CONTROL
For the Process Industries

Flowmeter Shootout Part II: Traditional Technologies

How to Choose Among Turbine, Positive Displacement, Thermal, Variable Area, and Open Channel Using Paradigm Cases

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This article is the second in a three-part series on flowmeter technologies and selection. February's installment described new technologies and introduced the paradigm-case selection method. In April, users reveal how they choose flowmeters.

A great deal of attention is being paid today to new-technology flowmeters. Coriolis, magnetic, ultrasonic, and vortex are called new technologies mainly in contrast with differential-pressure flowmeters, which have been around for nearly 100 years.

New-technology flowmeters also contrast with traditional-technology flowmeters. Traditional technologies include turbine, positive displacement, thermal, variable area, and open channel. While some traditional technologies are less complex than new technologies, there are still some very interesting developments among these flowmeters. New products are still being introduced, and the annual sales of some of these types of meters exceed those of some new technology meters.

This article describes the operating principles of each of the traditional-technology flowmeters. It also looks at the paradigm-case applications for each type: the case where conditions are optimal for the operation of that type of flowmeter. Paradigm cases are a subset of the broader class of applications where a given technology will work.

TABLE I.
PARADIGM CASES

Technology	Paradigm case conditions	Comment
Turbine	Clean liquids or gases Enough flow to spin	Low-viscosity liquids are best
Positive-displacement	Liquids and gases Clean, non-corrosive, non-erosive	Medium to high viscosity is best
Thermal	Clean gases Known heat capacity	Low cost is an advantage
Variable-area	Clean liquids Low viscosity High accuracy not required	Spot checks of flow Most have no output signal
Open-channel:		
Weirs and flumes	Free-flowing streams Hydraulic structure is feasible	Weir: Stream has substantial slope Flume: Stream has little slope Liquid has impurities Flow velocity is high
Area-velocity	Partially filled pipes	Diameter 6 in. and larger

Which flowmeter is best for which application?

According to this method, users should select the type of flowmeter whose paradigm cases are closest to their application. The method then advises looking at application, performance, cost, and supplier criteria to narrow the choice down to a particular flowmeter.

Turbine Style

Turbine for Clean, Low-Viscosity Fluids

Turbine meters have a spinning rotor with propeller-like blades mounted on bearings in a housing. The rotor spins as water or other fluid passes over it. Flowrate is proportional to the rotational speed of the rotor. A variety of methods are used to detect the rotor speed, including mechanical shafts and electronic sensors.

Turbine meters differ according to the design of the spinning rotor. Several variations include paddlewheel meters and propeller meters. Paddlewheel meters have the axis of rotation perpendicular to the direction of the flow--many paddlewheel meters are insertion devices. Propeller meters have a rotor that is suspended in the flowstream.

Turbine meters can be used on both liquids and gases. Paradigm-case conditions for turbine flowmeters include clean liquids or gases flowing at sufficient speed to operate the meters. Since turbine meters are sensitive to swirl and to flow profile effects, a straight run prior to the meter is recommended. Dirt or impurities in the liquid or gas can damage the meter.

Turbine meters are also sensitive to viscosity: low-viscosity fluids are best. Gas and liquid meters require different designs due to the different densities.

Positive-displacement style

Positive-Displacement for Slow or Thick Flows

Positive displacement flowmeters repeatedly fill and empty compartments of known volume with the liquid or gas from the flowstream. Flowrate is calculated from the rate these compartments are filled and emptied. Types include nutating disc, oval gear, and helical gear.

Nutating disc flowmeters get their name from the idea of nutation, which means nodding or rocking. A nutating disc meter has a round disc mounted on a spindle in a cylindrical chamber. By tracking the movements of the spindle, the flowmeter determines the number of times the chamber traps and empties fluid. This information is used to determine flowrate.

With oval gear flowmeters, two oval gears or rotors are mounted inside a cylinder. As the fluid flows through the cylinder, the pressure of the fluid causes the rotors to rotate. As flowrate increases, so does the rotational speed of the rotors.

Helical gear flowmeters get their name from the shape of their gears or rotors. These rotors resemble the shape of a helix, which is a spiral-shaped structure. As the fluid flows through the meter, it enters the compartments in the rotors, causing the rotors to rotate. Flowrate is calculated from the speed of rotation.

There are a number of other types of positive-displacement flowmeters, including oscillating piston, rotating crescent, rotating paddle, sliding vane, and others. These chiefly differ according to the way they trap the liquid in compartments with different shapes.

Positive-displacement (PD) meters can measure both liquids and gases. Like turbine meters, PD flowmeters work best with clean, non-corrosive, and non-erosive liquids and gases, although some models will tolerate some impurities. Because of their high accuracy, PD meters are widely used at residences to measure the amount of gas or water used.

Some designs require that only lubricating fluid be measured, because the rotors are exposed to the fluid. PD meters differ from turbine meters in that they handle medium and high-viscosity liquids well. For this reason, they are often used to measure the flow of hydraulic fluids. PD meters above 10 in. tend to be heavy, large, and relatively expensive. PD meters require very little upstream piping, and can easily handle low flows. Pressure drop can be an issue.

Thermal-mass style

Thermal for Known Gases

Thermal flowmeters measure the mass flow of liquids and gases. Some measure the rate of heat loss that occurs when a heated thin film or wire thermistor is positioned in the fluid. Others keep a probe at a constant temperature and measure the amount of energy required.

Thermal flowmeters are sometimes classified as energy balance and thermal convection. Energy balance flowmeters use a small capillary tube. Fluid temperature is measured at the inlet and the outlet, and a known amount of heat is added to the flowstream. The increase in temperature varies with the specific heat of the fluid and the mass flow. Energy balance flowmeters are used with small gas flows, where the gas is clean and there is not a wide range in temperature.

Thermal convection flowmeters use a heated sensor inserted into the flowstream. Mass flow is based on the temperature difference between the heated sensor and the ambient flowstream. Some thermal convection flowmeters measure the temperature difference, others measure the amount of energy required to maintain a constant difference between the heated sensor and the fluid.

Thermal flowmeters got their start as hot-wire anemometers, used for turbulence and velocity profile research. Hot-wire anemometers were very small and fragile, consisting of a heated, thin wire element. They were susceptible to dirt and breakage, so they were mainly used in research rather than industrial environments.

The paradigm case application for thermal flowmeters is clean gases of known heat capacity. Thermal meters are often used to measure the flow of pure gases, or mixed gases of known composition. They are widely used to measure airflow in ducts and flare gas. Some models have also been designed to measure the flow of liquids.


Variable-area style

Variable-Area for Low Cost
Variable-area flowmeters, also called rotameters, consist of a vertical tube with an inlet at one end and an outlet at the other. Inside the tube is a float whose density is greater than the density of the fluid. As the fluid passes through the tube at varying speeds, the float rises or falls, maintaining a dynamic balance between the upward and downward forces acting on the float and the fluid. The height of the float in the tube indicates the flowrate. The metering tube normally includes a scale, and flowrate is often read manually.

Variable area (VA) flowmeters are classified according to the shape of the tube and type of float. Tapered-tube meters consist of a tapered tube with a float that moves upward with the force of the fluid. Orifice VA meters have a fixed orifice inside an upright compartment. The float is tapered at the bottom, and moves up and down within the orifice. Piston-type VA meters use a piston instead of a float to indicate flowrate.

The low accuracy of many VA meters limits their use in process applications. Because many VA meters do not produce an output signal, but must be read manually, they are not widely used for monitoring and control applications. Paradigm applications for VA flowmeters are for clean liquids of low viscosity, where high accuracy is not a requirement. VA meters are good for spot checks of local flowrates, and to check the accuracy of other flowmeters.

Both pressure and temperature limits apply to VA meters, but metal tubes handle higher parameters than glass. VA meters can measure gases, provided the gas is sufficiently dense and flowing at a fast enough rate lift the float.


Open-channel style

Open-Channel Depends on the Conduit
Open-channel flowmeters offer a major contrast to most other types. Instead of closed pipes or conduits, they measure the flow of liquids in rivers, streams, canals, and irrigation ditches, where liquid flows in a channel or conduit with a free surface. The flow of liquids in partially filled pipes, when not under pressure, is considered open-channel flow.

A number of different methods are used to measure open channel flow. The methods discussed here include the use of weirs and flumes, and the area-velocity method. Others include dilution and the timed-gravimetric method.

Weirs and flumes are among the most common methods. A weir or flume is a hydraulic structure with a known depth-to-flow relationship. Flowrate can be determined by measuring the depth of flow.

A weir is somewhat like a dam placed across the open channel. It is positioned so that liquid can flow over it. Weirs are classified according to the type of opening they have: V-notch, rectangular, and trapezoidal are common.

A flume is a shaped portion of the open channel with a slope or area different from the channel. There are many types of flumes, including Parshall, Palmer-Bowlus, H-type, and trapezoidal. Flowrate is calculated based on depth measurements made at specific points in the flume.

The area-velocity method is used when a weir or flume it is not practical. The average flow velocity is calculated, and this value is multiplied by the flow area to derive the flowrate.

Area-velocity methods include Doppler, transit-time, electromagnetic, and radar. The Doppler method bounces ultrasonic signals off bubbles or submerged particles in the flowstream. A sensor detects the returning frequencies, and uses this value to calculate flow. Transit-time transducers rely on the fact that ultrasonic signals travel faster with the flowstream than against it. By measuring the time of travel of ultrasonic signals across the flowstream, transit time transducers calculate flowrate. Electromagnetic probes rely on Faraday's principle: when a conductor (in this case the fluid) moves through a magnetic field, it creates a voltage in proportion to flowrate. Radar flowmeters bounce a radar signal off the flowstream and determine flowrate by analyzing the difference between the transmitted and reflected frequencies.

Like weirs and flumes, the above four area-velocity methods require a level or depth measurement to determine the area of the flow involved, and can use the same level instrumentation.

The paradigm case for open-channel flowmeters depends on the type. For weirs, it's a free-flowing stream with sufficient slope for relatively rapid flow through the weir. Weirs do not work well on flat-sloped channels or in situations where head loss is an issue. In the paradigm case, the liquid should be clean so solid materials, silt, and sand will not collect behind the weir and interfere with proper measurement. If impurities are present, a weir bulkhead or a stilling basin can be used. Weirs typically cost less than flumes, so they are normally considered first among hydraulic-structure methods.

Flumes are normally used only when weirs will not work, so their paradigm case applications should be defined accordingly. Like weirs, flumes are hydraulic structures used in free-flowing streams, not partially filled pipes. Flumes can handle high-velocity flow better than weirs. They are better when the slope is relatively flat and pressure loss is a consideration. Flumes also can tolerate some impurities, because these will simply sweep through the flume rather than getting caught on the edge of a weir.

The considerations for weirs vs. flumes are very similar to those for orifice plates vs. venturis. Like orifice plates, weirs shape the flow and have edges where impurities can collect. Flumes are shaped like venturis and can handle high-speed flow and impurities like venturis. A complete statement of paradigm conditions would specify what conditions are optimal for each type of weir and each type of flume.

The paradigm case for the area-velocity method is measurement of flow in partially filled pipes with diameters 6 in. and larger. The area-velocity method is better for pipes than for free-flowing streams because without a hydraulic structure to shape the flow, it is difficult to get an accurate measurement of area. The bottom of a stream can be irregular, while the area of a pipe is more easily known. Since the area-velocity method does not require the installation of a weir or flume, it works well for temporary flow-monitoring applications such as infiltration and inflow studies. It can also be used in free-flowing streams that are too large to allow the installation of a weir or flume.

Traditional Technologies Still Strong

Much has been written in the past five years about the superiority of new-technology flowmeters over traditional-technology meters. And there is no doubt that there is a fundamental shift in the market towards newer technologies, notably ultrasonic and Coriolis, and away from more traditional flowmeters.

But these shifts often take many years to complete, and awareness that a shift is occurring may present opportunities to traditional-technology suppliers. Even if a flowmeter market is flat, customers as a group will spend as much on that type of flowmeter this year as they did the preceding year. If some suppliers are reducing their research investments in traditional-technology flowmeters, it may present an opportunity for other suppliers of those same technologies.

For suppliers that continue to do research and bring out innovative products, there is a good chance customers will buy improved over unimproved models. Some suppliers can have increasing sales in a flat or even in a declining market.

Many traditional technologies have a niche that will never go away. The most obvious example is open-channel flowmeters, which by their very nature will not be supplanted by closed-pipe meters. Turbine and positive displacement flowmeters also have the advantages that they are highly accurate and well understood. Suppliers are continuing to improve the technology of these meters, making them less subject to failure. Thermal meters have a price advantage in measuring the flow of pure gases. Variable-area meters will continue to be used to make spot checks of flow.

Because turbine meters work best on low-viscosity liquids, while positive displacement meters are better in liquids of medium to high viscosity, these meters are more complementary than competing. Turbine meters compete with ultrasonic meters in the area of natural gas flow measurement. Thermal mass meters compete with ultrasonic meters and differential pressure-based meters for flare gas and combustion air measurement.

The single most important thing that flowmeter suppliers can do to increase market share is to educate end users about the correct use of their technology. This will not only prevent end users from using a flowmeter that is not suited for a particular application, it will help them better understand the technologies they use. Laying out the paradigm-case applications is a good start in that direction.

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