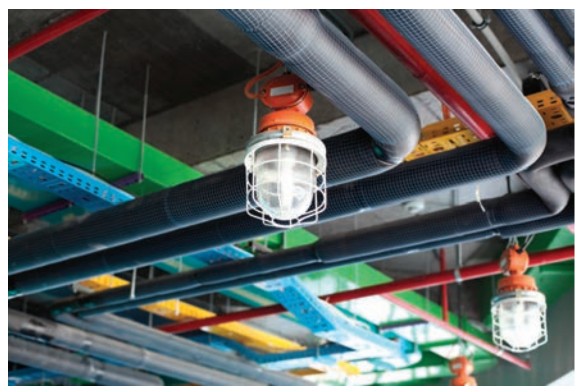
Badger Meter

Choosing the Right Flow Meter



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White Paper

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INTRODUCTION

Flow measurement is a critical aspect of plant operation in the chemical processing industry (CPI). Users choosing equipment to meter the flow of liquid or gas processes must consider a wide range of factors to arrive at an optimal solution. Experience has shown there are significant differences between meter technologies, with each type of device having its own advantages and disadvantages for processing facilities.

The following article describes the key criteria in flow meter selection. It evaluates the most common instrument designs and offers guidance in implementing the right solution for specific applications.

TODAY'S INDUSTRY REQUIREMENTS

To succeed in a competitive global marketplace, chemical manufacturers must meet rigorous demands for process efficiency, asset reliability and energy consumption. Plants are also getting larger, putting pressures on capital investment, on-stream reliability and product quality.

Leading chemical companies have recognized the importance of sustainable manufacturing practices. The need for this approach as a basic business tenet is balanced between a genuine desire to protect the environment and very practical economic drivers of maximizing plant productivity and revenue. Resource scarcity makes it essential for long-term business success to use only the necessary amounts of limited resources, like water, petroleum and other raw materials (See Fig. 1).

With a growing focus on corporate responsibility and sustainability, the monitoring of greenhouse gas (GHG) emissions is critical to all chemical-related businesses. Firms must ensure regulatory compliance while protecting assets, personnel and the environment. Another crucial concern is custody transfer, with increasing energy costs driving the need for improved fiscal metering of high-value products.

TYPICAL FLOW APPLICATIONS

In modern chemical plants, personnel need to make faster and better decisions by capturing, managing and analyzing the right data at the right time. These facilities rely heavily on flow processes, and thus accurate and reliable measurement technology is vital to the efficiency and safety of their operations (See Fig. 2).

Typical flow-metering applications in the chemical/petrochemical sector include:

- Chemical Batching
- Dosing/Blending
- Catalyst Injection
- Chemical Recovery
- Custody Transfer
- Steam Flow
- Lube Oil Loading
- Process Cooling
- Pressure Regulation
- Leak Detection
- Fuel Consumption Monitoring
- Fiscal Transfer
- Product Load-out
- Reactor Feed
- Safety Shutdown
- Waste Treatment
- Emissions Monitoring

Most chemical processing plants have two primary flow measurement challenges: accuracy and cost. The goal is to correctly match the right flow meter to the right application to achieve the best performance for the lowest purchase prices and total cost of ownership.

COMMON MEASUREMENT TECHNOLOGIES

Flow meters are excellent tools to measure, monitor, and control the distribution of a host of process fluids. The question is which technology to use, since a wide variety of meter designs are available. Each type of meter has pros and cons, and must be properly deployed to achieve optimal performance.

Coriolis

Coriolis meters contain a vibrating tube in which a fluid flow causes changes in frequency, phase shift or amplitude. The sensor signal is fed into the integrally mounted pc-board. The resulting output signal is strictly proportional to the real mass flow rate, whereas thermal mass flow meters are dependent of the physical properties of the fluid.

One of the most important features of Coriolis flow meters is that they directly measure fluid mass over a wide range of temperatures with a very high degree of accuracy. Their unobstructed, open flow design is suitable for viscous, non-conductive fluids that are difficult to measure with other technologies. With no internal moving parts, Coriolis meters require a minimum amount of attention once installed. However, they are sometimes considered too sophisticated, expensive or unwieldy for certain applications (See Fig. 3).

Differential Pressure

Differential Pressure (DP) meters measure the pressure differential across the meter and extract the square root. They have a primary element that causes a change in kinetic energy, creating differential pressure in the pipe, and a secondary element measuring the differential pressure and providing a signal or read-out converted to the actual flow value.

Differential Pressure meters are versatile instruments, which employ a proven, well-understood measuring technology that does not require moving parts in the flow stream. DP meters are not greatly affected by viscosity changes. However, they have a history of limited accuracy and turndown, as well as complex installation requirements.

Electromagnetic

Electromagnetic meters employ Faraday's law of electromagnetic induction, whereby voltage is induced when a conductor moves through a magnetic field. The liquid acts as the conductor, with energized coils outside the flow tube creating the magnetic field. The produced voltage is directly proportional to the flow rate.

Electromagnetic meters will measure virtually any conductive fluid or slurry. This includes process water and wastewater. They provide low pressure drop, high accuracy, high turndown ratio, and excellent repeatability. The meters have no moving parts or flow obstructions, and are relatively unaffected by viscosity, temperature and pressure when correctly specified. Nevertheless, their propensity to foul can cause maintenance issues. Electromagnetic meters tend to be heavy in larger sizes and may be prohibitively expensive for some purposes.

Positive Displacement

Positive Displacement (PD) meters separate liquid into specific increments, and the flow rate is an accumulation of these measured increments over time. The rotational speed of a PD meter's impeller is a function of the process flow. An internally coupled counter, either electronic or mechanical, monitors the measuring element's rotations to provide a volumetric recording of the flow total.

Positive Displacement meters are highly accurate (especially at low flows) and have one of the largest turndown ratios. The devices are easy to maintain as they have only one or two moving parts. There is no need for straight pipe lengths as with other metering approaches. However, PD meters require clean fluids and can be large and burdensome to install.

Thermal Mass

Thermal Mass meters utilize a heated sensing element isolated from the fluid flow path. The flow stream conducts heat from the sensing element, which is directly proportional to the mass flow rate. The meter's electronics package includes the flow analyzer, temperature compensator, and a signal conditioner providing a linear output directly proportional to mass flow.

Thermal mass meters carry a relatively low purchase price. They are designed to work with clean gases of known heat capacity, as well as some low-pressure gases not dense enough for Coriolis meters to measure. The main disadvantage of thermal technology is low-to-medium accuracy, although suppliers have improved the capabilities of these meters in recent years.

Turbine

Turbine meters contain a freely suspended rotor, and the flow against its vanes causes the device to rotate at a rate proportional to flow velocity. A sensor/transmitter is used to detect the rotational rate of the rotor; when the fluid moves faster, more pulses are generated. The transmitter processes the pulse signal to determine the flow of the fluid in either forward or reverse direction.

Turbine meters incorporate a time-tested measuring principle, and are known for high-accuracy, wide turndown and repeatable measurements. They produce a high-resolution pulse rate output signal proportional to fluid velocity, and hence, to volumetric flow rate. Turbine meters are limited to use with clean fluids only. Bearing wear — a common concern with this type of device — was largely addressed by the development of ceramic journal bearings. As a mechanical meter, turbines require periodic recalibration and service.

Impeller

Impeller meters are frequently used in large diameter water distribution systems. The device consists of a paddle wheel inserted perpendicularly into a process stream. The number of rotations of the paddlewheel is directly proportional to the velocity of the process.

Impeller meter attributes include: direct volumetric flow measurement (often with visual indication), universal mounting, fast response with good repeatability, and relatively low cost. Note their performance suffers in applications with low fluid velocity. The meters are also sensitive to flow profile. They can only be used in clean, low-viscosity media.

Variable Area

Variable Area meters are inferential measurement devices consisting of two main components: a tapered metering tube and a float that rides within the tube. The float position — a balance of upward flow and float weight — is a linear function of flow rate. Operators can take direct readings based on the float position with transparent glass and plastic tubes.

Simple, inexpensive and reliable, Variable Area meters provide practical flow measurement solutions for many applications. Be advised most of these meters must be mounted perfectly vertical. They also need to be calibrated for viscous liquids and compressed gases. Furthermore, their turndown is limited and accuracy relatively low.

Ultrasonic

There are two types of ultrasonic meters: transit time and Doppler. Both designs will detect and measure bi-directional flow rates without invading the flow stream. Ultrasonic meters are ideal for troubleshooting, diagnostics and leak detection. They can be used with all types of corrosive fluids, as well as gases, and are insensitive to changes in temperature, viscosity, density or pressure (See Fig. 4)

Ultrasonic meters have no moving or wetted parts, suffer no pressure loss, offer a large turndown ratio, and provide maintenance-free operation—important advantages over conventional mechanical meters. Conversely, the precision of these meters becomes much less dependable at low flow rates. Unknown internal piping variables can shift the flow signal and create inaccuracies.

Vortex

Vortex meters make use of a principle called the von Kármán effect, whereby flow will alternately generate vortices when passing by a bluff body. A bluff body is a piece of material with a broad, flat front that extends vertically into the flow stream. Flow velocity is proportional to the frequency of the vortices. Flow rate is calculated by multiplying the area of the pipe times the velocity of the flow.

Vortex meters have no moving parts that are subject to wear, and thus regular maintenance is not necessary. Only clean liquids can be measured with this type of instrument. They are particularly well suited for measurement of gas emissions produced by wastewater. Vortex meters may introduce pressure drop due to obstructions in the flow path.

Oval Gear

Oval Gear meters utilize a positive displacement meter design, whereby fluid enters the inlet port and then passes through the metering chamber. Inside the chamber, fluid forces the internal gears to rotate before exiting through the outlet port. Each rotation of the gears displaces a specific volume of fluid. As the gears rotate, a magnet on each end of the gear passes a reed switch, which send pulses to the microprocessor in the register to change the LED display segments.

The latest breed of Oval Gear meters directly measures actual volume. It features a wide flow range, minimalpressure drop and extended viscosity range. This design offers easy installation and high accuracy, and measures high temperature, viscous and caustic liquids with simple calibration.

Nutating Disc

Nutating Disc meters are most commonly used in water-metering applications. A disc attached to a sphere is mounted inside a spherical chamber. As fluid flows through the chamber, the disc and sphere unit wobble or "nutate." This effect causes a pin, mounted on the sphere perpendicular to the disc, to rock. Each revolution of the pin indicates a fixed volume of liquid has passed.

Nutating Disc meters have a reputation for high accuracy and repeatability, but viscosities below their designated threshold adversely affect performance. Meters made with aluminum or bronze discs can be used to meter hot oil and chemicals.

KEY FACTORS IN METER SELECTION

In a typical chemical production facility, fluid characteristics (single or double phase, viscosity, turbidity, etc.), flow profile (laminar, transitional, turbulent, etc.), flow range, and accuracy requirements are all important considerations in determining the right flow meter for a particular measurement task. Additional considerations such as mechanical restrictions and output-connectivity options impact the user's choice.

For CPI operations, the key factors in meter selection include:

Process Media
Different flow meters are designed to operate best in different fluids and under different operating conditions. That's why it is important to understand the limitations inherent to each style of instrument. Fluids are conventionally classified as either liquids or gases. The most important difference between these two types of fluid lies in their relative compressibility (i.e., gases can be compressed much more easily than liquids). Consequently, any change that involves significant pressure variations is generally accompanied by much larger changes in mass density in the case of a gas than in the case of a liquid.

Type of Measurement
Industrial flow measurements fall under one of two categories: mass or volumetric. Volumetric flow rate is the volume of fluid passing through a given volume per unit time. Mass flow rate is the movement of mass per time. It can be calculated from the density of the liquid (or gas), its velocity, and the cross sectional area of flow. Volumetric measuring devices, like variable area meters or turbine flow meters, are unable to distinguish temperature or pressure changes. Mass flow measurement would require additional sensors for these parameters and a flow computer to compensate for the variations in these process conditions. Thermal mass flow meters are virtually insensitive to variations in temperature or pressure.

Flow Rate Information
A crucial aspect of flow meter selection is determining whether flow rate data should be continuous or totalized. A flow rate has to do with the quantity of a gas or liquid moving through a pipe or channel within a given or standard period of time. A typical continuous flow measurement system consists of a primary flow device, flow sensor, transmitter, flow recorder, and totalizer.

Desired Accuracy

In chemical production processes, accurate flow measurements can be the difference between on-spec quality and wasted product. Flow meter accuracy is specified in percentage of actual reading (AR), percentage of calibrated span (CS), or percentage of full-scale (FS) units. It is normally stated at minimum, normal, and maximum flow rates. A clear understanding of these requirements is needed for a meter's performance to be acceptable over its full range.

Application Environment

Flow meters can be employed under a host of varying conditions in a chemical process plant. For example, users must decide whether the low or high flow range is most important for their metering application. This information will help in sizing the correct instrument for the job. Pressure and temperature conditions are equally important process parameters. Users should also consider pressure drop (the decrease in pressure from one point in a pipe to another point downstream) in flow measurement devices, especially with high-viscosity fluids. In addition, viscosity and density may fluctuate due to a physical or temperature change in the process fluid.

Fluid Characteristics

Users should be cautious that the selected flow meter is compatible with the fluid and conditions they are working with. Many chemical and petrochemical operations involve abrasive or corrosive fluids, which move under aerated, pulsating, swirling or reverse-flow conditions. Thick and coarse materials can clog or damage internal meter components—hindering accuracy and resulting in frequent downtime and repair.

Installation Requirements

Planning a flow meter installation starts with knowing the line size, pipe direction, material of construction, and flange-pressure rating. Complications due to equipment accessibility, valves, regulators, and available straight-pipe run lengths should also be identified. Nearly all flow meters must be installed with a run of straight pipe before and after their mounting location. Where this is not possible, a flow conditioner can be used to isolate liquid flow disturbances from the flow meter while minimizing the pressure drop across the conditioner.

Power Availability

Pneumatic instrumentation was once used in most hazardous area applications, since there was no power source to cause an explosion. Today's installations normally call for intrinsically safe instruments, which are "current limited" by safety barriers to eliminate a potential spark. Another option is to employ fiber optics. Turbine flow meters offer an advantage in environments where a power source is not available. They do not require external power to provide a local rate/total indicator display for a field application, and instead rely on a battery-power indicator. Solar-powered systems can also be used in remote areas without power.

Necessary Approvals

Chemical firms are obliged to comply with strict standards set by the U.S. Environmental Protection Agency (EPA), North American Industry Classification System (NAICS), American Chemical Society (ACS) and other regulatory bodies. Approvals for the use of flow measurement equipment in hazardous plant locations include FM Class 1 Division 1, Groups A, B, C and D; and FM Class 1, Zone 1 AEx d (ia) ia/IIC/T3-T6. Standards such as the Measuring Instruments Directive (MID) in the European Union (EU) apply to fiscal and custody transfer metering for liquids and gases. In terms of environmental emissions, industrial flow meters must meet the Electromagnetic Compatibility (EMC) Standards EN55011:1992 and EN61326-1:1997.

Output/Indication

Flow meter users must decide whether measurement data is needed locally or remotely. For remote indication, the transmission can be analog, digital, or shared. The choice of a digital communications protocol such as HART®, FOUNDATION Fieldbus™ or Modbus also figures into this decision. In a large chemical facility, flow readings are typically supplied to an industrial automation and control system (IACS) for use in process control and optimization strategies.

OTHER IMPORTANT CONSIDERATIONS

Companies purchasing flow meters should remember that accurate instruments cost more based on their capabilities. It is better to locate the type of meter suited to a specific application before sacrificing features for cost savings. Users should closely evaluate their process conditions, including flow rates, pressure and temperature, and operating ranges. Do not be swayed by lower priced alternatives that would be applied outside of their capabilities.

All meters are affected to some extent by the medium they are metering and by the way they are installed. Consequently, their performance in real world conditions will often be different from the reference conditions under which they calibrated. For the lowest uncertainty of measurement, positive displacement meters are generally the best option. Electromagnetic meters provide for the widest flow range and turbine meters are usually the best choice for the highest short-term repeatability. Despite their high initial cost, Coriolis meters are ideal for measuring particularly viscous substances and anywhere that the measurement of mass rather than volume is required.

Flow meter users should also take care to examine long-term ownership costs. A flow meter with a low purchase price may be very expensive to maintain. Alternatively, a meter with a high purchase price may require very little service. Lower purchase price does not always represent the best value.

Generally speaking, flow meters with few or no moving parts require less attention than more complex instruments. Meters incorporating multiple moving parts can malfunction due to dirt, grit or grime present in the process fluid. Meters with impulse lines can also plug or corrode, and units with flow dividers and pipe bends sometimes suffer from abrasive media wear and blockages. Changes in temperature also affect the internal dimensions of the meter and require compensation.

The need to recalibrate a flow meter depends on how well the instrument fits a particular application. If the application is critical, meter accuracy should be checked at frequent intervals. Otherwise, recalibration may not be necessary for years because the application is non-critical, or nothing will change the meter's performance.

No matter the chosen flow meter technology, overall system accuracy will not exceed that of equipment used to perform the meter calibration. The most precise flow calibration systems on the market employ a positive displacement design. This type of calibrator, directly traceable to the National Institute of Standards and Technology (NIST) via water draw validation, provides total accuracy of at least 0.05 percent.

FIGURES

Figure 1: Leading chemical companies have recognized the importance of sustainable manufacturing practices.

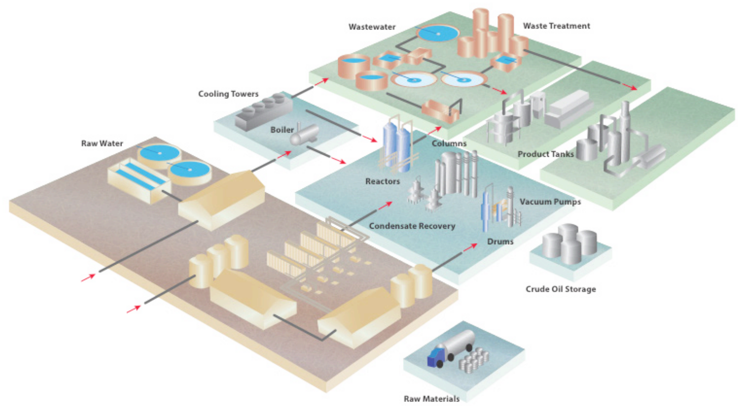

Figure 2: Modern chemical/petrochemical plants rely heavily on flow processes, and thus accurate and reliable measurement technology is vital to the efficiency and safety of their operations.

Figure 3: Coriolis flow meters are designed to directly measure fluid mass over a wide range of temperatures with a very high degree of accuracy.

Figure 4: Clamp-on ultrasonic flow meters can be used for troubleshooting a wide range of flow issues, from verifying the reading of another meter to monitoring flow systems over an extended time period.

SUMMARY

Choosing the right flow measurement solution can have a major impact on operational and business performance. For this reason, companies anticipating a flow meter purchase should consult with a knowledgeable instrumentation supplier in the early stages of a project. The effort spent learning about basic flow measurement techniques, and available meter options, will ensure a successful application once the equipment is installed.

ABOUT BADGER METER

Badger Meter is an innovator in flow measurement and control products, serving water utilities, municipalities, and commercial and industrial customers worldwide. The company's products measure water, oil, chemicals, and other fluids, and are known for accuracy, long-lasting durability and for providing valuable and timely measurement data. For more information, visit www.badgermeter.com.

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