

FLOW METER TECHNOLOGIES FOR LIQUID AND GAS MEASUREMENT

Courtney Vaughan - Flow & Density Business Development Manager

Emerson Measurement Solutions - Houston, Texas - 2026

Introduction

Accurate flow measurement is critical across the oil and gas, chemical, power, water, and process industries. Flow data impacts custody transfer transactions, process control, product quality, energy management, safety systems, and regulatory compliance. This paper provides an overview of common industrial flowmeter technologies and discusses key selection criteria and performance considerations.

Selection Considerations

Flowmeter selection should begin with understanding accuracy, repeatability, and rangeability required for the application. Accuracy affects accountability and process efficiency, repeatability supports stable process control, and turndown determines the useful operating range of the meter. In addition to the measurement performance, other selection factors like process fluid type and parameters, ambient/environment conditions, available power, piping configuration, hazardous area requirements, safety requirements, maintenance requirements, initial cost, associated installation costs, and total lifecycle costs are also critical considerations for selecting the appropriate technology for a particular application.

Common Flow Measurement Technologies

Most common technologies for industrial use include differential pressure, positive displacement, turbine, magnetic, vortex, ultrasonic, and Coriolis flowmeters. Each technology uses a different measurement principle and offers distinct advantages and limitations. This paper is not intended to be all-encompassing of every type of flow meter available, rather to discuss the most commonly used technologies for measuring flow.

Differential Pressure Flowmeters

Differential pressure meters infer flow from pressure changes generated by a restriction. The most common restriction type is an orifice plate, but there are many other types. The restriction device (called the Primary Element) is paired with a pressure transmitter (Secondary Element) that is capable of measuring differential across two ports: one port before the restriction where pressure will be higher (P1), and one port after the restriction where pressure will be lower (P2). The transmitter converts the difference between P1 and P2 to flow using an equation. Temperature and static line pressure sometimes measured as well, which can compensate for changes in density and compressibility of the fluid being measured, and the final flow output becomes more accurate. For custody transfer applications, a flow computer is added (Tertiary Element) to perform final calculations and meet industry requirements. Differential pressure is the most common and oldest form of flow technology on the market.

Advantages:

- Well understood, versatile, and cost effective technology
- Can be used for both liquids and gases
- Generally 0.5 – 5 % Accuracy
- No need for wet calibration
- Loop Powered

Disadvantages:

- Permanent pressure loss (energy costs)
- Impulse lines and many components (plugging, leak points)
- Longer straight pipe run requirements
- Limited turndown
- Accuracy affected by plate wear

Positive Displacement Flowmeters

Positive displacement meters directly measure discrete fluid volumes using mechanical elements. A known quantity of fluid is metered with each rotation of the inner mechanism. Rotations are picked up by several means, but most often converted to electrical pulses. During calibration, a correlation is established between the rate of the electrical pulses and the rate of fluid flow, which creates a unique “K-Factor” for each meter. These are commonly used in custody transfer of crude and refined liquids, but also have versions used for measuring gas flow as well.

Advantages:

- Power not always required if using mechanical counter
- Well accepted technology
- Good for high viscosity fluids
- No upstream / downstream straight runs required
- Some models can be custody grade transfer accuracy

Disadvantages:

- Permanent pressure loss (energy costs)
- Mostly used for liquids, although there are a few gas designs
- Large line sizes = higher cost and size/weight
- Mechanical wear (higher maintenance)
- Can require other components (i.e. strainer)

Turbine Flowmeters

Turbine meters measure fluid velocity through rotor speed. A rotating set of blades, similar to a fan or boat propeller, are placed inside of a tubular body/pipe. As flow goes through the pipe, the energy of the fluid spins the rotor, and each rotation (or portions of each rotation) are converted to an electrical pulse. Similar to the positive displacement meter, during calibration a correlation is established between the rate of the electrical pulses and the rate of fluid flow, which creates a unique “K-Factor” for each meter. Commonly used for both custody transfer and process control, liquids and gases.

Advantages:

- Low Pressure Drop
- Well accepted technology
- Good for refined and high viscosity fluids
- Can be custody transfer accuracy
- Power not always required

Disadvantages:

- Limited turndown (5:1 or 10:1)
- Mechanical wear (higher maintenance)
- Different calibration factor for each fluid
- Can require other components (i.e. flow conditioner, strainer)
- Longer straight pipe run requirements

Magnetic Flowmeters

Magnetic flowmeters operate according to Faraday’s Law and are ideal for conductive liquids. “Mag Meters” use electromagnetic principles and the conductivity of the fluid flowing through them to produce a small voltage. The voltage generated is proportional to the fluid flow rate. During calibration, a correlation is established between the voltage generated and the flow rate, creating a flow calibration factor that is unique to each meter. Very frequently used for water flow measurement, as well as harsh chemicals due their non-metallic inner liner.

Advantages:

- No obstructions, no pressure drop
- Can handle/measure highly corrosive fluids
- Large line sizes available
- No moving parts = no maintenance

Disadvantages:

- Liquids only, and must be conductive
- Has straight run requirements
- Chemical reactions and solids can cause noisy outputs (error)
- Sometimes turndown is limited (5:1 or 10:1)

Vortex Flowmeters

Vortex meters utilize vortex shedding frequency to determine flow. Using the Von Karman effect, a “shedder bar” is placed directly into the flowing stream. The shedder bar creates a pattern of alternating vortices downstream of the bar. A highly sensitive mechanism is placed where those vortices occur at their strongest, and is deflected side to side. Those deflections are converted to electrical pulses. Similar to positive displacement and turbine meters, during calibration a correlation is established between the rate of the electrical pulses and the rate of fluid flow, which creates a unique “K-Factor” for each meter. Commonly used in steam flow applications and other “clean” fluids and gases.

Advantages:

- Low pressure drop
- Can measure liquid, gas, & vapor
- Simple installation
- No moving parts = no maintenance

Disadvantages:

- Generally not for custody transfer
- Has straight pipe run requirements
- Generally not for viscosities above 10cP
- Hydraulic noise & vibration can cause error

Ultrasonic Flowmeters

Ultrasonic flowmeters determine flow from transit-time differences of acoustic signals. They are available as both inline as well as externally-mounted installations, and provide excellent diagnostics and large-line-size capability. Transducers are placed strategically on the meter body or exterior of the pipe, and propagate ultra-high frequency sound waves from one side of the pipe to the other at an angle. One transducer sends while the other receives, and then switch roles so that the receiver becomes the sender, and the sender becomes the receiver. When the angle of the sound wave is in the direction of fluid flow, the time for the sound wave to reach from the sending transducer to the receiving is measured (T1). When the angle of the sound wave is in opposition to the flow direction, the sound wave is slowed down by the force of the fluid flow, and that time is also measured (T2). The difference between T1 and T2 is proportional to the fluid flow rate. During calibration, the time difference is correlated to the flow rate, establishing a calibration factor. Inline installations are commonly used for liquid and gas custody transfer. Externally mounted units are commonly used for water flow and process control/monitoring.

Advantages:

- No obstructions, no pressure drop
- In-line or external to pipe installation options
- Some can be custody transfer grade accuracy
- Advanced process & meter diagnostics
- No moving parts = no maintenance
- Large line sizes available

Disadvantages:

- Has straight run piping requirements
- Sometimes requires flow conditioner
- Sometimes can be higher CAPEX cost

Coriolis Mass Flowmeters

Coriolis meters directly measure mass flow of both liquids and gases, as well liquid density using vibrating/oscillating tube technology. Flow is diverted into tube(s) that are oscillated side to side. This induces Coriolis forces and results in the tubes “twisting” to a very small degree. The amount of “twist” is timed from one side of the tubes to the other, using sensors placed on each end of the tubes. That time of movement from one end of the tubes to the other is proportional to the mass flow of the fluid passing through the meter. During calibration, that time is correlated to mass flow and a flow calibration factor is established.

These same sensors also detect the resonant frequency of the tubes, and the resonant frequency correlates with fluid density. During calibration, the resonant frequency of the tubes with both air and water in them is detected, and a density calibration factor is established. It is important to note that while the meter accurately measures mass flow for both liquids and gases,

the density measurement function is designed for liquid density measurement only. Changes in gas density do not have enough of an impact on the resonant frequency to reliably produce a density correlation with gases.

Commonly used for custody transfer and critical process applications.

Advantages:

- Direct mass flow measurement of liquids and gases
- Direct liquid density measurement
- Custody transfer grade accuracy
- Advanced process and meter diagnostics
- No moving parts = no maintenance
- No straight run piping requirements

Disadvantages:

- 16" max meter size
- Not recommended for steam
- Higher CAPEX cost

Conclusion

No single technology is suitable for every application. Successful selection requires balancing accuracy, maintenance, installation requirements, operating cost, diagnostics capability, and lifecycle value. Understanding the strengths and limitations of each technology allows users to select the best solution for their process.