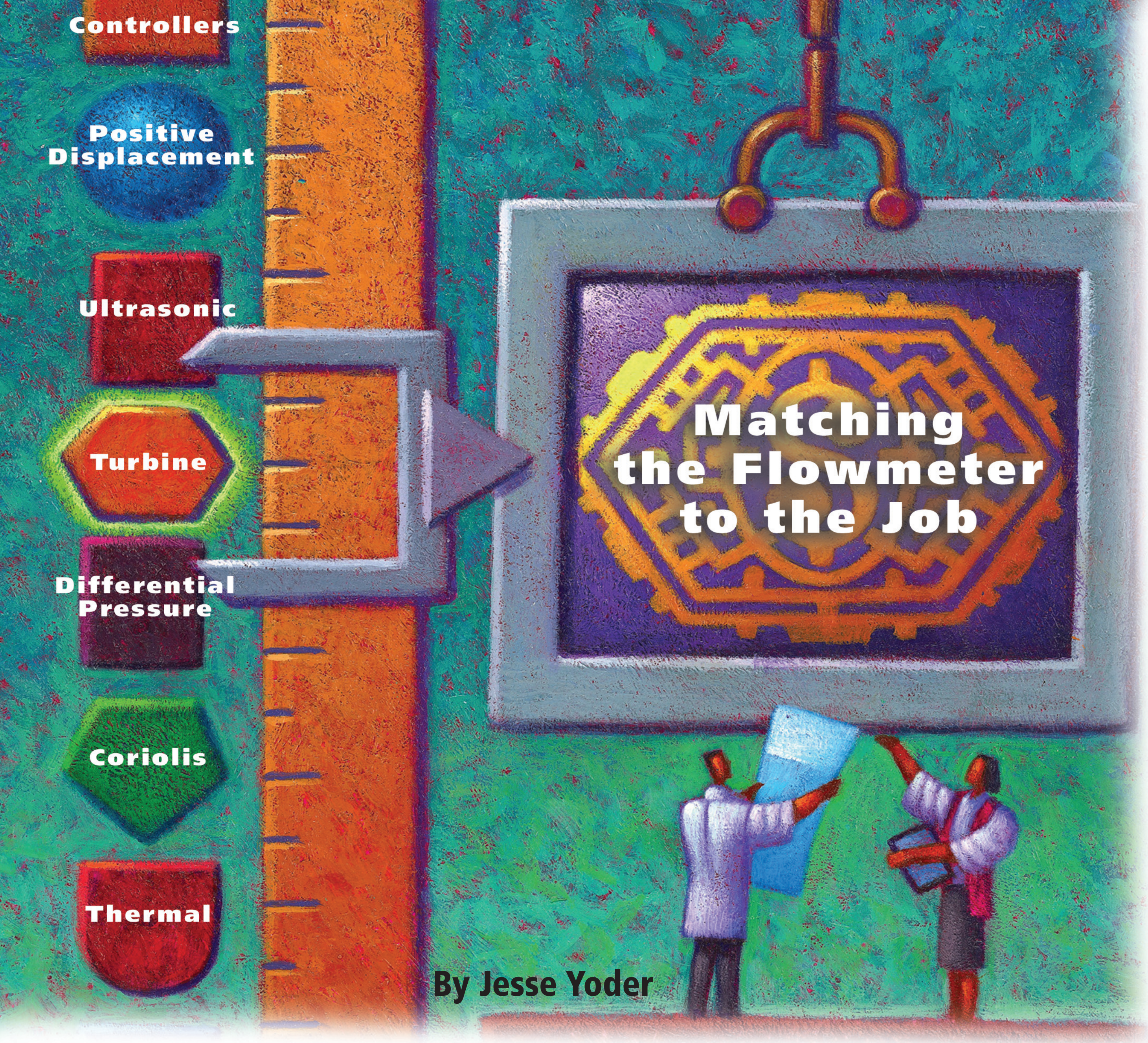


Matching the Flowmeter to the Job

By Jesse Yoder

GAS MEASUREMENT TRENDS

Matter exists in three different states: solid, liquid, and gas. Flow measurement is primarily concerned with measuring the flow of liquids and gases. Gas, which is the primary focus of this article, takes many forms. Types of gas include natural gas, fuel gas, atmospheric gas, compressed natural gas, and many others. Individual gases that are especially important include hydrogen, oxygen, nitrogen, and carbon dioxide. Air is a gas, or, more precisely, a mixture of gases, including nitrogen, oxygen, argon, etc. Steam, which is water vapor, can also be considered a form of gas.

Gas flow measurement can be divided into three broad categories: industrial, commercial, and residential. Industrial gas flow measurement includes flow measurement that occurs in manufacturing and process plants, including chemical plants and refineries. Commercial gas flow measurement occurs at businesses and commercial buildings such as restaurants, office buildings, and apartment complexes. This is a form of utility measurement, since these flowmeters typically measure the amount of natural gas used by the business or in the commercial building. Residential gas flow measurement refers to flowmeters that measure the amount of gas used at individual homes and apartments.

Utility meters are meters used to measure gas or water entering a building or plant for the purpose of billing the plant for its use of gas or water. These meters are typically sold to a gas or water utility and installed at the building or plant by the utility company. Meters used within a building or plant for internal allocation purposes of gas, water, or other liquids, are considered to be industrial meters. They are typically sold to the owners of the plant or building itself, rather than to a utility company.

Natural gas plays an especially important role in the flowmeter industry. Natural gas is a vital source of fuel and energy. Like coal and petroleum, it is a fossil fuel. Like air, natural gas is a mixture of gases. These include methane, ethane, propane, butane, and other alkanes. Natural gas is found in the ground, along with petroleum. It is extracted and refined into fuels that supply a significant portion of the world's energy.

Compressed natural gas is a source of fuel for alternative energy vehicles. Vehicles powered by natural gas are highly efficient and emit low amounts of carbon monoxide, nitrogen oxide, and pollutants harmful to the ozone layer. CNG-powered vehicles are fueled at filling stations that are very much like gasoline stations and several companies have created flowmeters specifically designed for these CNG filling stations.

Positive Displacement

Positive displacement flowmeters are widely used for utility gas measurement. One main type is the diaphragm meter. Diaphragm meters have several diaphragms that capture the fluid as it passes through the meter. Differential pressure across the meter causes one diaphragm to expand and one to contract. A rotating crank mechanism helps produce a smooth flow of gas through the meter. This mechanism is connected via gearing to the index, which registers the amount of fluid that passes through the meter.

Another type of PD meter for gas flow measurement is the rotary meter. Rotary flowmeters have one or more rotors that are used to trap the fluid. With each rotation of the rotors, a specific amount of fluid is captured. Flow rate is proportional to the rotational velocity of the rotors. Rotary meters are used for both liquid and gas industrial applications.

Turbine

Turbine flowmeters have a rotor that spins in proportion to flow rate. There are many types of turbine meters, but many of those used for gas flow are called axial meters. Axial turbine meters have a rotor that revolves around the axis of flow. Most flowmeters for oil measurement and for measuring industrial liquids and gases are axial flowmeters. Axial meters differ according to the number of blades and the shape of the rotors. Axial meters for liquids have a different design from axial meters for gas applications. Like PD meters, turbine meters are used as a billing meter to measure the amount of gas used at commercial buildings and industrial plants.

One main difference between turbine and positive displacement flowmeters is that turbine meters compute flow based on a velocity measurement, while positive displacement meters actually capture the flow and measure it volumetrically. Turbine meters excel at measuring clean, steady, medium to high-speed flow of low-viscosity fluids. Positive displacement meters, by contrast, excel at measuring low-speed flows and high-viscosity fluids. While there are some applications in which they compete, turbine and positive displacement flowmeters are more complementary than competing.

Positive displacement meters for gas applications also face some competition from turbine flowmeters. However, PD meters are mainly used for the smaller pipe sizes, and most PD meters for commercial and industrial gas applications have sizes somewhere between 1½ inches and 10 inches. Turbine meters, by contrast, perform best with steady, high-volume flows. For this reason, turbine meters are more likely to be used for pipe sizes above 10 inches. While turbine and PD meters overlap in the four-to-10 inch size range, PD meters still have an advantage in the lower sizes. Low flow rates are not an obstacle for PD meters.

Ultrasonic

The use of ultrasonic flowmeters to measure natural gas flow gained momentum following the publication of AGA-9 in June 1998. The report, issued by the American Gas Association (*www.aga.org*), outlines criteria for using ultrasonic flowmeters for custody transfer of natural gas. Prior to the release of AGA-9, the association had previously issued reports on differential pressure flowmeters (AGA-3) and turbine flowmeters (AGA-7). Since the publication of AGA-9, the AGA has also issued a report on the use of Coriolis flowmeters (AGA-11).

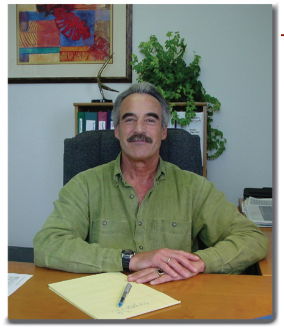
The use of ultrasonic flowmeters is continuing to grow, both for custody transfer and process gas measurement. Unlike PD and turbine meters, ultrasonic flowmeters do not have moving parts. And pressure drop is much reduced with an ultrasonic meter when compared to PD, turbine, and DP meters. Installation of ultrasonic meters is relatively straightforward, and maintenance requirements are low.

Ultrasonic flowmeters come as both inline and clamp-on configurations. Some have one ultrasonic beam, while those with higher accuracy use multiple beams. These are known as multipath ultrasonic flowmeters. Meters used for custody transfer purposes are inline multipath meters. Most of these custody transfer meters use four, five, or six paths, depending on manufacturer, to make a highly accurate measurement. Manufacturers include Instromet (*www.instromet.com*), Emerson Daniel (*www.emersonprocess.com/daniel/*), and FMC Measurement Solutions (*www.fmcmeasurementsolutions.com*).

Differential Pressure

DP flowmeters consist of a differential pressure transmitter and a primary element. The primary element places a constriction in the flow stream, and the DP transmitter measures the difference in pressure upstream and downstream of the constriction. The transmitter or a flow computer then computes flow, using

Commentary: Industrial Gas Efficiency



By Bob Steinberg

Are you maximizing operating efficiencies? Are you wasting energy heating a building with all the doors open? Are you adjusting for peak usage? Are you providing your gas broker with an accurate assessment for your next gas allocation? With gas prices rising as fast and as high as they are, these are all very important, top-of-mind questions to ask.

Under current market conditions, the accurate monitoring of gas flow rate and consumption should be high on the industrial priority list. No longer is it sufficient to depend solely on the billing meter, as most facilities demand tighter control of their gas usage. As such, it may be time to consider placing NIST-traceable thermal mass flowmeters at both the billing meter and the entry of the plant, thus providing the capability to track gas usage within your facility each minute, each hour, and each day.

In addition, to get an even better handle on plant efficiency, thermal mass flowmeters can be configured to monitor the gas lines going into different building locations or departments. By submetering, you can assess departmental inefficiencies, assign costs to different operating areas, and institute conservation measures as appropriate.

Taking it one step farther, you can optimize your combustion process by monitoring the natural gas (or backup fuel of propane) into a furnace or burner (along with the air or oxygen line). Proper control of the air/fuel ratio can improve efficiency, lower fuel consumption, improve product quality, and increase product yields.

Thermal mass flowmeters are a good fit for measuring natural gas at the plant for a number of reasons. They are affordable (typically \$1,500 to \$3,000), and they measure mass flow directly (SCFM, SCFH, LBS/Min, etc.) without the need for temperature and pressure corrections. This eliminates ancillary equipment, such as temperature and pressure gauges and their associated wiring and installation. Further, thermal mass flowmeters are rangeable over a 100-to-1 turndown (i.e., their operating range is from 1 percent of specified full scale to 100 percent of full scale). Orifice plates and venturis, on the other hand, generally have a turndown in the range of 3-to-1 to 5-to-1. Turbine meters and vortex meters typically have a 10-to-1 turndown.

The wide turndown offered by thermal mass meters is useful in natural gas applications due to the large swings in demand throughout the day, especially at off-hours when production is at its lowest capacity. Also, seasonal variations can be quite severe. On burner applications, the low-end sensitivity inherent in a thermal mass flowmeter is particularly pronounced. In fact, many manufacturers can resolve flow rates as low as 0.1 of an SCFM in a one-inch pipe (approximately 15 SFPM).

Thermal mass meters also have negligible pressure drop, which is particularly important in conserving natural gas usage. With a linear 4-20 mA output (proportional to mass flow of the gas), thermal mass meters are suitable for a DCS, PLC, or Data Logger.

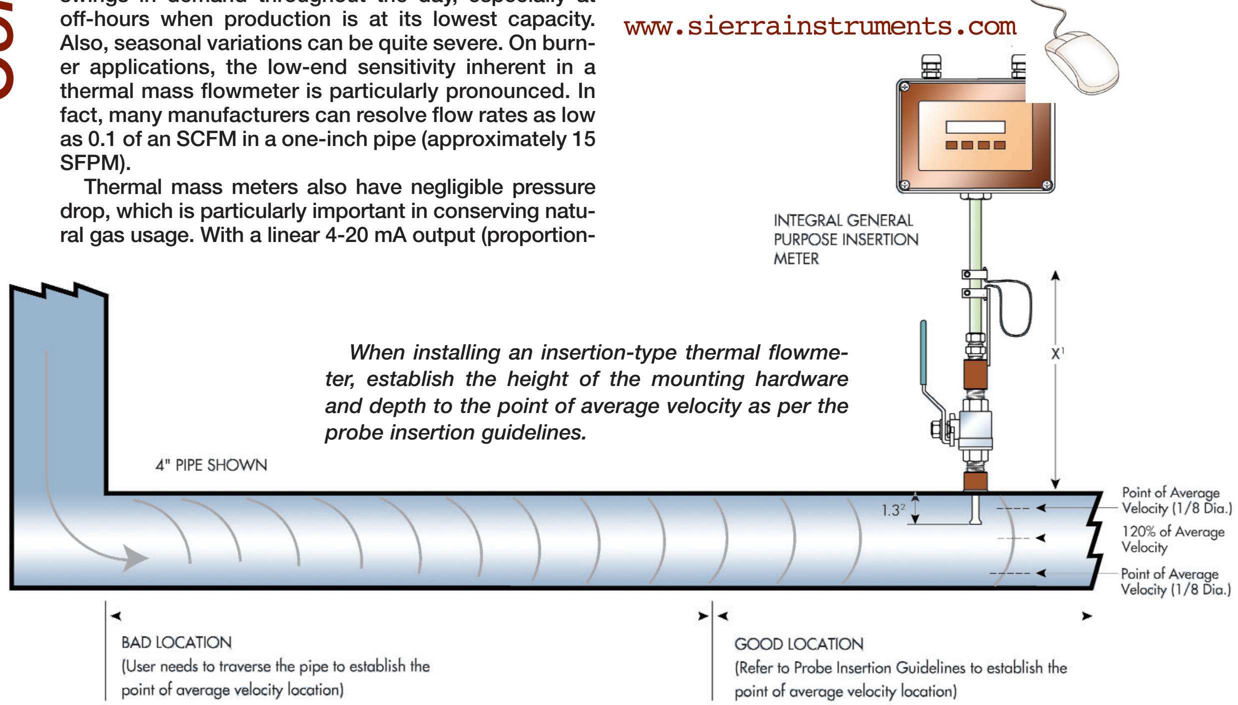
Also, the meters have no moving parts, are dirt insensitive (and cleanable if necessary), and have high accuracy and repeatability that is typically 0.25 percent. Furthermore they are easy to install, as all manufacturers offer both in-line styles with NPT fittings or flanges for the smaller lines and insertion styles for medium-to-large lines. The insertion styles can be installed with a half coupling and some mounting hardware, such as a compression fitting or valve assembly. Most manufacturers offer both integral and remote styles in either general-purpose enclosures (typically NEMA 4X) or explosion-proof enclosures (Class I, Div 1, Groups B, C, and D).

Fundamentally, thermal mass flow meters operate on the principal of heat transfer. In the case of the "constant temperature method," there are always two reference grade platinum sensors. One of the sensors is self-heated and the other is the reference and measures the gas temperature. As gas flows by the heated sensor, the gas molecules carry heat away from the surface of the sensor and the sensor cools down as it loses energy. The sensor drive circuit replenishes the lost energy by heating the flow sensor up until it is a constant temperature differential above the reference sensor. The electrical power required to maintain constant temperature differential is directly proportional to the gas mass flow rate.

Because of this methodology, thermal mass flowmeters provide an affordable means to monitor natural gas at the plant, at the department, or at the burner. As a result, users have an opportunity to realize improved operating efficiencies, promote conservation, and monitor and improve plant processes.

About the Author

Bob Steinberg is the president of Sage Metering Inc., a manufacturer of thermal gas mass flowmeters for industrial and municipal applications. Mr. Steinberg has started three successful enterprises and has over 20 years of management, sales, and marketing experience in the process industry. In addition, he has had extensive experience managing, supporting and training industrial rep organizations, specifically in the thermal mass flowmeter industry. Mr. Steinberg can be reached at bob@sagemetering.com *or 866 677-7243.*



When installing an insertion-type thermal flowmeter, establish the height of the mounting hardware and depth to the point of average velocity as per the probe insertion guidelines.

Bernoulli's theorem.

Types of primary elements include orifice plates, venturis, flow nozzles, pitot tubes, wedges, and others. Venturis are especially suited to high-speed flows. Orifice plates are still the most widely used type of primary elements. However, they can be disadvantageous because they can generate a pressure drop and can be knocked out of position by impurities in the flow stream. Orifice plates are also subject to wear over time.

DP flowmeters are used to measure the flow of liquid, gas, and steam. Like ultrasonic and turbine meters, they are used for the custody transfer of natural gas. In many cases, end-users buy their pressure transmitters and primary elements from different suppliers. However, several vendors have integrated the pressure transmitter with the primary element to form a complete flowmeter that can be calibrated with the primary element and DP transmitter already in place.

Coriolis

Coriolis flowmeters are known for their accuracy. However, Coriolis meters are primarily used for liquid flow measurement because gases are less dense than liquids and are somewhat more difficult to measure. Still, a number of suppliers have developed Coriolis meters for gas flow measurement, and this is a growing focus area. One application that Coriolis has come to excel in is in measuring compressed natural gas for alternative fuel vehicles. Here they compete primarily with turbine flowmeters.

Thermal

Thermal flowmeters are used almost exclusively to measure gas flow. Thermal flowmeters typically inject heat into the flow stream and then measure how quickly it dissipates. This value is proportional to mass flow. Two methods used are called constant current and constant temperature.

Thermal flowmeters grew out of the use of hot-wire anemometers for research applications. Early companies to develop thermal flowmeters include Sierra Instruments (*www.sierrainstruments.com*), Kurz Instruments (*www.kurz-instruments.com*), and Fluid Components International (*www.fluid-components.com*). Thermal flowmeters excel at measuring gas at low flow rates. Measuring low flows is a difficult proposition for some meters, including vortex, which makes thermal meters a hot commodity for gas measurement. Accuracy levels are improving for thermal flowmeters as well, as suppliers introduce product improvements.

One application where thermal flowmeters are widely used is in the measurement of stack flows. Gas flow has to be measured in smoke stacks to conform to Environmental Protection Agency reporting requirements. Insertion thermal flowmeters are used to measure the flow of sulfur dioxide (SO_2), nitrogen oxide (NO_X), and other industrial pollutants. Because of the large size of the stacks, insertion

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Circle 22 or Request Info Instantly at www.FlowControlNetwork.com thermal meters that use multiple measuring points are a good fit for these applications. DP flowmeters with averaging pitot tubes, and ultrasonic flowmeters are also commonly used for smoke stack applications.

Mass Flow Controllers

Mass flow controllers not only measure flow; they also control it. They differ from thermal flowmeters in that most divert a small portion of the flow into a parallel channel, and then measure the flow through that parallel channel. The flowmeter then performs a calculation to determine mass flow through the entire flowmeter. Most also contain an integrated valve that is used to control flow. A setpoint is determined, usually by the user, and the valve is adjusted so that flow reaches that setpoint.

Most mass flow controllers use thermal methods to determine flow rate in the parallel flow path, though some use a differential pressure principle. And some mass flow controllers are sold without the valve, meaning they are functioning as flowmeters rather than controllers. Mass flow controllers are widely used in the semiconductor industry, but many have industrial applications. It is important for a mass flow controller to know what gas is being measured in order to ensure an accurate measurement. Mass flow controllers can also be used to measure liquid flow.

Other Types

Vortex and variable area flowmeters are also used to measure gas flow. Vortex flowmeters are one of the few types of meters, besides DP, that can accurately measure the flow of liquid, steam, and gas. However, vortex meters especially excel at measuring steam flow, since they can handle high temperatures.

Variable areas meters can measure the flow of both liquid and gas, and they also are used for a limited amount of steam flow measurement. Variable-area meters rely on a float that rises in proportion to flow rate. They are primarily a low-cost alternative where a visual indication of flow is sufficient. While most still must be read visually, some variable-area meters have been manufactured with transmitters.

With eight types of flowmeters measuring gas flow, there is no shortage of technology available. Some applications, such as custody transfer of natural gas, CNG measurement, and stack flow measurement, have become the focal point of competition among the meter types. FC

Jesse Yoder, Ph.D., is a regular contributor to *Flow Control.* The president of Flow Research Inc., Dr. Yoder has been a leading analyst in the process control industry since 1986. He has written over 60 market studies on industrial automation and process control and has published numerous journal articles. Dr. Yoder's latest study, *The World Market for Gas Flow Measurement*, covers eight of the most prominent flowmeter types in the gas measurement field. Dr. Yoder can be reached at *jesse@flowresearch.com* or 781 245-3200.

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