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Technical Paper

Thermal Mass Flowmeters Help Reduce Energy Costs and Enhance Emissions Monitoring Systems.

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Purpose

Accurate, repeatable measurement of air and process gases is a key factor in improving accountability, productivity and energy management processes.

Abstract

The thermal mass flow meter's ability to deliver a direct reading of mass flow rates of air, natural gas and other fuel gases provides a simple, reliable and cost-effective method for tracking and reporting fuel consumption.

Accurate, repeatable measurement of air and gas, at low and varying flow rates, is also a critical variable in combustion control. Conventional flow meters require pressure and temperature transmitters to compensate for density changes. The thermal mass flow meter, however, measures gas mass flow directly, with no need for additional hardware. The thermal meter also provides better rangeability and a lower pressure drop than orifices, venturis or turbine meters.

Rising energy prices have made daily accounting of natural gas usage a priority for large industrial facilities with multiple processes and/or buildings. Fuel gas flow meters are used to analyze demand, improve operating efficiency, reduce waste and adjust for peak usage. Thermal mass flow meters are frequently used for these energy-accounting applications. In addition, thermal flow meters can help plant managers provide accurate usage reports for environmental compliance, as well as compare measured usage to billing reports from gas providers.

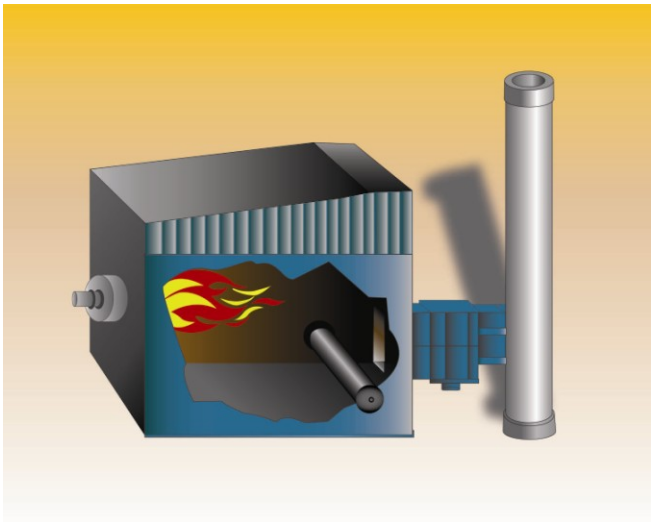

Figure 1. Rising energy prices have made a daily accounting of natural gas usage a priority.

Although manufacturers have made significant improvements in process heating efficiency, the U.S. industry's total energy use for process heating is expected to increase. With overall thermal efficiency of process equipment varying from 15% to 80%, compared to the thermal efficiency of steam generation, which varies from 65% to 85%, there is clearly an opportunity to achieve significant energy savings, improve productivity and enhance competitiveness. The U.S. Department of Energy's Industrial Technologies Program has identified improved burner control systems as a significant opportunity for reducing energy operating costs, waste and environmental emissions.

Plant managers seeking to improve combustion performance and product quality must balance fuel and energy-saving measures with emissions reduction priorities. In many process heating operations, such as drying, incineration and heat treating, excess air is often a process requirement.

In these cases combustion air and excess air used to suppress emissions must be heated, which increases fuel consumption and may result in incomplete combustion. One of the most effective techniques for improving efficiency and reducing emissions in these applications is a precise control strategy, based on mass flow measurement of fuel and airflow.

Unlike orifice plates, turbine meters, and other volumetric flow devices, the thermal mass flow meter is virtually immune to changes in temperature and pressure, and is capable of providing a more accurate measurement of mass flow rate.

Flow Meter Type	Measures	Mass flow requirements
Turbine Meter	Q	Needs P, T
Orifice Plate	Q^2	Needs P, T, $\sqrt{\ }$
Venturi	Q^K	Needs P^M, T^N
Thermal Meter	$\dot{m}$	Measures mass directly

Figure 2. Comparison of gas flow measurement techniques

As shown in Figure 2, most conventional flow meters measure volumetric flow and require additional measurements of pressure and temperature to calculate density and mass flow. Because the thermal mass flow meter measures mass flow directly, it provides the most reliable, repeatable, and accurate measurement. The flow meter also provides better rangeability and a lower pressure drop than conventional flow meters.

Sophisticated burner control systems optimize air/fuel ratio control to obtain peak thermal efficiency over the entire range of the burner, and to facilitate proactive emissions control. Mass flow control of air and fuel is used to automatically compensate for changes in temperature or pressure that affect combustion performance. Many systems also utilize fuel totalizing and other data outputs for DCS interfacing and remote system monitoring.

Thermal mass flow meters are designed for installation in fuel gas and air feed lines found in process heating and utility operations. In addition to the primary benefits of direct mass flow measurement, low-flow sensitivity, and fast response, the instrument's no-moving parts design also helps reduce maintenance costs.

Thermal Mass Flowmeters Help Manufacturers Meet Air Quality Management Requirements

The Federal Clean Air Act (FCAA) requires the U.S. EPA to set national ambient air quality standards to ensure public health. State agencies, as well as regional and metropolitan air quality management districts, are responsible for ensuring attainment and maintenance of these standards. These agencies have published rules and regulations regarding NOx and CO emissions from industrial, institutional and commercial boilers, steam generators and process heaters.

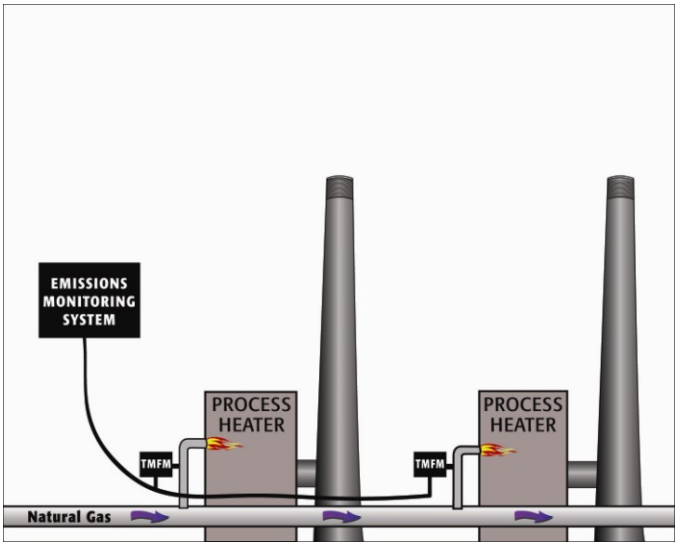

Figure 3. Thermal mass flow meters incorporate a non-resetting totalizer to help track and report fuel consumption.

Owners or operators of units subject to these regulations may install a non-resetting totalizing fuel flow meter to measure the total fuel used by each individual unit, as shown in Figure 3. The regulations specify mass flow measurement of fuel usage and if a volumetric flow meter is installed it must compensate for pressure and temperature using integral gauges.

The thermal mass flow meter's ability to deliver a direct reading of mass flow rate of natural gas and other fuel gases – without temperature and pressure compensation – provides a simple, reliable and cost-effective method for tracking and reporting fuel consumption.

The thermal mass flowmeter features a variety of analog and digital output signals to easily interface with the emissions management system and an integrated, non-resetting totalizer helps manufacturers meet air quality management equipment requirements. The instrument also offers a very broad measurement range (100 to 1 typical) and is suitable for very low velocity flow measurement.

Thermal Mass Flowmeters Facilitate Energy Accounting, Sub-metering and Custody Transfer

Rising energy prices have made daily accounting of natural gas usage a priority for large industrial facilities with multiple processes and/or buildings. Fuel gas flow meters are used to analyze demand, improve operating efficiency, reduce waste and adjust for peak usage.

The thermal mass flow meter has become the preferred device for many energy accounting applications. In addition, these instruments help plant managers provide accurate usage reports for environmental compliance, and compare measured usage to billing reports from gas providers.

Figure 4. Thermal mass flow meters are available in both insertion-type and inline configurations.

Insertion-type flow meters are easily mounted in suitable installation points throughout the facility, and provide an accurate, repeatable reading of natural gas consumption by plant, process, or tenant. In constrained areas, inline meters reduce the traditional requirements for straight, unobstructed upstream piping and simplify installation (Figure 4).

Typical applications include:

- Sub-metering by department or process helps manufacturers assess inefficiencies, assign costs and implement conservation measures.
- University campuses and industrial parks use totalizing flow meters to allocate fuel costs to various buildings and/or tenants.
- Natural gas check meters are often used to document usage, negotiate rates and resolve billing disputes.
- Thermal mass flow meters may be used to monitor and bill for fuel consumption on skid-mounted generators and compressors.

In addition to the primary benefits of direct measurement of mass flow rate, low-flow sensitivity, and fast response, the flowmeter's no-moving parts design also helps reduce maintenance costs. One manufacturer replaced a fuel measurement system that consisted of turbine meters with ancillary pressure and temperature transducers with thermal mass flow meters. Not only did they reduce the time and expense associated with servicing the turbine meters, they also found that the thermal flow meters' wide turndown provided a more accurate measurement at low and varied loads, ensuring accurate cost-allocation and improving combustion control capability.

How It Works

The Fox Thermal Instruments flow meter uses a constant temperature differential (Delta T) technology to measure mass flow rate of air and gases. The flow sensor consists of two Resistance Temperature Detectors (RTD's). The sensor elements are constructed of a reference grade platinum wire wound around ceramic mandrels that are inserted into stainless steel or Hastelloy tubes.

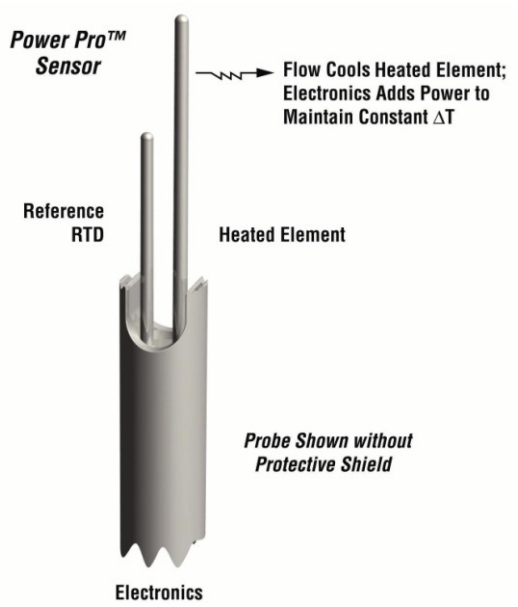

Figure 5. Thermal mass flow meter principle of operation

As shown in Figure 5, the reference RTD measures the gas temperature. The instrument electronics heat the mass flow sensor, or heated element, to constant temperature differential (Delta T) above the gas temperature and measure the cooling effect of the gas flow.

The electrical power required to maintain a constant temperature differential is directly proportional to the gas mass flow rate. The instrument's microprocessor then linearizes this signal to deliver linear output signals.

Specifying a Flowmeter for Process Heating Applications

The most important consideration in flow meter selection is the appropriate technology. For example, some flow meters are suitable for air and gas applications, but not useful for liquids, while others may offer the most effective solution for steam monitoring. A thorough examination of the application parameters, including your plant layout, processes, and installation environment can help save you time, money and headaches down the road.

In addition to mechanical and electrical requirements you may also want to consider other issues relevant to your plant's operation -- such as maintenance schedules, energy conservation initiatives and your maintenance personnel's familiarity with flow meter technology.

It is also critical to evaluate the piping requirements and flow characteristics of the fluid to be measured, including the expected minimum and maximum pressure and temperature values as well as normal operating values. In terms of the piping set-up, you should account for the following: direction, size, material, pipe schedule, flange-pressure ratings, upstream or downstream turns, valving, and available straight-pipe run lengths.

Accuracy and rangeability are the most critical characteristics of a flow meter. Most manufacturers provide these specifications for water, air or a specific gas. Ensure that these specifications meet the requirements of your particular fluid or process.

Some flow meter installation procedures are more complicated than others, and it is important to determine if the meter you've chosen can be inserted directly into the process pipe or if the line must be cut, spliced or penetrated in various locations. The installation process can affect the complexity and cost of the flow meter, as well as the instrument's ability to maintain specified accuracy.

Most flow meters require a specific length of upstream and downstream straight-run pipe to generate a well developed flow profile and that length will differ from one technology to another. This is especially important in retrofit installations, where additional piping may increase the cost of installation.

Finally, consider the flow meter's cost-of-ownership over its life cycle. Some devices require frequent cleaning or removal from service for maintenance or recalibration. Some meters may have a low initial cost, but require frequent maintenance or have a short service life, whereas a more expensive instrument may be less costly to install, require less maintenance and provide a much better ROI.

Bottom Line

Thermal mass flow meters provide the real-time measurement required for sophisticated combustion control systems, as well as other critical flow measurement applications. These include wastewater aeration, hydrogen monitoring, land fill monitoring, purge monitoring and flare gas and vent gas measurement. Based on the thermal sensing principle, a proven direct mass flow measurement technology, thermal mass flow meters offer one of the most accurate, repeatable and reliable methods for measuring flow rates of air and gases.

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