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How to Overcome Thermal Mass Flow Meter Limitations

By Wayne Shannon

The thermal mass flowmeter is a widely accepted instrument that measures gas mass flow. The device is used in various industries, including oil and gas, refining, chemical, mining, and wastewater. The meter is an accurate, reliable, and cost-effective solution for many applications. However, like any technology, the flow meter's limitations may present challenges that should be addressed before implementation. Here we will consider nine limitations of thermal mass flow meters and how to overcome them.

1. Condensed Moisture may Cause Inaccuracies

The primary principle of thermal mass flow measurement involves heat transfer caused by gas flow. Condensed moisture in the gas that contacts the heated sensor rapidly increases heat transfer, and the instrument responds with a spike, creating inaccurate flow measurement.

Angling the flow sensor in the pipe can help combat inaccuracy associated with condensed moisture.

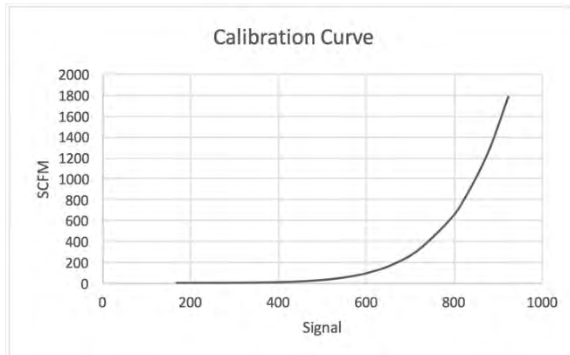
How to overcome this challenge:

- A knockout drum (KO drum), or knockout pot, separates moisture drops from the gas. When gas flows into the vessel, resulting in a reduction in gas velocity and a change in flow direction, gravity causes the moisture to fall while the gas flows upward and out, effectively removing moisture drops from the gas.
- Angling the thermal mass flow sensor in the pipe is another method that can mitigate inaccuracies associated with condensed moisture. Angle the sensor in such a way that if condensate develops it flows away from the sensor.

2. Diminished Sensitivity at Higher Velocities

There is a nonlinear relationship between the mass velocity and heat transfer in thermal flow measurement. While thermal mass flow meters provide excellent sensitivity for low gas flow, there is diminished sensitivity at high velocities. When selecting a thermal mass flow meter for a given application, the meter is sized based on mass velocity referenced to the STP (Standard Temperature and Pressure) conditions. Other types of flow meters are sized based on the velocity at operating conditions.

As gas pressure increases, the gas molecules pack closer together, resulting in increased gas density. With increasing gas density, the mass velocity measured by thermal mass flow meters increases while the actual velocity at operating conditions remains the same.



Thermal mass flow meter calibration curve

How to overcome this challenge:

Because the thermal meter loses sensitivity at higher mass velocities, there is an upper limit on velocity and the instrument can overrange. For this reason, it is uncommon to use thermal mass flow meters in compressed gas systems with pressures greater than 150 PSI. In these cases, vortex-shedding or differential-pressure flow measurement are options.

3. Calibrating for Different Gas Types

Every gas has different physical properties that impact heat transfer. For this reason, a thermal mass flow meter can only accurately measure the gas (or gas mixture) the meter was calibrated for. During calibration on a flow bench, a controlled amount of the specified gas flows past the meter's sensor, and the signal is measured. This process is repeated multiple times over the operating range to establish the relationship between mass flow and the signal for the gas and sensor being calibrated.

How to overcome this challenge:

Occasionally, safety or hazardous conditions may make it impossible to flow the actual gas (or gas mixture) during calibration. In these cases, the calibration is performed using a surrogate gas with similar heat transfer characteristics combined with analytical adjustments based on the relative heat transfer properties of the actual and calibration gases.

4. Calibration Verification

Once a thermal mass flow meter has been calibrated, the question becomes, when does it need to be re-calibrated? Some manufacturers require their meter to be returned to the factory or an authorized NIST-traceable facility for recalibration.

This recalibration can be expensive, and it is certainly inconvenient to remove a meter from service. With the advancements in technology over the years, some thermal mass flow meters, such as Sage Metering, have developed ways to verify that the meter is still in calibration. These calibration verification procedures vary from manufacturer to manufacturer. While some methods are straightforward and easy, others are complicated, time-consuming, and require the meter to be removed from the pipe.

How to overcome this challenge:

In one manufacturer's verification process (Sage Metering), the in-situ method, the user may verify the meter is in calibration by comparing one data point with the original calibration data. In this case, a retraction assembly with a compression seal and ball valve permits the user to withdraw the sensor from the pipe, creating a no-flow condition even though the gas line is still in service. It is then possible to compare the zero flow signals during the test and calibration, and if they match, this comparison verifies that the meter remains in calibration.

5. Gas Composition Variation

Given that a thermal mass flow meter requires calibration for the gas being measured, any change in the gas composition will produce incorrect data (see challenge #3 regarding the calibration). The degree of inaccuracy will, of course, depend on the gas variation.

How to overcome this challenge:

Biogas is a mixture of varying amounts of methane and carbon dioxide. In most cases, the change in heat transfer from the gas difference impacts the overall accuracy less than 5 percent. In many circumstances, this is considered acceptable. However, in other applications, such as flare gas at a refinery or chemical plant, there can be substantial variation in composition, which significantly impacts the meter's accuracy. Knowing the gas composition provides the capability for some manufacturers to develop correction factors for the new gas.

6. Undeveloped Flow Profile

Most flow technologies require a minimum of upstream and downstream straight run, and generally, there is more emphasis on the upstream range. During the calibration of the thermal mass flowmeter, the test station provides a fully developed turbulent flow profile at the sensor. Duplication of this flow profile in the field will provide the most accurate results, whereas, deviations from the recommended distance create inaccuracies. As a guideline, a distance of 15-25 pipe diameters downstream of a single elbow is typically sufficient. Often, the recommended straight run is not available at the site to create the ideal flow profile.

How to overcome this challenge:

- At times, the client chooses to use the thermal mass flow meter with the undeveloped profile and sacrifice some accuracy, knowing the data will be highly repeatable.
- Alternatively, a flow conditioner assembly can assist when insufficient straight run is an issue. Flow conditioners provide a uniform flow profile at the sensor location. This uniform flow profile is different from the fully developed flow profile, which occurs with the adequate straight run. For this reason, it is necessary to calibrate the flow meter with the flow conditioner when using such a device to provide uniform flow profile.

7. Flow Sensor Buildup

Whenever there is buildup on a flow meter sensor, the meter's accuracy decreases. For the thermal mass flow meter, any buildup on the flow sensor will reduce the heat transfer and cause the meter to read lower than expected. Additionally, the built-up material increases the thermal mass and decreases the response time to changes in gas flow rate.

How to overcome this challenge:

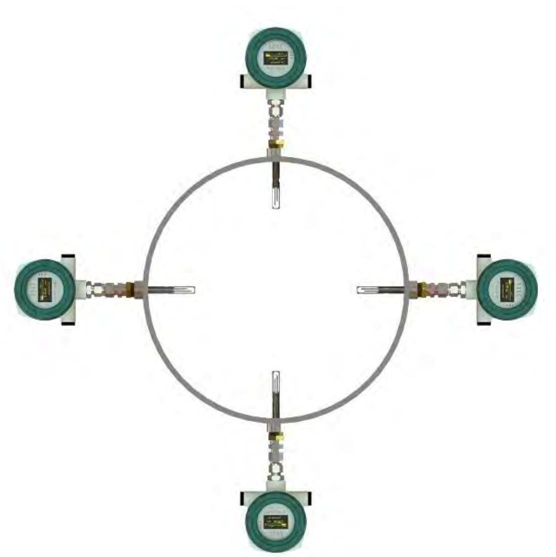
If the thermal mass flow meter is designed to include a retractable element that includes a compression seal and ball valve, the insertion probe of the meter can easily be removed from the pipe and cleaned without disrupting service.

8. Large Ducts

The probe of a thermal mass flow meter inserts into a pipe, and the meter measures the gas flow at the sensor location. An accurate flow measurement is achieved when the recommended straight-run distance is available. Since the desired straight run is predicated on the pipe diameter, obtaining the recommended distances for large duct runs can be challenging; making it difficult to achieve an accurate measurement.

How to overcome this challenge:

Improve overall accuracy by increasing the number of measurement points. In these cases, the use of multiple flow



Increasing the number of measurement points can help improve flow measurement accuracy in large ducts.

meters at different locations across the duct and averaging the flow measurements improves accuracy.

9. Low Velocities

Thermal mass flowmeters excel in low-velocity measurements. Of course, accurate measurement is dependent on having the meter calibrated at low velocities. Not all thermal mass flow meter manufacturers have the ability to calibrate the instruments at very low flow rates.

How to overcome this challenge:

If you have a low-velocity application, always contact the manufacturer being considered to ensure they have the capacity to calibrate the meter over the specified velocity range correctly.

Parting thoughts

Every flow measurement technology has limits. When pushing the boundaries of a thermal mass flowmeter, challenges may arise. In all situations, the best way to overcome challenges is to convey the specific details of the application and operating environment to the manufacturer so the solution provider can ensure the technology under consideration can deliver the desired results.

About the Author

Wayne Shannon is product marketing manager for Sage Metering. Wayne has over 20 years' experience with applications, product marketing, and sales of thermal dispersion mass flow meters. He has been directly involved with recommending and applying thermal mass flowmeters in a wide variety of industries. Wayne has a bachelor's degree in Chemical Engineering and an MBA in Marketing.

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