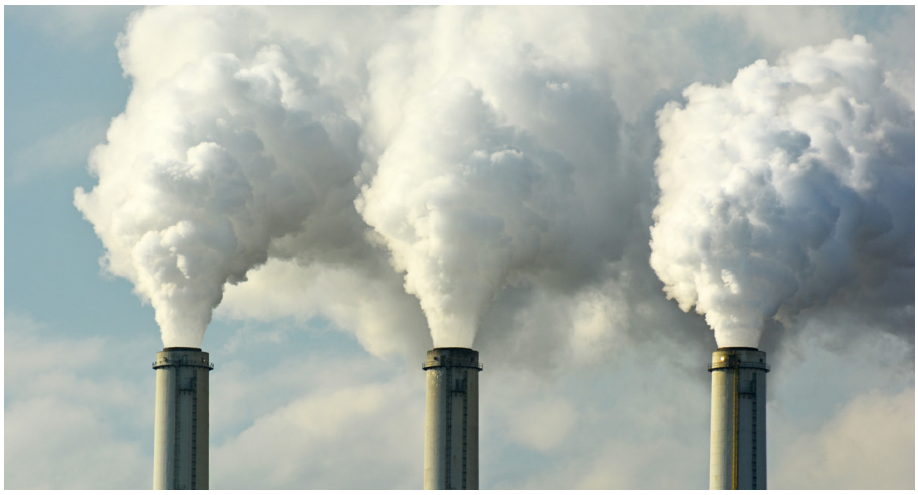
WHITE PAPER

8 Greenhouse Gas Emissions Monitoring Applications:

Benefits of Thermal Mass Flow Measurement



A Study of the Most Common Applications of Emissions Monitoring for Regulatory Reporting

Written by:

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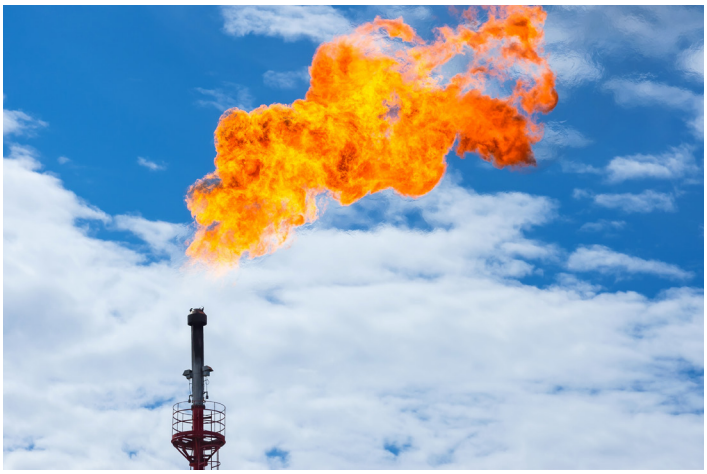
FOX™ THERMAL

OIL & GAS | INDUSTRIAL | BIOGAS | WASTEWATER

PURPOSE

To provide a convenient and easy-to-follow method of finding the right flow meter technology for emissions monitoring applications across multiple industries. Use these 8 application examples to guide you through the process of choosing a flow meter technology right for your emissions monitoring application.



BLM COMPLIANCE & API STANDARDS

BLM, 40 CFR Subpart 3175
Requirements for enforcement of 3175 include the frequency for calibration/verification of facility measurement points at key locations in place on or before January 17, 2017. Frequency may be quarterly, semi-annually, or annually.

API 14.10
Americal Petroleum Institute (API) published API MPMS Chapter 14.10, Measurement of Flow to Flares, in June of 2007. The standard was written in response to the Texas Committee on Environmental Quality (TCEQ) 2004 issuance of Subchapter H to Chapter 115 of Title 30 of the Texas Administrative Code. This regulation places new monitoring requirements that included flare flow meter accuracy requirement of 5% at flow rates of equivalent to 30%, 60%, and 90% of the flare meters full scale.

API 22.3
API 14.10 references API MPMS Chapter 22.3 directly for requirements on the testing protocol for flare gas metering. API 22.3 addresses the testing requirement for flare flow meters with emphasis on the procedures for manufacturers to present the data from the protocol in a similar fashion.

#1: FLARE AND COMBUSTOR GAS MONITORING

Flare gas systems are used in a wide variety of applications and are generally used to burn off excess gas, usually hydrocarbons. A flare gas system may contain open flame flares or flame-enclosed combustors; the differences between the two are highlighted in the table below.

It is generally easy to tell the difference between a flare and a combustor on site. A flare will usually be thin and very tall to allow room for the open flame to burn high above without causing danger to any surrounding equipment, landscape, or personnel. A combustor, on the other hand, may be much shorter and have a wider diameter in order to fully enclose the combustion process.

Whether using a combustor or a flare, the purpose of these types of equipment is to burn waste gases from facilities, converting chemical and organic hydrocarbons into primarily water vapor and CO_2. Some processes also use relief valves to vent flammable gases to the flare stack during upset conditions. Applications include oil and gas well drilling operations, oil refineries, chemical process plants, gas distribution infrastructure, and landfills. Flares are subject to stringent regulations, requiring operators to measure, record and report the amount of flared gases.

Due to the potential for large changes in flow rates, density, pressure and gas composition, flare gas measurement is

Flares vs. Combustors	
Flares	**Combustors**
Open flame	Flame enclosed
Lights up the night sky	Flame hidden, fewer public complaints
Tall flare stack structure	Low profile
High noise level upon burning	Lower noise level
Releases CO2 into the atmosphere	Releases CO2 into the atmosphere

Flares are defined as open flame flaring devices and combustors are enclosed combustion devices.

one of the most difficult and demanding flow applications. Fox Thermal mass flow meters have demonstrated their ability to measure the low flow rates typical of normal flare conditions, and also the high velocities found in upset conditions.

Fluid composition and installation anomalies can also affect flow meter performance. Fox Thermal calibration lab employs a wide range of gases, gas mixtures, temperatures, pressures and line sizes to simulate actual fluid and process conditions. This real-world approach improves installed accuracy and minimizes measurement uncertainty.

#2: NATURAL GAS MONITORING

The U.S. EPA sets national ambient air quality and greenhouse gas emission 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.

Owners or operators of units subject to these regulations may install a non-resetting totalizing fuel flow meter (TFF) to measure the fuel used by each individual unit. 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.

Thermal Mass flow meters deliver a direct reading of mass flow rate of natural gas and other fuel gases - without temperature and pressure compensation - and provide a simple, reliable and cost-effective methods for tracking and reporting fuel consumption.

THERMAL FLOW METERS HELP REDUCE FUEL COSTS AND IMPROVE EMISSIONS CONTROL

Tuning burners to reduce excess air is a cost-effective technique for reducing heat lost in exhaust. Monitoring and adjusting air-to-fuel ratios to maintain optimum combustion not only conserves fuel but also helps reduce emissions.

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.

Accurate, repeatable measurement of air and gas, at low and varying flow rates, is a critical variable in advanced combustion control. Fox Thermal flow meters are designed for use in fuel gas and air feed lines found in process heating and utility operations. In addition to the primary benefits of direct measurement of mass flow rate, low-flow sensitivity, and fast response, the meter's no-moving parts design also helps reduce maintenance costs.

Associated Petroleum Gas (APG)

APG, or Associated Gas, is a form of natural gas which is found with deposits of petroleum, either dissolved in the oil or as a free "gas cap" above the oil in the reservoir. Historically, this type of gas was released as a waste product from the petroleum extraction industry. Due to the remote location of many oil fields, either at sea or on land, this gas is simply burnt off in gas flares. When this occurs the gas is referred to as flare gas.

The gas can be utilized in a number of ways after processing: be sold and included in the natural gas distribution networks, used for on-site electricity generation with engines or turbines, reinjected for enhanced oil recovery, or used as feedstock for the petrochemical industry.

#3: WASTEWATER DIGESTER GAS MONITORING

Wastewater Treatment Plants (WWTPs) use large heated digester tanks to remove and dispose of solid waste material. Here, bacteria break down the material, producing digester gas in the process. Methane is a primary component of anaerobic digester gas (ADG) and a large wastewater treatment plant can produce roughly one million cubic feet of this gas each day.

Most WWTPs utilize recovered gas to fuel boilers and flare off the excess. Other biogas uses include fuel for combustion engines to generate electricity, fuel for natural gas vehicles, and sale and distribution to neighboring industries and communities.

EPA INDUSTRIAL WASTEWATER RULES

40 CFR PART 98 SUBPART II

According to the EPA, under the Greenhouse Gas Reporting Program (GHGRP), owners or operators of certain facilities that use anaerobic processes to treat industrial wastewater and wastewater treatment sludge must report emissions from processes present at the facility if aggregate annual greenhouse gas (GHG) emissions are equal to or more than 25,000 metric tons of carbon dioxide equivalent (CO_2e). Owners and operators are required to collect wastewater characterization and biogas emissions data, calculate GHG emissions, and follow the specified procedures for quality assurance, missing data, recordkeeping, and reporting per the requirements of 40 CFR Part 98 Subpart II – Industrial Wastewater Treatment.

AFFECTED OPERATIONS

Anaerobic processes used to treat industrial wastewater and wastewater treatment sludge at these facility types:

- Pulp and paper manufacturing;
- Food processing (fruits, vegetables, meat, and poultry processing only);
- Ethanol production; and
- Petroleum refining.

AFFECTED PROCESSES

- Anaerobic reators;
- Anaerobic lagoons;
- Anaerobic sludge digesters; and
- Biogas destruction devices.

ADG is a wet, dirty gas, often containing hydrogen sulfides, which may condense and accumulate on pipe walls or equipment inside of the pipe. Selecting a flow meter with no moving parts can dramatically reduce costs associated with maintenance and repair.

Most digester gas applications operate at relatively low pressure. Fox Thermal flow meters create virtually no pressure drop and can be used to accurately measure these flow rates. They are widely used in WWTPs to optimize digester processes, comply with environmental regulations, and control fuel and air flow ratios in combustion processes.

#4: VENT GAS MONITORING

Rising levels of volatile organic compounds (VOCs) in the atmosphere are a subject of general concern and increasing environmental regulation. In order to monitor and quantify emissions, VOC concentrations as well as VOC flow rates must be measured to evaluate mass emission rate.

A study conducted for the Texas Environmental Research Commission (TERC) evaluated emission factors and regional emissions of speciated VOCs from oil and condensate storage tanks at wellhead and gathering sites in East Texas.

Storage tank emissions were measured by determining vent gas flow rates and sampling the vent gas for chemical composition. Tank batteries having multiple tanks were sampled through common vent gas gathering pipes

located at the tops of the tanks. Flow rates were measured using a Fox Thermal mass flow meter.

The TERC flow measurement team reported that..."Overall we were very pleased with the accuracy and reliability of the Fox Thermal flow meters."

#5: LANDFILL GAS RECOVERY AND MONITORING

Landfill Gas (LFG) contains methane, a potent greenhouse gas. The EPA requires landfill operators to collect the methane produced on site, and where it is not being used for energy production, it must be flared to prevent its release.

Landfill Gas to Energy (LFGTE) facilities typically extract gases from multiple wellheads, which are connected to a common header pipe, and then recovered for a variety of uses, including:

- Fueling on-site engines or turbines
- Generating electricity for surrounding homes and businesses
- **Conversion to Liquid Natural Gas, a clean vehicle fuel**

Accurate flow monitoring is essential for gathering system-wide information on the amount of gas being extracted, flared or recovered. Some of the measurement challenges in the LFG environment are changing gas compositions, varying flow rates caused by seasonal temperature changes, and wet, dirty and potentially explosive gases.

Fox Thermal mass flow meters can help LFGTE operators comply with clean air regulations, as well as improve the operation of co-gen engines or methane oxidizers. With turndown up to 1000:1, specified accuracy of ±1% of reading plus 0.2% of full scale, and repeatability of ±0.2% of full scale, Fox Thermal flow meters exceed the requirements of EPA's 40 CFR part 98.

#6: BIOGAS AND DIGESTER GAS MONITORING

Biogas is produced when organic matter, such as sewage, manure or vegetable matter, decomposes in the absence of oxygen. This may take place in a landfill site or in an anaerobic digester. The biogas mixture is typically 70% methane and 30% carbon dioxide.

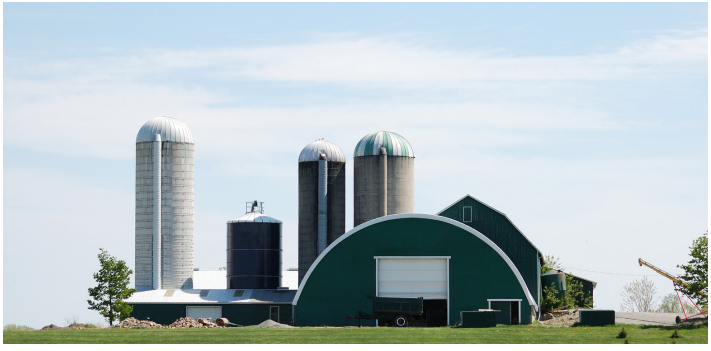
Methane is a powerful greenhouse gas that remains in the atmosphere for approximately 9 to 15 years. Methane is also a primary constituent of natural gas, and a valuable energy source. As a result, efforts to utilize methane emissions can provide significant energy, economic and environmental benefits.

Landfills are the largest human-related source of methane in the U.S., accounting for 34% of all methane emissions. Fox Thermal mass flow meters are widely used in many landfill, wastewater and sewage treatment applications, including:

- Digester gas flow monitoring
- Oxygen/ozone flow monitoring
- Chlorine gas flow monitoring
- Sample flow for gas chromatography

Methane is also produced during the anaerobic decomposition of organic material in livestock manure management systems. These systems can produce significant amounts of methane.

Many large swine and dairy operations are turning manure into a valuable resource by substituting biogas for natural gas or propane as fuel, and by monetizing the resulting carbon credits through greenhouse gas emissions allowance trading systems.



TECHNOLOGY COMPARISON: FOX THERMAL FLOW METERS VS COMPETING FLOW TECHNOLOGY

Thermal mass flow meters operate by the constant temperature differential method and provide a direct mass flow rate without the need for temperature or pressure compensation.

	OTHER TECHNOLOGIES	THERMAL MASS FLOW BY FOX THERMAL
Flow Measurement of gases	Other technologies require multiple instruments to determine the volumetric flow rate at reference conditions.	Direct mass flow measurement of air and gases in standard volumetric units (ie MSCFD, SCFM, or NM3/H) or mass units (ie LBS/M or KG/H). Each meter has the option for the user to select a variety of flow units (see Operating Specs on product datasheets).
Pressure or temperature compensation	Differential pressure flow meters require pressure and temperature compensation.	No additional pressure or temperature compensation is required. This is a time and cost saving measure. No additional calculations or equipment are needed to calculate flow because the meter measures the mass flow rate.
Turndown	Vortex meters are only suitable for very high flow rates. DP meters do not have good turndown.	Repeatability and exceptionally broad measurement range: up to 1000:1 (100:1 typical). Whether the flow is at a very high or low velocity, Fox Thermal mass flow meters can measure it.
Pressure Drop	If a DP meter is used to measure low velocity flow, a very small orifice is required, resulting in high pressure drop.	Low pressure drop. The pressure drop of a thermal mass flow meter is negligible.
Moving Parts	A meter with moving parts, like a Turbine meter, will need regular maintenance.	No moving parts which means no problems with wear, binding, etc.
Price	Ultrasonic meters are especially expensive.	Cost effective. Thermal mass flow meters offer a low cost alternative.
Installation	Some meter technologies are complicated and difficult to install, require additional equipment, or long straight pipe run requirements.	Easy to install with insertion and inline configurations. Insertion meters are easy to install, inline meters come equipped with flow conditioners to help reduce the straight run requirements. Communication options available and intrinsic to meter electronics.
Operation	Most manufacturers build meters for a single purpose, gas calibration, or application. The customer must sift through pages of specs to find the right meter for their application. This is time consuming and ineffective.	Microprocessor based, field rangeable electronics. Fox Thermal pioneered the use of microprocessors in thermal mass flow meters and continues to create innovative solutions to measurement needs across many industries and applications. Gas-SelectX®, available in models FT1, FT4A, and FT4X, allows the user to change the gas selection in the field. Displays with configuration panels and free software allow users to interact and program the meter in the field. Using the online Product Configurator, the customer can enter process data into the system for an instant Fox Product recommendation: no need to search a list of meters for the one that's right for you!

CALIBRATION ENSURES RELIABILITY

Fox Thermal's Calibration Lab offers our valued customers the services they need to ensure that their flow meters meet specified performance parameters and provide accurate, repeatable measurements in the field, day after day, year after year.

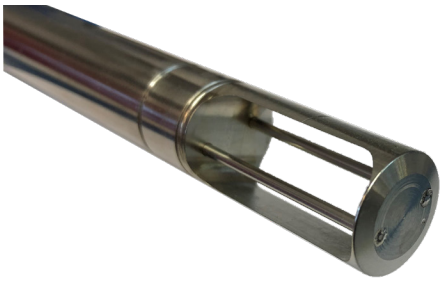
Automated data acquisition optimizes calibration accuracy and efficiency and reduces the opportunity for human error. It also facilitates access to calibration data, parameters, flow conditions and instrument variables.

The Fox Thermal Cal Lab employs a wide range of gases, gas mixtures, pressures, temperatures, and line sizes to simulate actual fluid and process conditions. This real-world approach improves installed accuracy and minimizes measurement uncertainty.

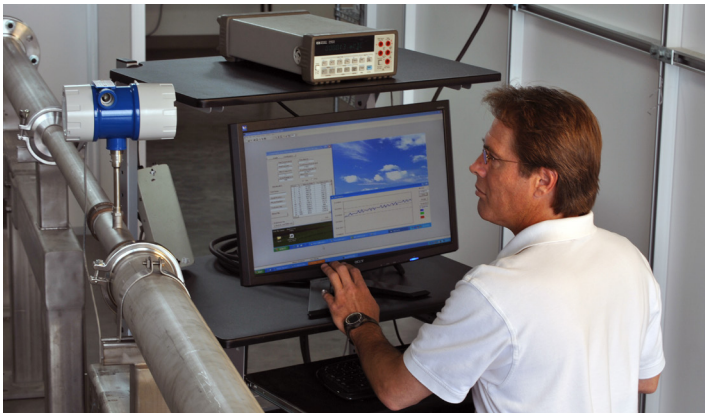
Calibration capability range from as low as 0.02 SCFM (.03 NM3/HR) and up to many thousands of SCFM (NM3/HR) using velocity equivalency methods. The Calibration Lab is also equipped to calibrate for applications with temperature ranges from -40 to 650˚F (-40 to 343˚C) and pressure ranges from 0 to 500 psig (0 to 35 barg).

SPECIALTY LIVESTOCK ANAEROBIC DIGESTER SYSTEM MANUFACTURER SPECIFIES FOX THERMAL FLOW METERS

Leaders in livestock anaerobic digester systems use Fox Thermal flow meters to measure the methane that is captured by the biodigester and then used to fuel boilers and generators associated with their applications. The Fox Thermal flow meter's stainless steel sensor and wide measurement range provide a simple solution here.



The DDC-Sensor™ sensor has the digital platform for greater flow meter programmability and a more robust non-cantilevered RTD design..



Calibration Technician performing an actual gas calibration in the flow laboratory.

Variations in flow rate caused by seasonal climate changes and the gas spikes that occur after feeding the digester are not a challenge for Fox Thermal flow meters. Their exceptional low flow sensitivity and ability to directly measure mass flow make them ideal for fuel flow measurement over a wide range of temperatures, pressures and flow rates.

The industry is moving away from traditional DP metering technology after concluding that the technology was unsuitable for the varying flow rates and corrosive gases they encounter.

Fox Thermal flow meters are also used to monitor flare gas from the digester. Measuring all combusted methane, including the excess gas that is flared, is an important element of the certification process needed to document, verify, register and monetize reductions in greenhouse gas emissions.

#7: CO2E MONITORING

FOX THERMAL GIVES YOU THE GREEN LIGHT ON CO2E MONITORING

Aimed at U.S. companies that release more than 25,000 metric tons per year of CO_2-equivalent (CO_2e) emissions, the U.S. EPA mandate 40 CFR part 98, requires owners or operators of facilities that emit Greenhouse Gases (GHGs) to monitor and report annual mass emissions.

Fox Thermal mass flow meters' accuracy specification exceeds the requirements defined by the EPA rule, and helps provide a reliable, cost-effective solution to GHG emissions monitoring challenges. Fox Thermal flow meters

directly measure mass flow rate, have no moving parts and can be installed via a single insertion point on a pipe or duct. Other features include:

- Totalizer meets air quality management equipment requirements
- A variety of analog and digital output signals to easily interface with emissions management systems
- No additional pressure or temperature compensation required
- Broad measurement range (up to 1000:1; 100:1 typical) including very low velocity flow rates.

#8: COAL MINE METHANE RECOVERY AND MONITORING

Coal mine methane (CMM) is a potent greenhouse gas that, if vented to the atmosphere contributes to climate change. If not vented, however, CMM can create an explosive hazard inside the mine. However, if CMM is recovered safely and used for energy, it is a valuable, clean-burning fuel source.

There are three major sources of CMM:

- Degasification system (drainage) both pre-mine and gob
- Ventilation air (VAM)
- Abandoned or closed mines

As technology advances are made, as greenhouse gas reduction incentives increase, and as environmental pressure intensifies, the benefits of capturing and using CMM as a fuel gas become more significant.

Thermal mass flow meters can help mining operations comply with regulations, improve the operation of co-gen engines or methane oxidizers, and facilitate the data management processes needed to monetize greenhouse gas emission reduction.

The percentage of methane in the extracted gas can be as little as 1% (in VAM processes) to more than 20% in drainage systems. Other components in the gas may include air, carbon dioxide (CO_2) and/or nitrogen (N_2) in various combinations.

Because fluid composition anomalies can dramatically affect the performance of the flow meter, it is important that the measuring device be calibrated with an actual gas mixture.

SUMMARY OF BENEFITS

There are many benefits of thermal gas mass flow meters over other flow measurement technologies and Fox Thermal leads the industry for accuracy, quality, and innovative design. Benefits of Thermal Mass Flow Technology:

- Direct mass flow measurement of air and gases in standard volumetric units (e.g., SCFM or NM3/H) or mass units (e.g., LBS/M or KG/H)
- No additional pressure or temperature compensation required
- Repeatability and exceptionally broad measurement range: up to 1000:1 (100:1 typical)
- Standard linear 4-20mA output proportional to mass flow rate
- Low pressure drop
- No moving parts
- Cost-effective
- Available in insertion, inline & remote styles
- Measures flow rate and temperature

Calibration Validation		
Typical Requirements of Competitive Models	Other Thermal Flow Meters	Fox Thermal flow meter with CAL-V™
Stop the flow*	Required	Not Required
Remove meter from pipe		
Disconnect wires from flow meter		
Look up data on flow meter's calibration certificate		
Measure electrical characteristics with volt ohm meter		
Perform calculations to evaluate flow meter performance		
Set process pressure to manufacturer's calibration pressure		
Connect auxiliarty test equipment and/or test gases to flow meter		

**When using a retractor assembly for calibration validation test*

CONCLUSION

Emissions flow monitoring requires a flow meter that meets the accuracy and periodic calibration verification requirements set by national, state, and/or local environmental agencies. Fox Thermal flow meters meet and exceed these requirements with high accuracy, the Calibration Validation feature, and the advanced data logger offered on the FT4X.

Direct mass flow measurement, exceptional low-flow sensitivity, fast response, and low maintenance requirements distinguish the Fox Thermal product line. Virtually immune to changes in temperature and pressure, Fox flow meters deliver repeatable, accurate mass flow measurement under varying loads.

Disclaimer: Fox Thermal has made every effort to provide an accurate interpretation of the regulations mentioned in this paper; however Fox cannot be held responsible for errors, local differences, or recent changes. Contact the U.S. EPA or other regulatory body for the latest information on these laws and regulations.

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