter, has a float that moves up or down in a tapered tube. The distance is proportional to the liquid flow rate and the annular area between the float and the tube wall.

Variable-area meters, often called rotameters, consist essentially of a tapered tube and a float (Fig. 3). Although classified as differential pressure units, they are, in reality, constant differential pressure devices. Flanged-end fittings provide an easy means for installing them in pipes. When there is no liquid flow, the float rests freely at the bottom of the tube. As liquid enters the bottom of the tube, the float begins to rise. The position of the float varies directly with the flow rate. Its exact position is at the point where the differential pressure between the upper and lower surfaces balances the weight of the float.

Because flow rate can be read directly on a scale mounted next to the tube, no secondary flow-reading devices are necessary. However, if desired, automatic sensing devices can be used to sense the float's level and transmit a flow signal. Rotameter tubes are manufactured from glass, metal, or plastic. Tube diameters vary from ¼ to greater than 6 in.

Positive-Displacement Meters
Operation of these units consists of separating liquids into accurately measured increments and moving them on. Each segment is counted by a connecting register. Because every increment represents a discrete volume, positive-displacement units are popular for automatic batching and accounting applications. Positive-displacement meters are good candidates for measuring the flows of viscous liquids or for use where a simple mechanical meter system is needed.

Reciprocating piston meters are of the single and multiple-piston types. The specific choice depends on the range of flow rates required in the particular application. Piston meters can be used to handle a wide variety of liquids. A magnetically driven, oscillating piston meter is shown in Fig. 4. Liquid never comes in contact with gears or other parts that might clog or corrode.

Oval-gear meters have two rotating, oval-shaped gears with synchronized, close-fitting teeth. A fixed quantity of liquid passes through the meter with each revolution. Shaft rotation can be monitored to obtain specific flow rates.

NutatIng-disk meters have a moveable disk mounted on a concentric sphere located in a spherical side-walled chamber. The pressure of the liquid passing through the measuring chamber causes the disk to rock in a circulating path without rotating about its own axis. It is the only moving part in the measuring. A pin extending perpendicularly from the disk is connected to a mechanical counter that monitors the disk's rocking motions. Each cycle is proportional to a specific quantity of flow.

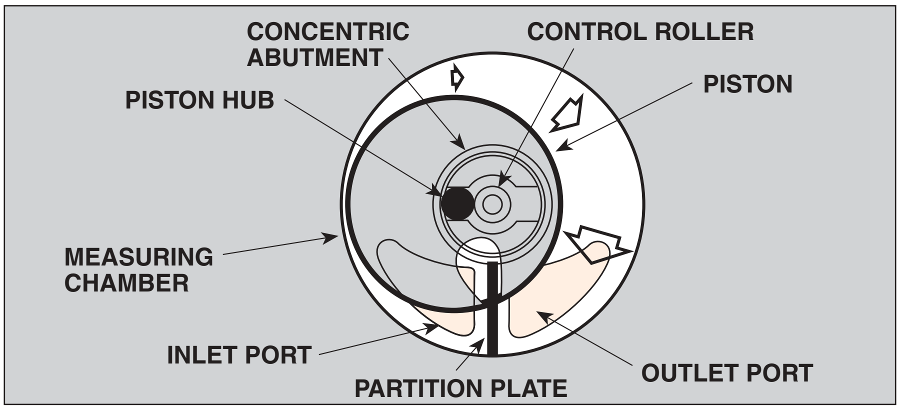
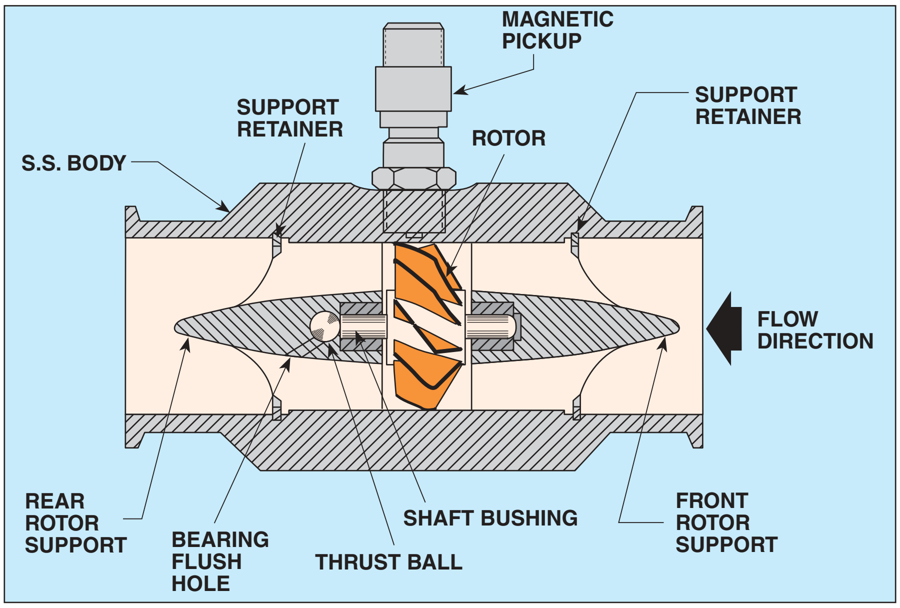


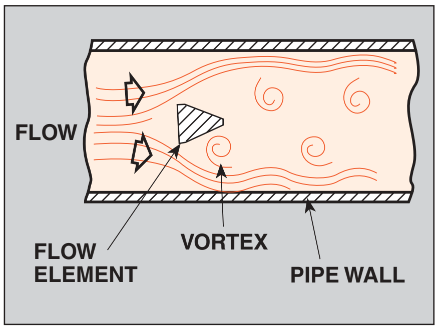
Figure 4: Oscillating-piston meter operates on magnetic drive principle so that liquid will not come in contact with parts. A partition plate between inlet and outlet ports forces incoming liquid to flow around a cylindrical measuring chamber and through the outlet port. The motion of the oscillating piston in the unit is transferred to a magnetic assembly in the measuring chamber which is compiled to a follower magnet on the other side of the chamber wall.



As is true with all positive-displacement meters, viscosity variations below a given threshold will affect measuring accuracies. Many sizes and capacities are available. The units can be made from a wide selection of construction materials.

Rotary-vane meters are available in several designs, but they all operate on the same principle. The basic unit consists of an equally divided, rotating impeller (containing two or more compartments) mounted inside the meter's housing. The impeller is in continuous contact with the casing. A fixed volume of liquid is swept to the meter's outlet from each compartment as the impeller rotates. The revolutions of the impeller are counted and registered in volumetric units.

Helix flowmeters consist of two radically pitched helical rotors geared together, with a small clearance between the rotors and the casing. The two rotors displace liquid axially from one end of the chamber to the other.



VELOCITY METERS

These instruments operate linearly with respect to the volume flow rate. Because there is no square-root relationship (as with differential pressure devices), their rangeability is greater. Velocity meters have minimum sensitivity to viscosity changes when used at Reynolds numbers above 10,000. Most velocity-type meter housings are equipped with flanges or fittings to permit them to be connected directly into pipelines.

Turbine meters have found widespread use for accurate liquid measurement applications. The unit consists of a multiple-bladed rotor mounted within a pipe, perpendicular to the liquid flow. The rotor spins as the liquid passes through the blades. The rotational speed is a direct function of flow rate and can be sensed by a magnetic pick-up, photoelectric cell, or gears. Electrical pulses can be counted and totalized (Fig. 5).

The number of electrical pulses counted for a given period of time is directly proportional to flow volume. A tachometer can be added to measure the turbine's rotational speed and to determine the liquid flow rate. Turbine meters, when properly specified and installed, have good accuracy, particularly with low-viscosity liquids.

A major concern with turbine meters is bearing wear. A "bearingless" design has been developed to avoid this problem.

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Liquid entering the meter travels through the spiraling vanes of a stator that imparts rotation to the liquid stream. The stream acts on a sphere, causing it to orbit in the space between the first stator and a similarly spiraled second stator. The orbiting movement of the sphere is detected electronically. The frequency of the resulting pulse output is proportional to flow rate.

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. The frequency of the vortex shedding is directly proportional to the velocity of the liquid flowing through the meter (Fig. 6).

The three major components of the flowmeter are a bluff body strutmounted across the flowmeter bore, a sensor to detect the presence of the vortex and to generate an electrical impulse, and a signal amplification and conditioning transmitter whose output is proportional to the flow rate (Fig. 7). The meter is equally suitable for flow rate or flow totalization measurements. Use for slurries or high viscosity liquids is not recommended.

Electromagnetic meters can handle most liquids and slurries, provided that the material being metered is electrically conductive. Major components are the flow tube (primary element) and a voltmeter (secondary element) (Fig. 8). 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.

Electromagnetic flowmeters operate pursuant to Faraday's law of electromagnetic induction which 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 (Fig. 9).

Figure 7: Vortex flowmeter is designed to be installed directly into pipelines without the need for special tools or complicated installation procedures. Unit is precalibrated and ready for use.

Figure 8: Wafer-type electromagnetic flowmeter is lightweight, compact, and can be easily installed between existing pipe flanges. The no-moving-part instrument has negligible pressure drop and can handle numerous liquids and slurries, provided they are conductive.

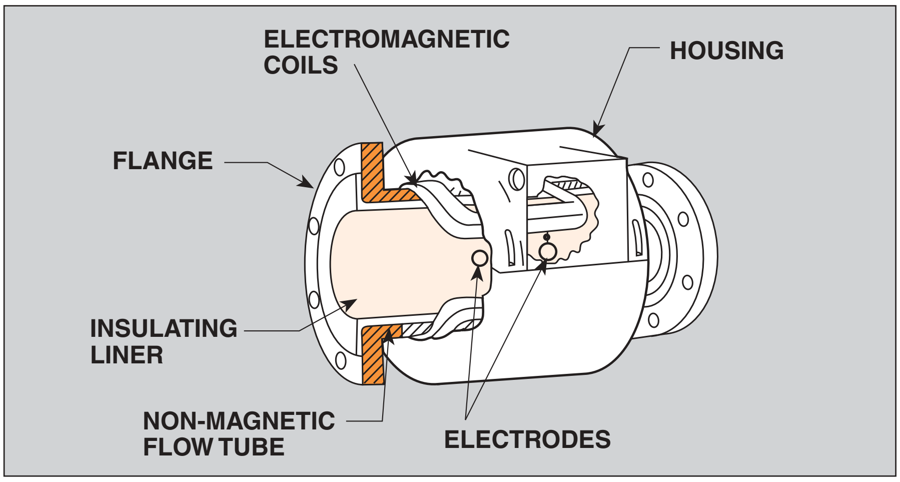
The amount of voltage produced is directly proportional to the flow rate. Two electrodes mounted in the pipe wall detect the voltage, which is measured by the secondary element.

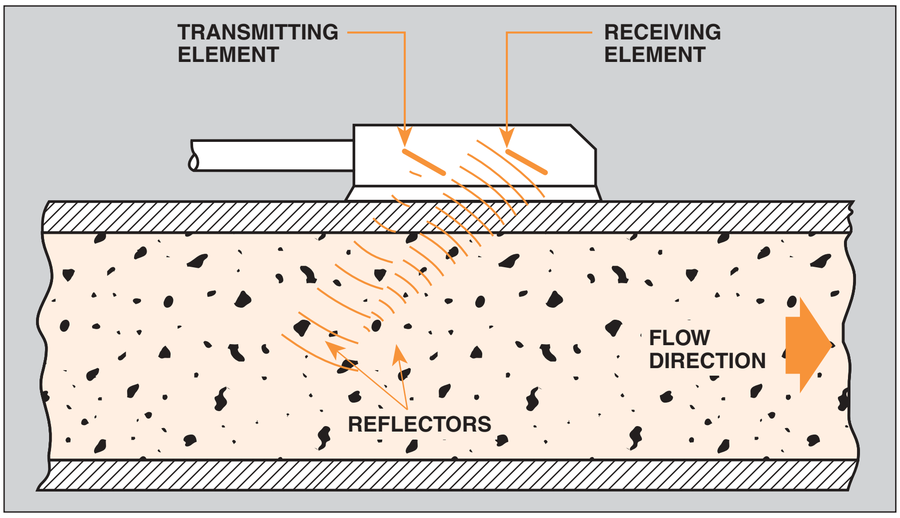
Electromagnetic flowmeters have major advantages: They can measure difficult and corrosive liquids and slurries, and they can measure forward as well as reverse flow with equal accuracy. Disadvantages of earlier designs were high power consumption and the necessity of a full pipe and no flow in order to initially set the meter to zero. Recent improvements have eliminated these problems. Pulse-type excitation techniques have reduced power consumption, because excitation occurs only half the time in the unit. Zero settings are no longer required.

Ultrasonic flowmeters can be divided into Doppler meters and time-of-travel (or transit) meters. Doppler meters measure 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 and any discontinuity in the liquid cause the pulse to be reflected to the receiver element (Fig. 10). 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 has recently been developed. The sensing heads are simply clamped to the outside of the pipe, and the instrument is ready to be used. Total weight, including the case, is 22 lb. A set of 4 to 20 mA output terminals permits the unit to be connected to a strip chart recorder or other remote device.

Time-of-travel meters have transducers mounted on each side of the pipe. The configuration is such that the sound waves traveling between the devices are at a 45° 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.



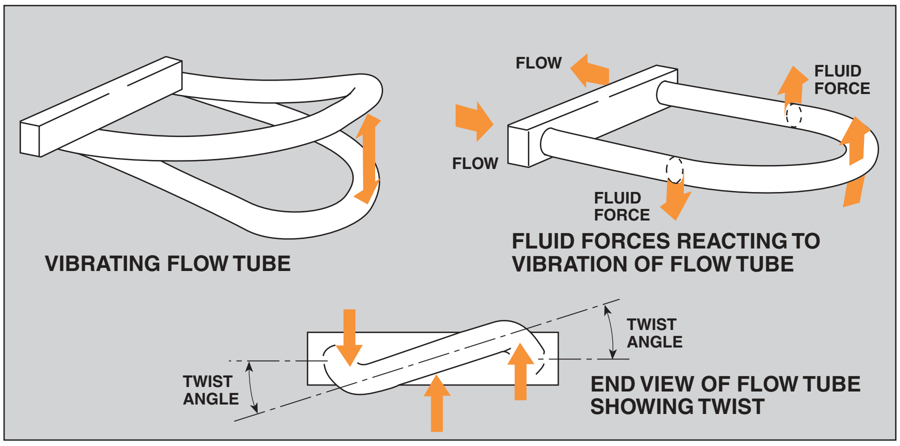


MASS FLOWMETERS

The continuing need for more accurate flow measurements in mass-related processes (chemical reactions, heat transfer, etc.) has resulted in the development of mass flowmeters. Various designs are available, but the one most commonly used for liquid flow applications is the Coriolis meter. Its operation is based on the natural phenomenon called the Coriolis force, hence the name.

Coriolis meters are true mass meters that measure the mass rate of flow directly, as opposed to volumetric flow. Because mass does not change, the meter is linear without having to be adjusted for variations in liquid properties. It also eliminates the need to compensate for changing temperature and pressure conditions. The meter is especially useful for measuring liquids whose viscosity varies with velocity at given temperatures and pressures.

Coriolis meters are also available in various designs. A popular unit consists of a U-shaped flow tube enclosed in a sensor housing connected to an electronics unit. The sensing unit can be installed directly into any process. The electronics unit can be located up to 500 feet from the sensor.



Inside the sensor housing, the U-shaped flow tube is vibrated at its natural frequency by a magnetic device located at the bend of the tube. The vibration is similar to that of a tuning fork, covering less than 0.1 in. and completing a full cycle about 80 times/sec. As the liquid flows through the tube, it is forced to take on the vertical movement of the tube (Fig. 11). When the tube is

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moving upward during half of its cycle, the liquid flowing into the meter resists being forced up by pushing down on the tube.

Having been forced upward, the liquid flowing out of the meter resists having its vertical motion decreased by pushing up on the tube. This action causes the tube to twist. When the tube is moving downward during the second half of its vibration cycle, it twists in the opposite direction.

The amount of twist is directly proportional to the mass flow rate of the liquid flowing through the tube. Magnetic sensors located on each side of the flow tube measure the tube velocities, which change as the tube twists. The sensors feed this information to the electronics unit, where it is processed and converted to a voltage proportional to mass flow rate. The meter has a wide range of applications from adhesives and coatings to liquid nitrogen.

Thermal-type mass flowmeters have traditionally been used for gas measurements, but designs for liquid flow measurements are available. These mass meters also operate independent of density, pressure, and viscosity. Thermal meters use a heated sensing element isolated from the fluid flow path. The flow stream conducts heat from the sensing element. The conducted heat is directly proportional to the mass flow rate. The sensor never comes into direct contact with the liquid (Fig. 12). The electronics package includes the flow analyzer, temperature compensator, and a signal conditioner that provides a linear output directly proportional to mass flow.

OPEN CHANNEL METERS

The “open channel” refers to any conduit in which liquid flows with a free surface. Included are tunnels, nonpressurized sewers, partially filled pipes, canals, streams, and rivers. Of the many techniques available for monitoring open-channel flows, depth-related methods are the most common. These techniques presume that the instantaneous flow rate can be determined from a measurement of the water depth, or head. Weirs and flumes are the oldest and most widely used primary devices for measuring open-channel flows.

Weirs operate on the principle that an obstruction in a channel will cause water to back up, creating a high level (head) behind the barrier. The head is a function of flow velocity, and, therefore, the flow rate through the device. Weirs consist of vertical plates with sharp crests. The top of the plate can be straight or notched. Weirs are classified in accordance with the shape of the notch. The basic types are V-notch, rectangular, and trapezoidal.

Flumes are generally used when head loss must be kept to a minimum, or if the flowing liquid contains large amounts of suspended solids. Flumes are to open channels what venturi tubes are to closed pipes. Popular flumes are the Parshall and Palmer-Bowlus designs.

The Parshall flume consists of a converging upstream section, a throat, and a diverging downstream section. Flume walls are vertical and the floor of the throat is inclined downward. Head loss through Parshall flumes is lower than for other types of open-channel flow measuring devices. High flow velocities help make the flume self-cleaning. Flow can be measured accurately under a wide range of conditions.

Palmer-Bowlus flumes have a trapezoidal throat of uniform cross-section and a length about equal to the diameter of the pipe in which it is installed. It is comparable to a Parshall flume in accuracy and in ability to pass debris without cleaning. A principal advantage is the comparative ease with which it can be installed in existing circular conduits, because a rectangular approach section is not required.

Discharge through weirs and flumes is a function of level, so level measurement techniques must be used with the equipment to determine flow rates. Staff gages and float-operated units are the simplest devices used for this purpose. Various electronic sensing, totalizing, and recording systems are also available.

A more recent development consists of using ultrasonic pulses to measure liquid levels. Measurements are made by sending sound pulses from a sensor to the surface of the liquid, and timing the echo return. Linearizing circuitry converts the height of the liquid into flow rate. A strip chart recorder logs the flow rate, and a digital totalizer registers the total gallons. Another recently introduced microprocessor-based system uses either ultrasonic or float sensors. A key-pad with an interactive liquid crystal display simplifies programming, control, and calibration tasks.

SELECTING A FLOWMETER

Experts claim that over 75 percent of the flowmeters installed in industry are not performing satisfactorily. Improper selection accounts for 90 percent of these problems. Obviously, flowmeter selection is no job for amateurs. The major steps involved in the selection process are shown in Fig. 13.

The most important requirement is knowing exactly what the instrument is supposed to do. Here are some questions to consider: Is the measurement for process control (where repeatability is the major concern), or for accounting or custody transfer (where high accuracy is important)? Is local indication or a remote signal required? If a remote output is required, is it to be a proportional signal, or a contact closure to start or stop another device?

Is the liquid viscous, clean, or a slurry? Is it electrically conductive? What is its specific gravity or density? What flow rates are involved in the application? What are the process’s operating temperatures and pressures? Accuracy (see glossary), range, linearity, repeatability and piping requirements must also be considered.

It is just as important to know what a flowmeter cannot do as well as what it can do before a final selection is made. Each instrument has

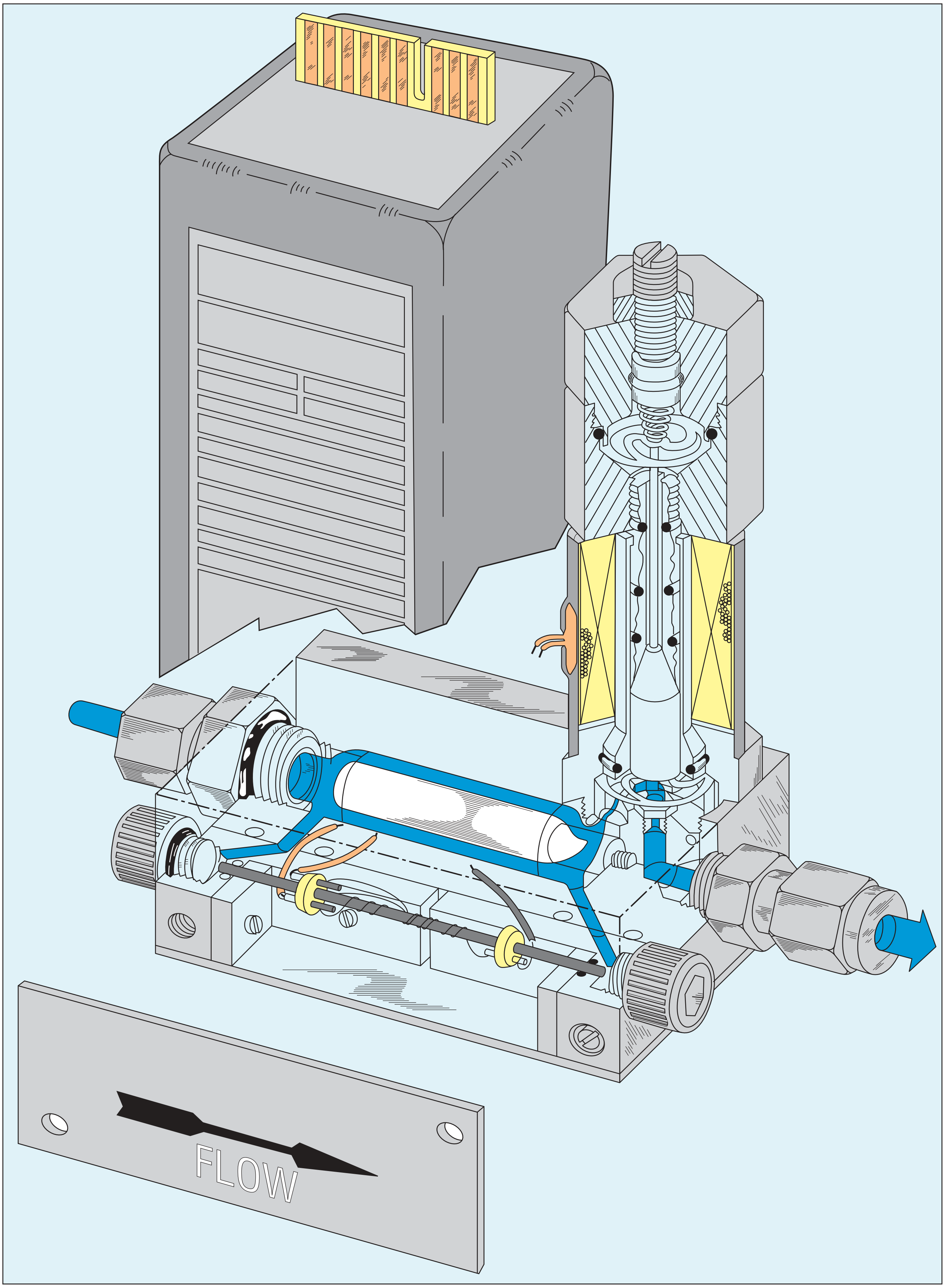

Figure 12: Thermal mass meters utilize a bypass design with RTD sensors to determine the flow rate.

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Table II. Questions To Ask When Selecting A Flowmeter

What range do you intend to cover?
0 to 100% , 25 to 100% , 50 to 100% ,
Other
What accuracy do you need? At:
100% , 75%
50% , 25%
What do you intend to do with meter output?
Indicate Totalize Record ________
Transmit Compute Other ________
What type of enclosure do you want?
Wall mount Panel mount NEMA Code
What are your piping considerations?
New Existing
Elevation Straight pipe run
Accessibility Environment
Who will service the meter?
Troubleshoot __________ Calibrate ____________
What type of service life do you want from the meter?

What pressure drop can you accept through the meter?

How much money can you appropriate? $________________
What do you want to meter?
Steam ______________ Condensate ______ Natural gas ___
Fuel oil (grade) ________, Chilled water _____
Heating hot water _____, Tower water ______
Domestic water _______, Other ___________
Other data required for selection:
Pressure: Min. ___________ Max. ________ Normal ________
Temperature: Min. ________Max. _________ Normal ________
Viscosity: Min. __________Max. _________ Normal ________
Flow Rate: Min. _________Max. _________ Normal ________
Pipe size: ______________Schedule _____ I.D. ___________

advantages and disadvantages, and the degree of performance satisfaction is directly related to how well an instrument's capabilities and shortcomings are matched to the application's requirements. Often, users have expectations of a flowmeter's performance that are not consistent with what the supplier has provided.

Most suppliers are anxious to help customers pick the right flowmeter for a particular job. Many provide questionnaires, checklists, and specification sheets designed to obtain the critical information necessary to match the correct flowmeter to the job.

Technological improvements of flowmeters must be considered also. For example, 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 (see accompanying section, "Selected Reference Material").

COST CONSIDERATIONS

There is a wide range of prices for flowmeters. Rotameters are usually the least expensive, with some small-sized units available for less than $100. Mass flowmeters cost the most. Prices start at about $3500. However, total system costs must always be considered when selecting flowmeters. For example, an orifice plate may cost only about $50. But the transmitter may add an additional $500 or $600, and sensing line fabrication and installation may cost even more. Installation, operation, and maintenance costs are important economic factors, too. Servicing can be expensive on some of the more complicated designs. As with many other products, a plan engineer generally gets what he pays for when he purchases a flowmeter. But the satisfaction that he receives with the product will depend on the care that he uses in selecting and installing the instrument. And that gets back to knowing the process, the products, and the flow-metering requirements. "Overbuying" is not uncommon. Plant engineers should not buy a flowmeter more capable or complicated than they need.

WORKING WITH FLOWMETERS

Although suppliers are always ready to provide flowmeter installation service, estimates are that approximately 75 percent of users install their own equipment. But installation mistakes are made. One of the most common is not allowing sufficient upstream and downstream straight-run piping for the flowmeter. Every design has a certain amount of tolerance to nonstable velocity conditions in the pipe, but all units require proper piping configurations to operate efficiently.

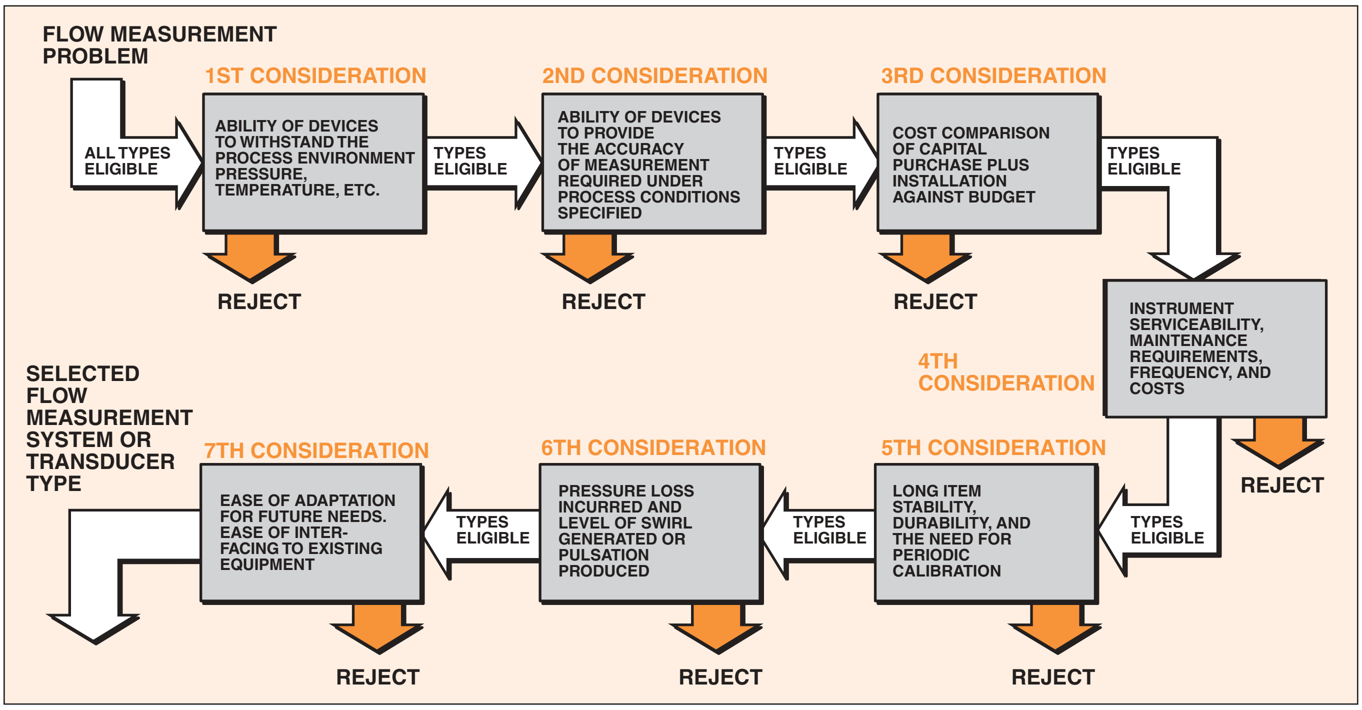

Figure 13: Major considerations involved in selecting flowmeters for specific applications include serviceability and maintenance requirements.

Proper piping provides a normal flow pattern for the device. Without it, accuracy and performance are adversely affected. Flowmeters are also installed backwards on occasion (especially true with orifice plates). Pressure-sensing lines may be reversed, too. With electrical components, intrinsic safety is an important consideration in hazardous areas. Most flowmeter suppliers offer intrinsically safe designs for such uses. Stray magnetic fields exist in most industrial plants. Power lines, relays, solenoids, transformers, motors, and generators all contribute their share of interference. Users must ensure themselves that the flowmeter they have selected is immune to such interference. Problems occur primarily with the electronic components in secondary elements, which must be protected. Strict adherence to the manufacturer's recommended installation practices will usually prevent such problems.

CALIBRATION

All flowmeters require initial calibration. Most of the time, the instrument is calibrated by the manufacturer for the specified service conditions. However, if qualified personnel are available in the plant, the user can perform his own calibrations.

The need to recalibrate depends to a great extent 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. If the application is critical, flowmeter accuracy should be checked at frequent intervals. In other cases, recalibration may not be necessary for years because the application is noncritical, or nothing will change the meter's performance. Some flowmeters require special equipment for calibration. Most manufacturers will provide such service in their plant or in the user's facility, where they will bring the equipment for on-site calibration.

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 at an early date. Flowmeters with no moving parts usually will require less attention than units with moving parts, but all flowmeters eventually require some kind of maintenance. Primary elements in differential pressure flowmeters require extensive piping, valves, and fittings when they are connected to their secondary elements, so maintenance may entail recurring effort in such installations. Impulse lines can plug or corrode and have to be cleaned or replaced. Improper location of the secondary element can result in measurement errors. Relocating the element can be expensive.

Flowmeters with moving parts require periodic internal inspection, especially if the liquid being metered is dirty or viscous. Installing filters ahead of such units will help minimize fouling and wear. Obstructionless instruments, 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 may occur are also potential problems for obstructionless instruments such as magnetic or ultrasonic units. If the coating is insulating, the operation of magnetic flowmeters will ultimately be impaired if the electrodes are insulated from the liquid. This condition can be prevented by periodic cleaning. With ultrasonic flowmeters, refraction angles may change and the sonic energy absorbed by the coating will cause the meter to become inoperative.