ACCURACY IN ADVERSITY

Matthew J. Olin and Scott A. Rouse, Sierra Instruments, USA, explore how advancements in natural gas sampling innovations are increasing flow metering accuracy for tough applications.

It is a fact of the industry that oil and gas companies are required, by various rules and regulations, to routinely perform gas sampling to establish gas composition, flow rates and gas properties. In order to comply with regulations, gas sampling tools must achieve high accuracy at low flows with varying gas compositions, temperatures and pressures. For many technologies, these requirements can be difficult to meet.

This article reviews various gas sampling challenges and describes how several recent innovations in thermal mass flow sensor technology offer gas analyser manufacturers, and oil and gas companies, new flow metering options to solve the gas sampling challenges that vex the industry.

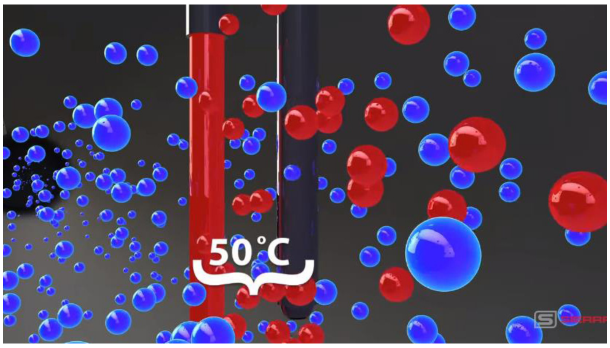

Figure 1. Thermal dispersion mass flow.

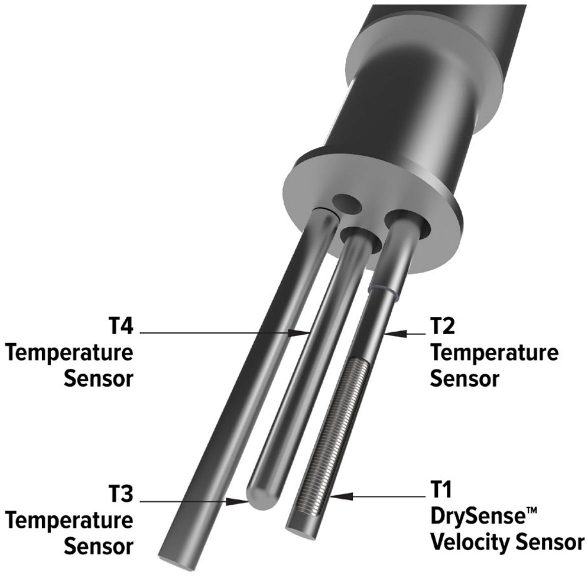

Figure 2. Advanced four-sensor QuadraTherm thermal sensor.

Natural gas sampling challenges

In order to comply with state and federal regulations, oil and gas companies need to take an adequate gas sample that is representative of the gas flow. This requirement to take a 'representative sample' is challenging for engineers. They must first carefully consider where to take this 'representative' gas sample from the source stream. The most accurate representative samples cannot be taken from a 'dead leg' or an area of heavy flow disturbance. In addition, the sample's chain of custody must be maintained in order to avoid contact with other contaminants. Engineers must also reduce and control the pressure to the analytical tool, stabilise and control the flow, all while protecting the analytical instrument from particulates, moisture and pressure/flow excursions.

Engineers must take the gas sample in as real time as possible, so that it correlates with actual process flow. With these gas sampling application challenges, the goal for oil and gas engineers is to take the most accurate gas flow sample, as quickly as possible, and with the lowest incurred cost.

When the optimal gas sampling location has been determined, there are still other inherent flow challenges to consider:

- Wide flow rate variations: turndowns of up to 1000:1 may be required.
- Changes in gas composition – wide gas density variations: traditional flow meters cannot successfully manage changes in gas composition and still maintain accuracy.
- Non-uniform flow profile: gas measurements generally have asymmetric and swirling flow.
- Very low pressure with variable temperature: most lines operate near atmospheric conditions with gas temperatures that vary with the gas source.

A lack of solutions

There are various analytical tools on the market today that attempt to meet all of the above gas sampling and flow metering application requirements. Gas chromatographs are still the most common tool, while new micro-analyser systems are gaining wide acceptance. A common thread in all such analysers is that the gas sample flow must be precisely measured and controlled, remain independent of pressure and temperature variations, and measure over a fairly wide range of flows at various compositions. In reality, it is not possible to have the flow rate unaffected by pressure and temperature variations.

Common technologies, such as averaging pitot tubes and insertion turbine meters, demonstrate poor performance in gas sampling applications. These devices measure volumetric flow, not mass flow, where mass flow is the required measurement. They also require a clean gas with constant gas composition. Additionally, they often cannot measure down to the low flows some gas samplers require. As a result, these technologies do not effectively provide the precise 'representative sampling' data required to meet government regulations.

There is, however, a new technology innovation based on the thermal dispersion principal that meets these challenges. This technology will be examined in detail below.

Thermal mass flow meter principle of operation

As the name implies, thermal dispersion mass flow meters use heat to measure flow and are the only other direct mass flow meter in existence, along with coriolis. Thermal technology has a major cost advantage over coriolis, being on average one fifth of the cost. Insertion probe thermal meters can be as much as one tenth of the cost for larger pipes.

As thermal is direct mass flow, there is no need for secondary measurements and flow computing to calculate mass flow. With thermal technology, mass flow rate is direct and unequivocal.

Thermal mass flow meters have no moving parts. The velocity sensor is heated continuously via

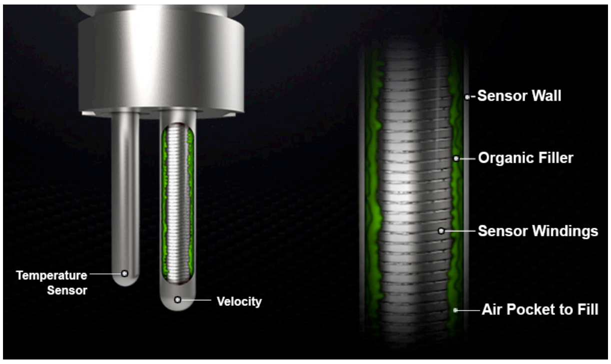

Figure 3. Wet sensor design.

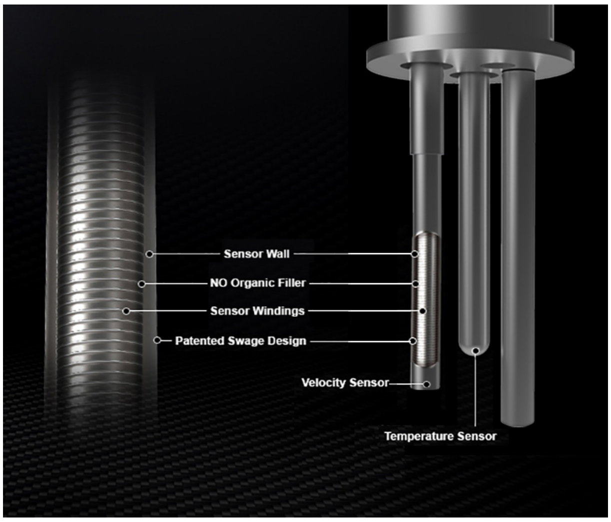

Figure 4. Dry sensor design.

electrical energy, so that a predefined temperature differential is always maintained between the two sensors. For example, 50°C (122°F) is the constant temperature differential for most thermal mass flow meters (Figure 1). As soon as the fluid flow begins, heat is drawn from the heated velocity sensor via the gas molecules flowing past. The heat is dissipated as it is carried off by the flow. As the gas molecule flows past the sensor, it heats up and carries this heat away with it downstream.

The corresponding cooling effect is measured and compensated for instantaneously by the instruments' sensor drive electronics, which instantly adds more heating current to the sensor to maintain that constant temperature differential of 50°C (122°F). Figure 1 shows that the gas molecules themselves transfer the heat. In a real world flow application, all of this happens in a millisecond continuously and never stops. In essence, a thermal mass flow meter is counting molecules that flow past, heat up, then take the heat away with them and carry it downstream – as a result, extremely sensitive, accurate and repeatable molecular mass flow measurement occurs.

Now that the basic measurement principal has been described, how is total mass flow rate of gas flowing through the pipe actually calculated? As described by King's law, the heating current required to maintain the constant temperature differential between the two sensors is proportional to the cooling effect caused by the gas molecules flowing by, and, therefore, is a direct measurement of total gas mass flow rate in the pipe. It is important to note that heat transfer from flowing gas is affected by the properties of the gas.

These are known gas properties, such as:

- Thermal conductivity.
- Density and viscosity.
- Heat capacity.

Innovation opens doors

Traditional thermal mass flow meters have limitations in gas sampling applications because they cannot accurately measure low flows with changing gas composition without factory recalibration.

However, recent innovations in thermal mass flow sensor technology have removed this barrier. Adding two more temperature sensors has given rise to the next generation four-sensor 'quad' thermal mass flow meters and now combine robust construction with extreme sensitivity – improving accuracy and turndown (Figure 2).

Compared to previous generations of 'two-sensor' thermal mass flow meters, the maximum flow rate has tripled with quad thermal flow meter technology. Even more notable is the improvement in the minimum detectable flow rate. An entirely new 'ultra low flow' market has opened up for industrial thermal meters and now, for the first time, quad thermal flow meters can manage changes in gas composition through on board gas mixing software in the field.

Accuracy specifications are comparable to coriolis meters at a much more economical price. Pioneered by Sierra Instruments, Inc., based in Monterey, California, quad thermal (QuadraTherm®) has a ±0.75% reading accuracy for insertion probe versions (an improvement on the 2% of reading previously possible with traditional thermal technology). The in-line version of the instrument improves on that with ±0.5% of reading accuracy.

These new advancements make quad thermal technology ideal for gas sampling applications.

Dry thermal sensor technology: the key to sensor stability

Many traditional thermal dispersion flow meters have 'wet' sensors that have heat lost via stem conduction that is not accounted for and can introduce errors as high as 20%, depending on the gradient between the gas temperature and the temperature outside of the pipe. This is because of the organic potting cement used in 'wet' sensors that will shift and crack over time (Figure 3) causing unwanted sensor drift, and resulting in a gradual degradation of flow measurement accuracy.

In a unique innovation, all Sierra 'dry' sensors (DrySense™) use no organics and will not shift or lose accuracy over the life of the meter. The dry construction of the sensor provides much improved sensor stability and accuracy (Figure 4).

Application challenges solved with new technology

With recent advancements, coupled with the inherent accuracy benefits of thermal mass flow technology, QuadraTherm thermal meters coupled with DrySense are now able to solve all the inherent challenges in gas sampling applications. These challenges are reviewed below.

Accuracy at low flow rates

In typical gas sampling applications natural gases of various compositions are being sampled, the piping is small, typically 0.5 in. - 0.25 in., and the flow range is very low, ranging from 0 - 10 nlpm or lower. Four-sensor thermal flow meters are capable of measuring flow accurately down to 0.01 mps, which equals approximately 0.1 nlpm in a 0.5 in. pipe. Previous generations of mass flow meters bottom out at 10 slpm. Due to this low flow sensitivity, the QuadraTherm mass flow meter is able to be calibrated with a full scale of 10 nlpm and a nominal flow of 1 nlpm.

Metering accuracy in changing gas compositions

Typically, the gas composition will vary with each sample point, which makes taking an accurate representative sample very challenging. With traditional thermal flow meters, when gas composition changes the meter must be sent back to the factory for recalibration, costing engineers valuable time and money in recalibration.

For the first time, QuadraTherm thermal flow meters, along with powerful microprocessors, can run flow measurement algorithms to compute the mass flow rate of any gas composition. The microprocessor takes the inputs from the four sensors and solves the First Law of Thermodynamics (heat energy in = heat energy out) for each data point.

This technology now can enable a gas mixing software app called qMix™, a powerful, user customisable gas mixing feature (Figure 5). qMix provides gas flow measurement field flexibility by allowing end users to create custom gases or gas mixtures to compensate for gas compositional changes.

It can be used when the gas composition changes in the pipe or when moving the meter to another location with a different gas composition. The major benefit is that, for the first time, users can experience the cost benefits of thermal flow meters versus other technology such as coriolis and still retain accuracy without returning the meter to the factory for recalibration every time gas composition changes.

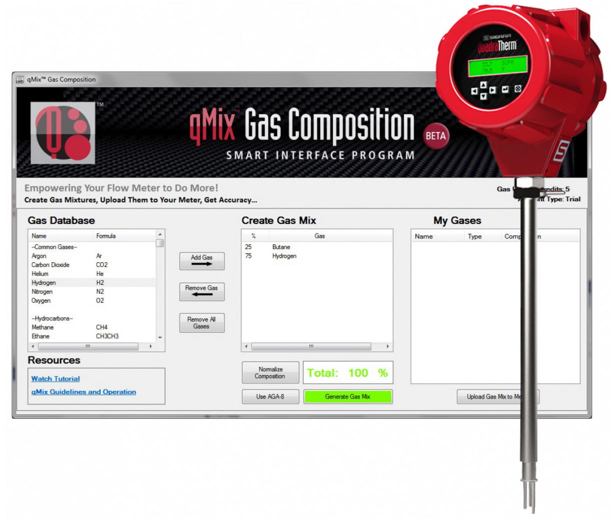

Figure 5. qMix Gas Composition Smart Interface Program.

Managing changes in varying pressure

In sampling applications, the pressure at the sample source can vary from 0 - 3 barg. While variations of 3 barg will not have a major effect on higher flow rates, pressure can greatly affect low flow rates and zero flow, in particular. To compensate for these pressure effects at low flow, the Raptor II OS Engine dynamically accounts for increased natural convection occurring as a result of pressure.

Meeting explosion proof requirement for gas sampling

ATEX, cFMus and IECEx approvals are often required for sampling devices and are a determining factor for this application, which makes an industrial flow meter a necessity. The four-sensor thermal flow meter is the only ATEX approved thermal mass flow meter that can measure flows this low (down to 0.01 mps).

Conclusion

While there are many alternatives to getting accurate flow data in gas sampling applications, advanced four-sensor thermal flow meters offer the most accurate flow measurements for the toughest gas sampling application requirements: high accuracy at low flows, accuracy when pressures change, and the ability to meet industrial explosion proof requirements. For the first time with thermal technology, four-sensor quad thermal flow meters, such as Sierra's QuadraTherm meter, can manage gas composition changes in the field without losing accuracy. This is why thermal technology is being readily adopted in oil and gas applications, in order to quickly comply with government gas sampling regulations, saving hundreds of thousands of dollars a day in compliance costs.