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Fundamentals of Thermal Mass Flow Measurement

Why are pressure and temperature correction not required?

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Introduction

As a manufacturer of thermal mass flow meters, we are often asked, "Why do we need to measure in *mass flow*? What is the difference between ACFM and SCFM? Why are pressure and temperature correction not required when measuring with a thermal mass flow meter? What is the thermal mass flow measurement theory? What are common applications to use thermal mass flow meters?" I hope this simple paper explains these questions and more.

Actual Flow versus Standard Flow

Gas is compressible – this is one of the reasons the accurate measurement of gas flow rates is difficult. As the temperature increases, the gas molecules move further apart, conversely, as the pressure increases the gas molecules move closer together. Most gas flow meters (differential pressure, turbine, positive displacement, vortex shedding) measure the gas flow at the actual operating conditions where the measurement is made. This flow rate is frequently referred to as ACFM (Actual Cubic Feet per Minute). What is more important, however, is the flow rate adjusted or corrected for a particular pressure and temperature. This flow rate is frequently referred to as STP (Standard Pressure and Temperature) and often measured in units of SCFM (Standard Cubic Feet per Minute).

This is why the flow rate measured by most gas flow meters require pressure and temperature correction to convert the flow rate from operating conditions (ACFM) to standard conditions (SCFM). Thus to get the mass flow rate of gas in standard conditions measurement of the actual flow rate at operating conditions, the operating pressure, and the operating temperature are required.

Thermal Flow Measurement

A thermal mass flow meter is a precision instrument that measures gas mass flow. It represents an entirely different method for measuring flow rate. These meters measure the heat transfer as the gas flows past a heated surface. The gas molecules create the heat transfer, the greater the number of gas molecules in contact with the heated surface the greater the heat transfer. Thus, this method of flow measurement is **dependent only on the number of gas molecules and is independent of the gas pressure and the gas temperature.**

temperature sensor. As gas flows past the heated flow sensor, heat transfer occurs. The instrument measures the amount of power required to recover the desired overheat which is proportional to the mass flow rate. The amount of power in the form of heat to the sensor is very low, permitting the use of this technology in natural gas, hydrogen, or other flammable gases.

Thermal Mass Flow Meters

Thermal mass flow measurement is an *inferred* flow measurement. These meters measure heat transfer and then relate the heat transfer to the mass flow rate from the NIST traceable calibration. While calibrating the flow meter, a known amount of gas is run past the sensor, and the signal is measured. This is performed multiple times over the operating range of the instrument. A curve showing signal vs. flow rate is created for each instrument. Figure 2 illustrates a typical curve.

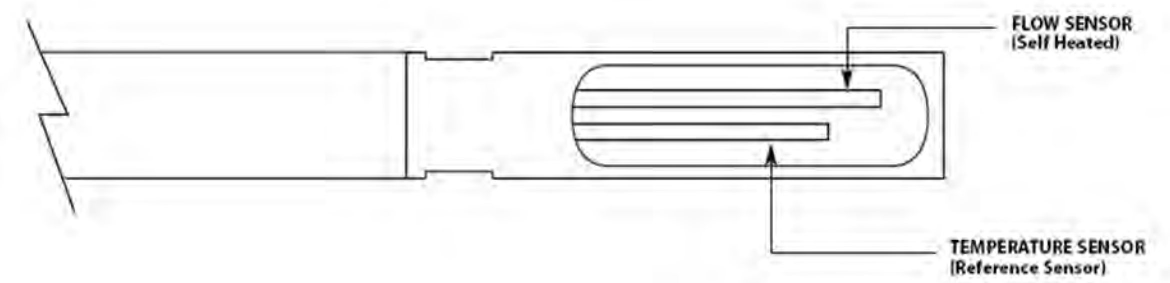
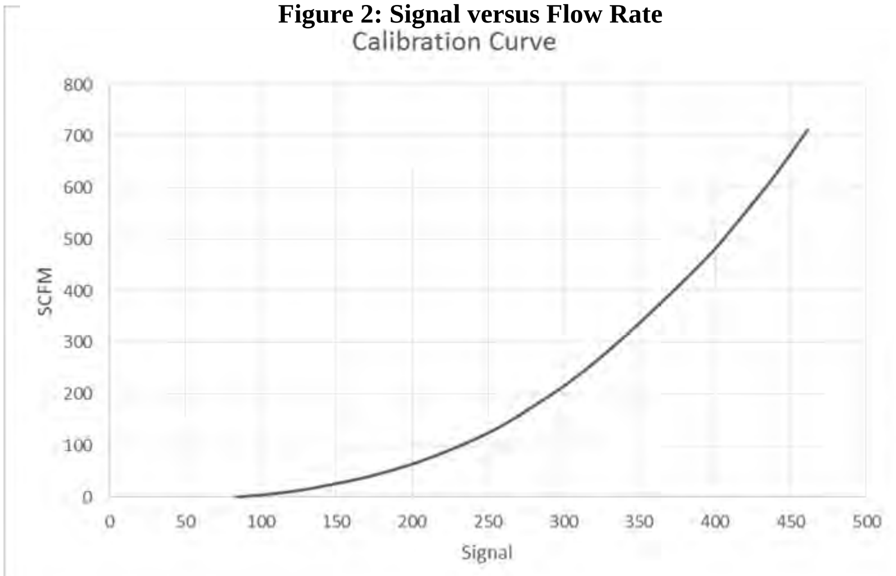


Figure 1: Sage Metering Sensor

Figure 1 is an illustration of the sensor used by Sage Metering.

The Sage meter consists of two high precision platinum sensors contained in a stainless steel covering. The **temperature sensor** is the reference and also provides a measurement of the gas temperature. The **flow sensor** is heated to maintain a slight temperature difference (overheat) above the

Figure 2: Signal versus Flow Rate



Benefits of Thermal Mass Flow Meter

Thermal Mass Flow Measurement provides the benefits of:

- Mass flow measurement without need for pressure and temperature correction
- Excellent sensitivity even at low flow rates
- High turndown capabilities
- Easy installation

- No moving parts ensures high reliability

Applications

Thermal mass flow meters are used in a broad range of applications. Here are some typical examples of the uses of thermal flow meters.

Natural Gas to Combustion Sources

Combustion sources such as boilers and furnaces have different efficiencies. By measuring the natural gas flow rate to a combustion source, the user can determine which operation is more efficient. The thermal mass flow meter is ideal for measuring natural gas flow rates to individual combustion sources.

Natural Gas Submetering

In facilities with different cost centers, submetering natural gas is frequently performed for cost allocations. When the cost of utilities is allocated to the various departments, there is an increased incentive to improve efficiency and reduce natural gas usage.

Compressed Air

Industrial air compressors use more electricity than most other industrial equipment and account for as much as a third of the energy consumption in a plant. A thermal mass flow meter helps determine the optimal number of compressor units needed. Additionally, air leaks waste up to 30% of the industrial compressors output. Thermal mass flow meters help define the extent of leakage in a system and quantify the lost energy. For more information read "ISO 50001 Energy Management: The Use of Thermal Mass Flow Meters in ISO 50001 Energy Management Systems" at http://goo.gl/zHnPAf.

Biogas Production

Biogas is produced from landfills as *landfill gas* and anaerobic digesters as *digester gas*, among other places. It is high in methane and often the focus of biogas-to-energy projects. Throughout the production, accurate gas flow measurement is needed, whether monitoring, biogas destruction or cogeneration. Additionally, specific gas flow is necessary for GHG emissions reporting to environmental agencies and/or carbon credit programs. To learn more, read "Digester Gas Flow at Wastewater Treatment Plants," or "Landfill Gas Monitoring, Recovery, and Flaring." Alternatively, visit http://goo.gl/l88gbs and http://goo.gl/n5pdEy.

Flare Gas

The measurement and monitoring of flare gas are necessary to assure that the flare system is operating correctly. This application is complicated by varying gas compositions. To learn more read, "Flare Gas Measurement Using Thermal Mass Flow Meters" at http://goo.gl/n5pdEy.

Aeration Air

The activated sludge process is used at wastewater treatment plants to treat sewage and industrial wastewaters. Microorganisms require Air flow to break down organic waste in this process. An optimum air flow throughout the system, sufficient to encourage consumption of waste by the microorganisms, and yet not excessive, is continuously sought.

Combustion Air

Combustion efficiency and energy management is achieved by optimizing air-to-fuel ratios through accurate and repeatable gas flow measurement. Direct measurement of combustion air flow and fuel flow provide the criteria needed to reach peak efficiency. For more information read, "Combustion Efficiency and Thermal Mass Flow Meters" at http://goo.gl/YcDzv7.

Conclusion

Since gas is compressible its volume changes under pressure or when heated (or cooled). Thermal mass flow measurement is based on heat transfer and measures mass flow, not volumetric flow and thus does not require temperature or pressure correction.

If you would like more information on the benefits of thermal mass flow meters, visit us at www.SageMetering.com or call toll-free 866-677-7243 or 831-242-2030.

Sage Metering References:

The following Sage Metering white papers are available on our website at http://goo.gl/n0K7CU.

- Flare Gas and 40 CFR 60 Subpart OOOO: Storage Vessels Approaching Quad O Deadline
- Flare Gas Measurement Using Thermal Mass Flow Meters
- Combustion Efficiency and Thermal Mass Flow Meters
- Greenhouse Gas Emissions Monitoring Using Thermal Mass Flow Meters

Also, these Sage in the Flow blogs may be of interest:

- Thermal Flow Working Principle and Theory
- Natural Gas Measurement