

Oil & Gas Production • Waste Management • Steel

# Industry Guide for Thermal Mass flow Meters

Bob Steinberg

## An Industry Guide for the Use of

## Thermal Mass Flow Meters

Oil & Gas Production • Waste Management • Steel

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Choose Wisely.

Sage Flow Meters

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# Introduction

The thermal mass flow meter measures the total *mass flow rate* through a pipe determined from convective heat transfer. Mass flow rate, rather than volumetric flow rate, is sought in most industrial applications, and thermal mass flow meters have the advantage of monitoring mass flow rate directly. Thermal mass flow meters optimize efficiency, save money, improve product quality, decrease harmful emissions, maintain system balance, combustion optimization, or provide leak detection.

Standard applications for this meter type include combustion air, preheated air, drying air, aeration and digester gas, fuel gas, natural gas distribution (non-custody transfer), stack gas, flare gas, HVAC, occupational safety, and health monitoring; environmental, natural convection, and fermentors.

This eBook outlines some of the thermal mass flow meter applications in the oil and gas industry, waste management, and steel industries. It also provides an overview of applications in automobile manufacturing, chemical and petrochemical, food and beverage, industrial compressed air, and pharma and biotech industries.

## The Principle of Operation

There are insertion and inline (also called “in-line”) thermal mass flow meters, and in either case, the probe of the meter supports two sensors that extend into the gas flow. The Sage Metering sensors are resistance temperature detectors (RTDs), consisting of durable reference-grade platinum windings protected in a 316 stainless steel sheath.

Figure 1: Sage insertion-style PARAMOUNT flow meter.

During the thermal mass flow meter operation, a circuit heats the flow sensor while a second detector acts as the reference-sensor to measure the gas temperature. Refer to Figure 2 (next page). As gas flows past the heated sensor, gas molecules carry heat away from the heated sensor. The circuitry maintains a constant overheat between the flow and reference sensor. A change in the mass (molecular) flow rate changes the amount of cooling, resulting in a temperature change, disrupting the circuit balance. Almost instantly, the circuit reestablishes the lost energy by varying the power to the flow-sensor to obtain the correct overheat temperature. The electrical power used to maintain this overheat determines the mass flow signal.

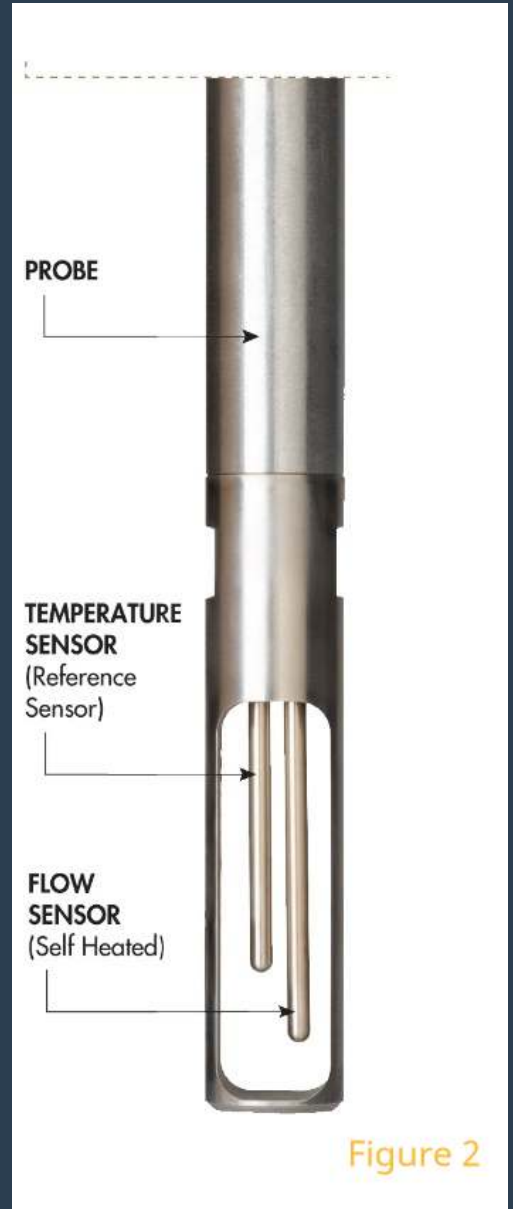


Figure 1

For the insertion-style flow meter, the sensors insert through a sealed compression fitting and isolation valve assembly or flanged mounting in a pipe, duct wall, or similar flow channel. For the inline meter, the sensor probe that supports both sensors is installed permanently into a pipe (with built-in flow conditioners) with flanged or threaded connections (or tube).

## Sage Metering

Sage Metering manufactures premium thermal mass flow meters to monitor and control gas mass flow in manufacturing processes, building management systems, and various environmental applications. The Sage flow meters, offered in both inline and insertion-style, increase productivity, reduce energy costs, maximize product yields, and tackle ecological applications, including carbon credit verification for greenhouse gas reduction.





Since Sage Metering began in 2002, it led the industry by introducing innovative features such as the "In-Situ Calibration Check," permitting users to quickly and easily verify that their flow meters retain the original NIST-traceable calibration. While the Sage Prime has been the Sage flagship model, with the introduction of the newest model in 2019, the Paramount™, and its revolutionary new software, SageCom™, the Paramount is positioned to become the premier thermal mass flow meter.

Figure 3: Sage Metering high-velocity NIST-traceable calibration facility.



# Chapter 1: Oil and Gas Production

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## Upstream

There are three sectors in the oil and gas industry: upstream, midstream, and downstream. The upstream segment involves exploring and gathering crude oil and natural gas deposits and is heavily involved in geological surveys, mining, drilling, and production.



Figure 4: Pumpjacks in an oil field extracting crude oil from a well.



Due to growing greenhouse gas (GHG) concerns, the upstream oil and gas sector faces new and more demanding Environmental Protection Agency (EPA) regulations requiring GHG emissions reduction and reporting. The statutes often require the use of vapor recovery units or combustion devices (flares).

## Compressor stations

Compressor stations are an essential component of the transportation of natural gas. These facilities are strategically located along natural gas pipelines where the gas compresses to a particular pressure, allowing the fluid to continue flowing toward its end destination. Compressor stations operate in both the upstream and midstream oil production segments and all segments of gas production. The number of compressor stations in a pipeline varies depending on the conditions and region but usually occurs every 40-100 miles. There are approximately 1,650 compressor stations in the United States containing nearly 9,000 compressors.



Figure 5: The compressor is the heart of a compressor station and the component that compresses the gas.

Each compressor station has many components, but the compressor is the cornerstone and is the equipment that compresses the gas. The compressor consists of an engine and a compressor, and pipeline gas fuels the machine, which powers the compressor.

### Measure Natural Gas

The pipeline gas used to fuel the compressor's engine needs to be measured. Since there is no transfer of ownership of the gas, a thermal mass flow meter is ideal for measuring the engine's natural gas flow. It measures mass flow and does not require the added expense of pressure or temperature sensors and a flow computer to determine flow correction. In this application, a two-inch pipe is typical, and the thermal mass flow meter can be an insertion style or an inline meter (as a flanged flow body). Of course, the insertion-style meter is simpler to install, and in either case, the meter has no moving parts.

### Dry Gas Seal

Dry gas seals are non-contacting closures. They are dry-running mechanical face seals that consist of a mating (rotating) ring and a primary (stationary) ring. When operating, the rotating ring's elevating geometry produces a fluid-dynamic drive causing the primary ring to separate. This separation generates a gap between the two rings, which could permit gas leakage into the surrounding area.

Compared to wet oil seals, dry gas seals are installed on over 90% of new compressors in varied applications, including those compressors routinely used on natural gas pipelines.

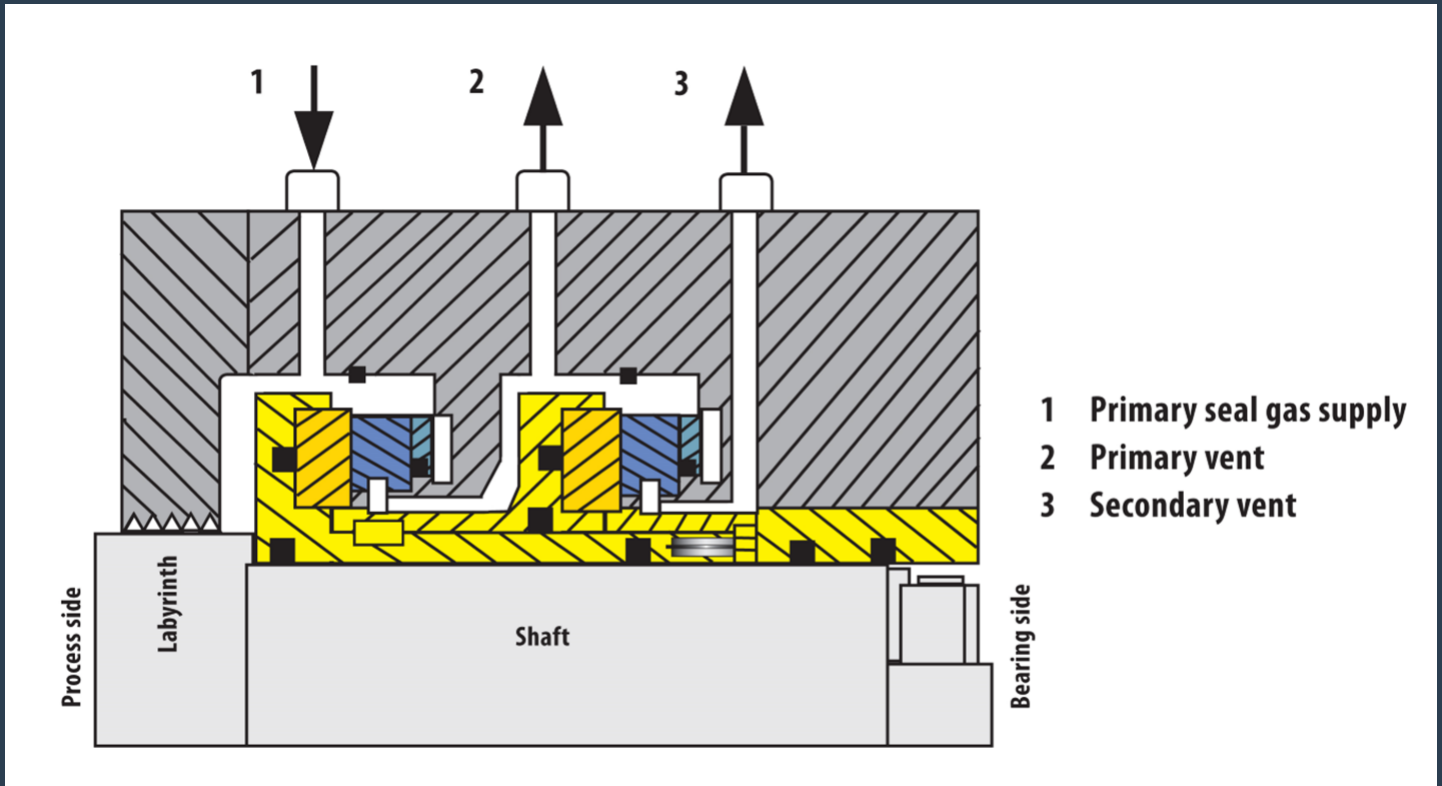


Figure 6: Tandem dry gas seal for compressor

Tandem-style dry seals consist of a primary seal and a secondary seal contained in a single cartridge. The gas seal system's function is to prevent leakage of the process gas into the atmosphere, accomplished by injecting high-pressure gas between the compressor labyrinth seal and the primary seal. Any leakage gas that passes through the primary seal vents to a flare. An even smaller amount may pass by the secondary seal and vent. However, the secondary seal's primary purpose is to serve as a backup in a primary seal failure. The secondary seal provides the necessary sealing until the compressor is shut down.

As the seals wear, the leakage gas flow to the flare increases, and measuring the seal gas flow is an effective way to monitor the seals' condition. The vent gas flow to the combustion device is relatively low, often in the range of 5 to 20 SCFM depending on compressor size. A typical pipe size here is 1 inch. The gas measurement in the seal vent line to the flare may also be required to report greenhouse gas emissions to meet EPA requirements. More information is available in the Sage Metering white paper, "[Greenhouse Gas Emissions Monitoring Using Thermal Mass Flow Meters](#)."

## Blowdown

During the compressor station's regular operation, the compressor may need to be taken offline for maintenance, standby operation, or shutdown. During these occasions, pressurized natural gas remains in the compressor and the adjoining pipeline. In some instances, it may be necessary to release or blowdown this gas, which can occur through venting the gas to an adjacent compressor. Alternatively, the gas may vent to a flare. During a shutdown, the pressure and flow rate in the blowdown piping varies considerably. The measurement of the natural gas discharged during a blowdown may be desirable.

## Advantages of Sage Thermal Mass Flow Meters in Compressor Station Applications

At a compressor station, a thermal mass flow meter meets the requirements and have the following benefits:

- Direct mass flow measurement without the need for pressure and temperature correction
- Insertion probe simplifies installation
- High rangeability with the ability to detect flows at very low velocities
- Factory calibrated – no need for field calibration
- Includes a simple method to verify the meter is within the calibration

### Recommended for Compressor Station Applications



**Paramount™** – The Sage Paramount has an optional Class I Div 1 rating (Div 2 is standard).



# Midstream

The midstream sector involves the processing, storage, and transportation of either crude oil, natural gas, natural gas liquids, or other products. In this sector, the oil and gas are brought to distributors by truck, train, or pipelines of transmission companies.



Figure 7: Oil & gas refinery

Crude oil refining and natural gas processing integrate many processes and require accurate gas measurement. Thermal mass flow meters are an excellent choice for measuring air and gas flows to various process units.

## Sulfur Recovery Unit

In natural gas processing and refining of high sulfur crude, hydrogen sulfide ( $\text{H}_2\text{S}$ ) is removed and converted to elemental sulfur using the Claus process. This process involves the reaction of  $\text{H}_2\text{S}$  with the oxygen ( $\text{O}_2$ ) present in the air to create sulfur dioxide ( $\text{SO}_2$ ) and water ( $\text{H}_2\text{O}$ ). The  $\text{H}_2\text{S}$  and  $\text{SO}_2$  then react with each other to produce sulfur ( $\text{S}$ ). The amount of air reacting with  $\text{H}_2\text{S}$  must be accurately controlled, so 1/3 of the  $\text{H}_2\text{S}$  is converted to  $\text{SO}_2$ . This reaction creates the desired 2:1 ratio between  $\text{H}_2\text{S}$  and  $\text{SO}_2$ . Too much air produces unreactive sulfur trioxide ( $\text{SO}_3$ ). Too little air forms less than the stoichiometric amounts of  $\text{H}_2\text{S}$  and  $\text{SO}_2$ , resulting in lower yields.

A thermal mass flow meter is the desired choice for the mass flow measurement of air. The primary advantage is direct mass flow measurement without ancillary equipment for pressure and temperature correction combined with the meter's high reliability.

## Process Heaters

There are numerous process heaters and other combustion sources in a refinery or gas production plant. By operating at the desired air-to-fuel ratio, one achieves the heater's most efficient control. Too much gas and the combustion runs rich, and uncombusted fuel discharges. Too much air means that the excess air is unnecessarily heated, reducing combustion efficiency.

Thermal mass flow meters frequently measure airflow and gas fuel flow to combustion sources to help achieve the most efficient combustion.

Explore using flow meters to achieve stoichiometric combustion to save energy and reduce pollutants in the Sage Metering white paper, "[Combustion Efficiency and Thermal Mass Flow Meters](#)."

## Greenhouse Gas Emissions

The EPA requires that many facilities report greenhouse gas (GHG) emissions. There are multiple methods for determining GHG emissions from combustion sources. One easy way is to measure and totalize the flow of natural gas consumed during the specified period and use EPA formulas for calculating GHG emissions.

A thermal mass flow meter can easily measure the natural gas flow, and the built-in non-resettable totalizer provides total fuel consumption. While other flowmeter types typically require significant piping modifications, due to the thermal mass flowmeter's rangeability, one can avoid piping modifications with an insertion-style thermal mass flow meter—permitting easy installation in the existing gas pipe.

Explore greenhouse gas emissions monitoring in applications of natural gas, biogas, landfill gas, digester gas, and flare gas in the Sage white paper, "[Greenhouse Gas Emissions Monitoring Using Thermal Mass Flow Meters](#)."

## Gas Flare

A gas flare is a combustion safety device that burns off the excess gas or unintentionally released gas. Without such a device, the gas released into the atmosphere may create an unsafe situation. Flares are common in gas production and oil refineries.

There are essential factors to consider when using a thermal mass flow meter on flare lines. Due to the changing gas composition in some flare gas streams, the thermal mass flow meter does not provide accurate flow measurement of the emitted flare gas and is not recommended in the main flow header unless the gas mix is known. Optionally, SageCom software can be utilized to modify the flow meter's calibration for a different gas mix, if known, by simply entering the new gas constituents. Additionally, the thermal mass flow meter has applications in the individual flare headers from the various process units where the gas composition is more consistent. The meter has excellent flow velocity sensitivity and even measures the flow of the continuous sweep gas. Suppose there is a release to the flare system. In that case, the strategically placed meters can indicate which process unit is sending gas to the flare and detect if any valves have not closed entirely after the unit resumes regular operation.

Explore overcoming the challenges of using mass flow meters with gas flaring in the Sage white paper, "[Flare Gas Measurement Using Thermal Mass Flow Meters](#)."

## Advantages of Sage Thermal Mass Flow Meters in Midstream Applications

Thermal mass flow meters provide the following benefits:

- Direct mass flow measurement without the need for pressure and temperature correction
- Excellent flow velocity sensitivity having the ability to measure flow rates that other flow meters cannot detect
- Easy to retrofit into existing piping with the insertion probe
- High turndown rates provide excellent rangeability
- SageCom software for updating the flow meter to a new gas mix
- A simple method to verify calibration of the meter

## Recommended for Midstream Applications



**Paramount™** – The Sage Paramount permits ease of communicating between the meter and the SageCom software with Bluetooth or a furnished USB cable and connector.



## Downstream

The downstream oil and gas industry is involved in the refining, distributing, and selling of various products, including jet fuel, gasoline, diesel, plastics, synthetic rubber, propane, and natural gas. This sector includes refineries, petrochemical plants, petroleum product distributors, and natural gas distribution companies.

While the thermal mass flow meter is not an AGA (American Gas Association) approved custody transfer meter, there are applications in natural gas distribution systems where the meter can benefit.

### Natural Gas Distribution Monitoring

Natural gas distribution companies measure their customers' total gas usage during a specific period through their custody transfer flow meters. These meters fail to communicate the actual real-time flow rate at various distribution points in the many feeder lines. In contrast, a



thermal mass flow meter is beneficial for real-time natural gas flow monitoring in distribution and service lines.

Figure 8: Natural gas pipes and valves at compressor station.

## Distribution Pipelines

Distribution pipes or “mains” are the intermediate phases between high-pressure transmission lines and low-pressure service pipelines. They operate at pressures varying from 30 psi up to 450 psi within small to mid-sized pipes of steel, cast iron, polyethylene, or occasionally copper, ranging from 2" to 24".

## Service Lines

The service pipelines are metered and deliver the natural gas to the gas customers. They are small pipes, typically polyethylene, steel, or copper, ranging from ½" to 2" and transmit the gas at low pressures ranging from 6 to 10 psi.

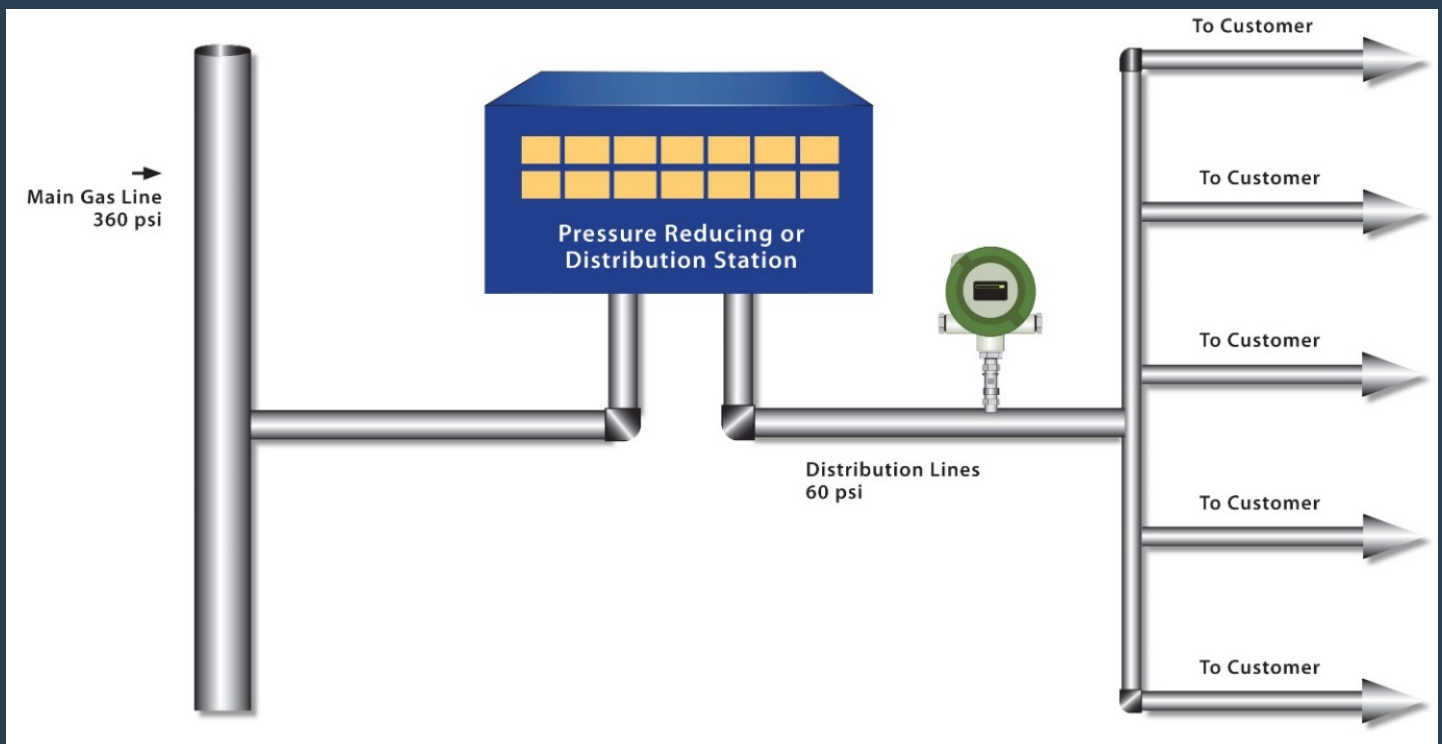


Figure 9: Thermal mass flow meters out-perform DP flowmeters for natural gas monitoring of service lines since they more accurately measure natural gas flow at low flow rates.

## Real-Time Non-Custody Applications to Avoid Bottlenecks

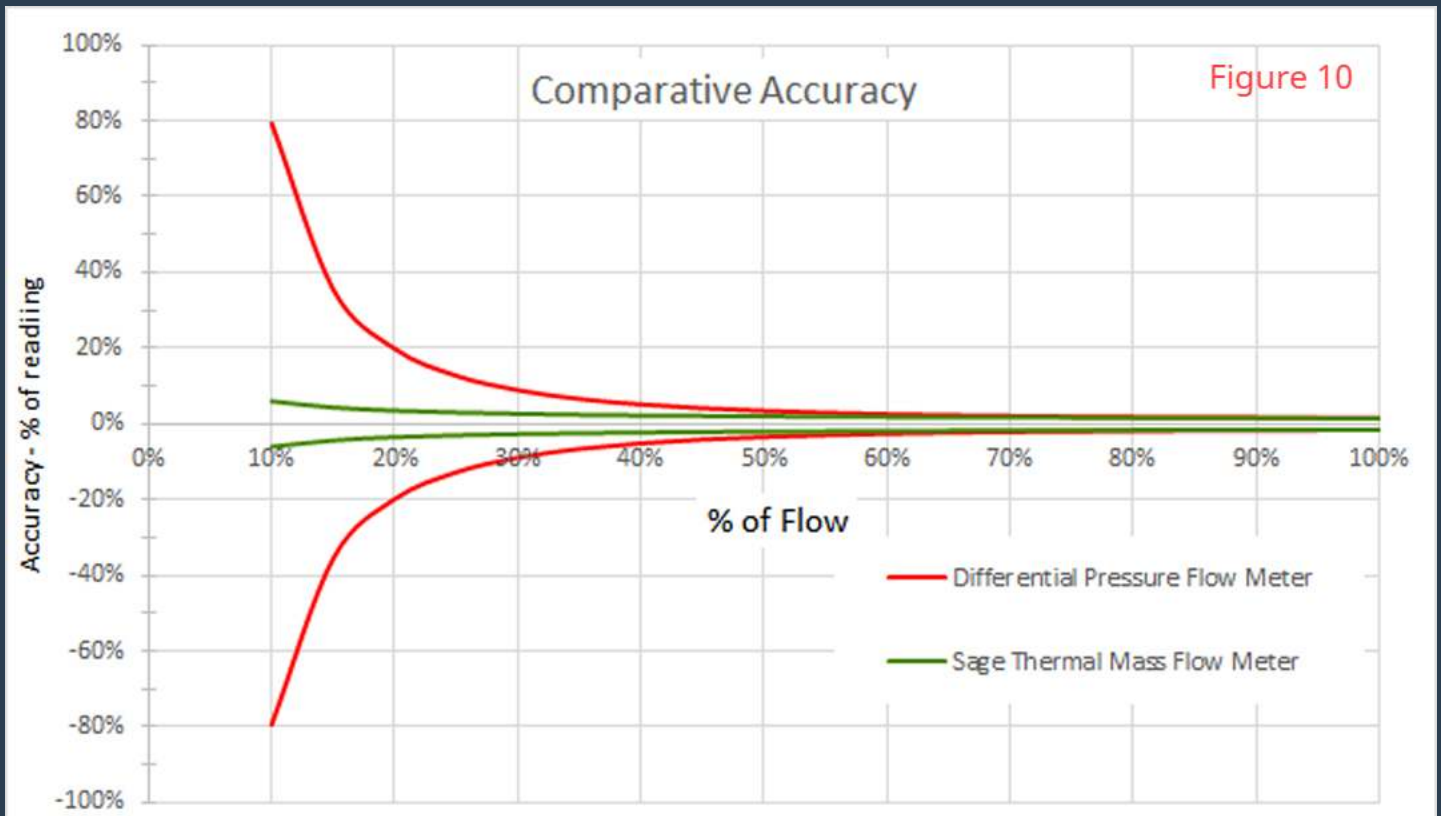
Flow meters can be installed in different locations to ascertain gas usage in the distribution systems for real-time measurement. By doing so, the distributor can anticipate the gas needs and avoid bottlenecks during peak demand periods, which typically are in the morning and early evening. Gas consumption also varies during the year, with peak usage for heating during the winter months. Some gas distribution companies use meters at the intermediate line to balance and model their system.

A thermal mass flow meter is perfect for these applications because they measure direct mass flow, have high rangeability, with simple installation by inserting the probe into the pipe through a ball valve and compression seal.

## Natural Gas Flow Monitoring

Many natural gas distribution companies use differential pressure (DP) flow meters upstream of custody transfer meters to monitor the gas flow to multiple industrial customers. Unfortunately, the gas flow can vary considerably depending on the time of the year, and DP flowmeters have reduced accuracy at low-flow conditions. For this reason, thermal mass flow meters are a better choice for the application, given that they more accurately measure natural gas flow at these low flow rates and have rangeability as high as 100:1.

Figure 10 (next page): The chart illustrates the accuracy of a DP flow meter versus the Sage Prime thermal mass flow meter illustrating that the thermal mass flow meter is more accurate at lower flow rates.



## Advantages of Sage Thermal Mass Flow Meters in Natural Gas Flow Monitoring

- Mass flow measurement without the need for temperature and pressure correction
- Easy in-situ calibration verification method to verify the accuracy and operation of the sensor and transmitter
- Wide turndown for precision measurement at a low or high flow
- With varying gas pressures and flow rates, the thermal mass meter has excellent low flow sensitivity and negligible pressure drop
- Easy installation
- Approved for use in hazardous areas (Class I Div 2 is standard with Div 1 optional on the Sage Paramount)
- Calibrated for natural gas
- Probe retraction device for easy removal for maintenance

## Recommended for Natural Gas Flow Monitoring



**Paramount™** – The Sage Paramount has an optional Class I Div 1 rating (Div 2 is standard).



## Nitrogen Blanketing for Storage Tanks



Many industries store liquids, gases, and even slurries in storage tanks or vessels. Often, when the storage material comes in contact with oxygen, the substance oxidizes and degrades or potentially creates a hazardous situation.

Figure 11: Industrial tanks

Tank blanketing, nitrogen blanketing, or tank padding is a process of introducing an inert gas, such as nitrogen (the most cost-effective), to a storage tank to prevent the introduction of air (oxygen) into the vessel containing the storage material, which is usually a liquid. When purging a container with inert or inactive gas, the storage vessel material does not contact the oxygen. For this reason, the life of the product is prolonged, and potentially explosive conditions are mitigated.

The petrochemical industry and the hydrocarbon industry use the tank blanketing process to prevent product contact with oxygen to avoid potentially hazardous conditions. The blanketing process maintains an inert gas atmosphere above a combustible or flammable liquid, reducing ignition potential.

## Tank Blanketing Systems

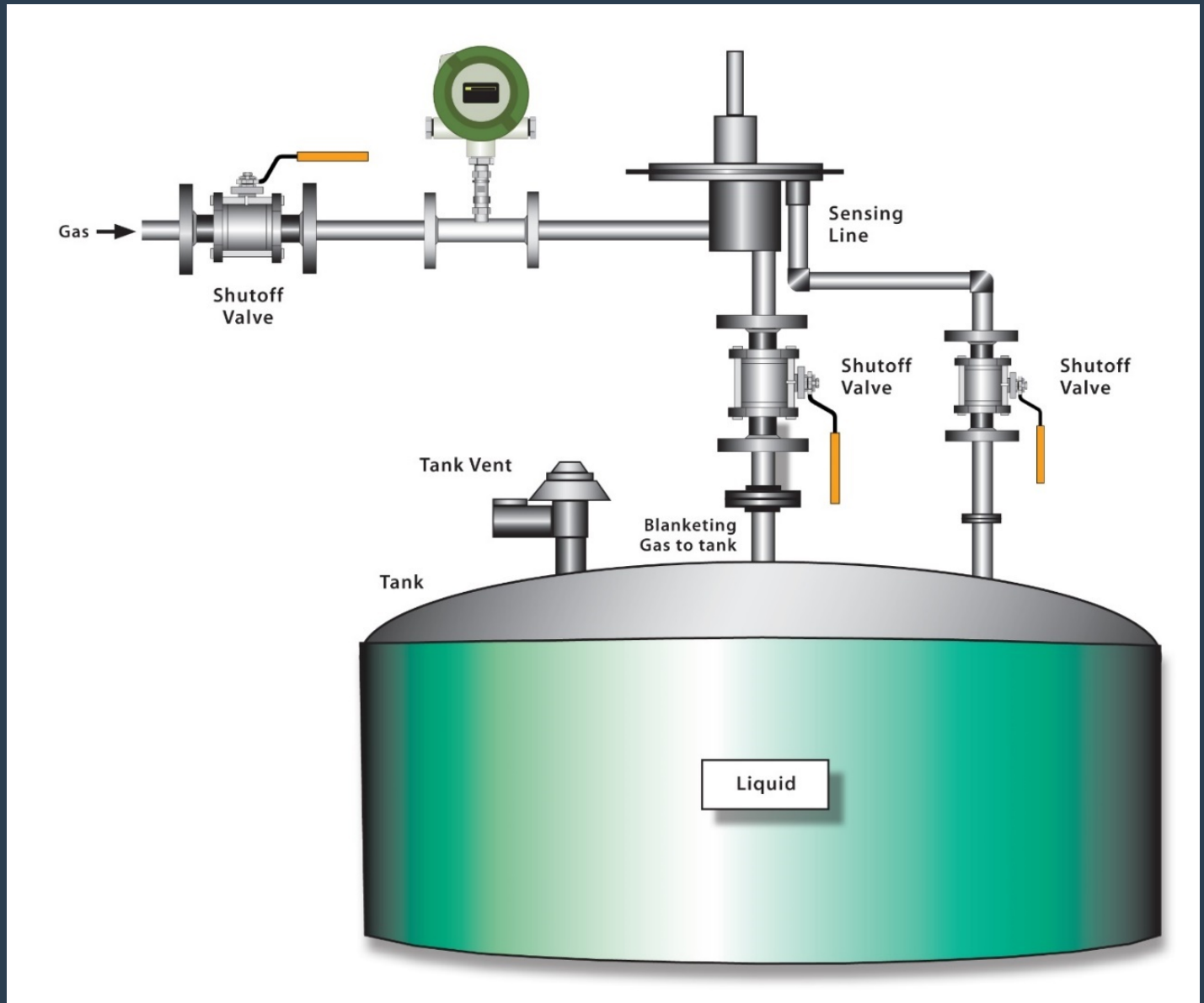
Tank blanketing systems are on fixed-roof tanks. The system includes a valve that controls the nitrogen coming into the tank. The valve is continuously adjusted to maintain a slight constant positive pressure in the vessel's vapor space. Usually, under static conditions, the valve is closed, shutting off the flow. If the material withdraws from the tank, the gas pressure decreases, and nitrogen flows into the vessel to compensate. The same occurs when the inert gas leaks from the tank. Similarly, if the temperature drops, there is a decrease in the vapor space's pressure, and nitrogen flows into the vessel.

When emptying the tank, significant flow rates of nitrogen can result. In this case, it is essential to maintain positive pressure in the tank. If the tank pump-out rate is higher than the rate of nitrogen flow replacement, negative pressure can cause the tank to suck in and collapse.

Facilities management is often interested in measuring the inert gas (nitrogen) flow to monitor consumption. Thermal mass flow meters can measure and totalize the amount of inert gas. They also can alert the operator if the gas is leaking to prevent losses. Some systems use the expensive Coriolis meter, in which case the thermal mass flow meter offers significant savings and ease of installation.

The Sage meter measures the flow rate, provides a visual display, a 4-20 mA signal, and shows totalized flow on the screen with a pulse output that the customers' external totalizer can receive.

Figure 12: The Sage thermal mass flow meter is available with remote electronics permitting the display to be at ground level rather than near the top of the tank, where the flow meter is likely to be installed.



## Advantages of Sage Thermal Mass Flow Meters in Tank Blanketing

- Mass flow measurement without the need for temperature and pressure correction
- Approved for use in hazardous areas (Class I Div 2 is standard with Div 1 optional on the Sage Paramount)
- No moving parts reduce maintenance; advantageous over positive displacement flow meters or turbine meters
- Calibrated for nitrogen gas composition
- Wide turndown for precision measurement at a low or high flow
- Temperature compensation for accuracy and repeatability with changing process and ambient temperatures
- Easy in-situ calibration verification method to verify the accuracy and operation of the sensor and transmitter

## Recommended for Tank Blanketing



**Paramount™** – The Sage Paramount has an optional Class I Div 1 rating (Div 2 is standard).



# Chapter 2: Waste Management

## Wastewater Treatment Plants

Wastewater treatment removes contaminants from wastewater, primarily sewage, and returns the treated effluent or discharge to the environment. The consistency of sewage varies in different areas depending on the mix of household sewage and industrial waste. There are multiple stages in wastewater treatment that have become more involved as technology has developed. The exact process and types of equipment vary between different plants.



Figure 13: Aerial view of the sewage treatment plant



Within a contemporary wastewater treatment process, thermal mass flow meters play a significant role in obtaining efficient operation of the various wastewater treatment stages.

## Aeration Air

The secondary treatment of wastewater is reducing the organic material in the water. By introducing air or oxygen into the wastewater, we promote microorganisms that break down organic material. This process is frequently accomplished using an activated sludge process and aeration basins, which introduce air into the wastewater through submerged piping and aeration nozzles.

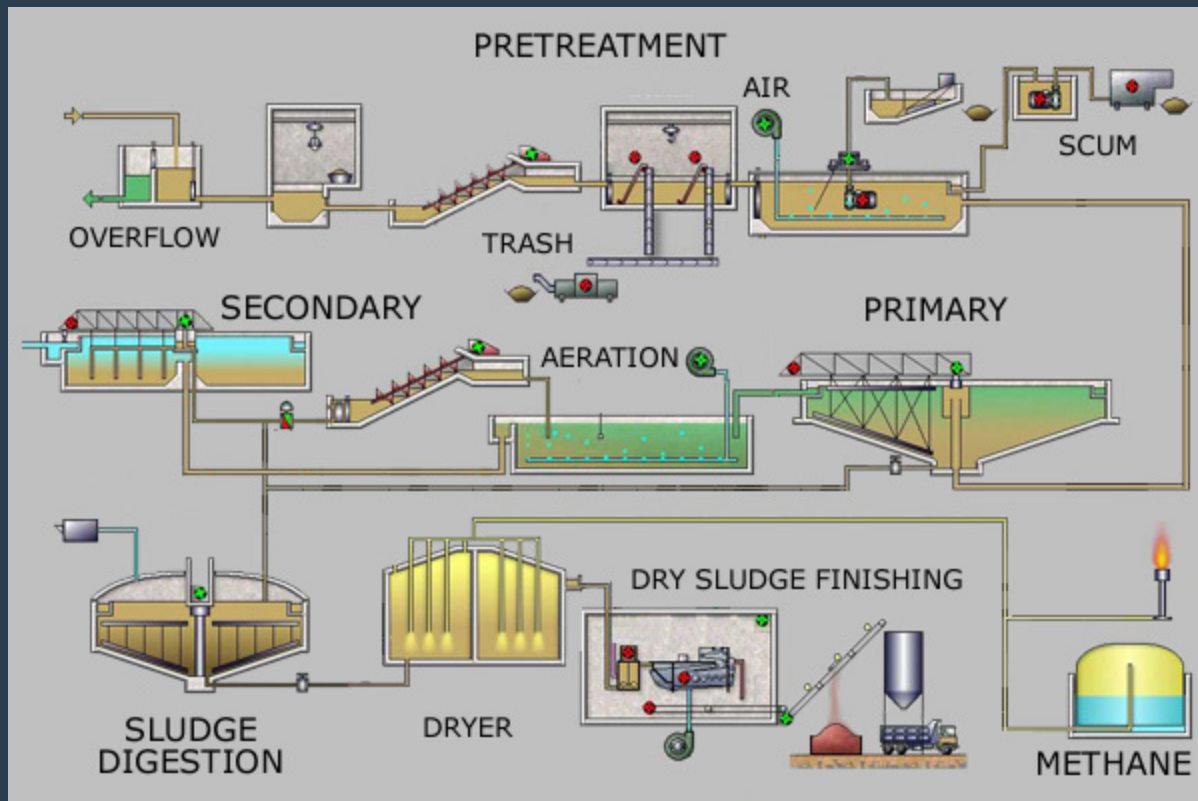


Figure 14: Attribution: [Leonard G.](#) at [English Wikipedia](#)

Aeration may occur through either mechanical agitation or a subsurface air system. A mechanical system uses blades, propellers, or brushes to agitate the wastewater to introduce air from the atmosphere. In a subsurface system, the air is introduced by blowers and diffusers submerged in the wastewater. Air blowers feed the main header, which may serve multiple aeration basins. From the main header, the air flows to various zones in an aeration basin. Depending on the design, flow meters may measure each zone's flow in each basin to obtain a balanced flow to each area. A dissolved oxygen (DO) meter controls the total amount of air flowing to the aeration basins.

At one time, the philosophy of "the more aeration air flow, the better" was practiced. As energy costs increased, however, wastewater treatment plants began to control the air flow to the different parts of the aeration basin to obtain the desired dissolved oxygen (DO) content. Thermal mass flow meters are ideal for monitoring the flow to each section of the aeration tank.

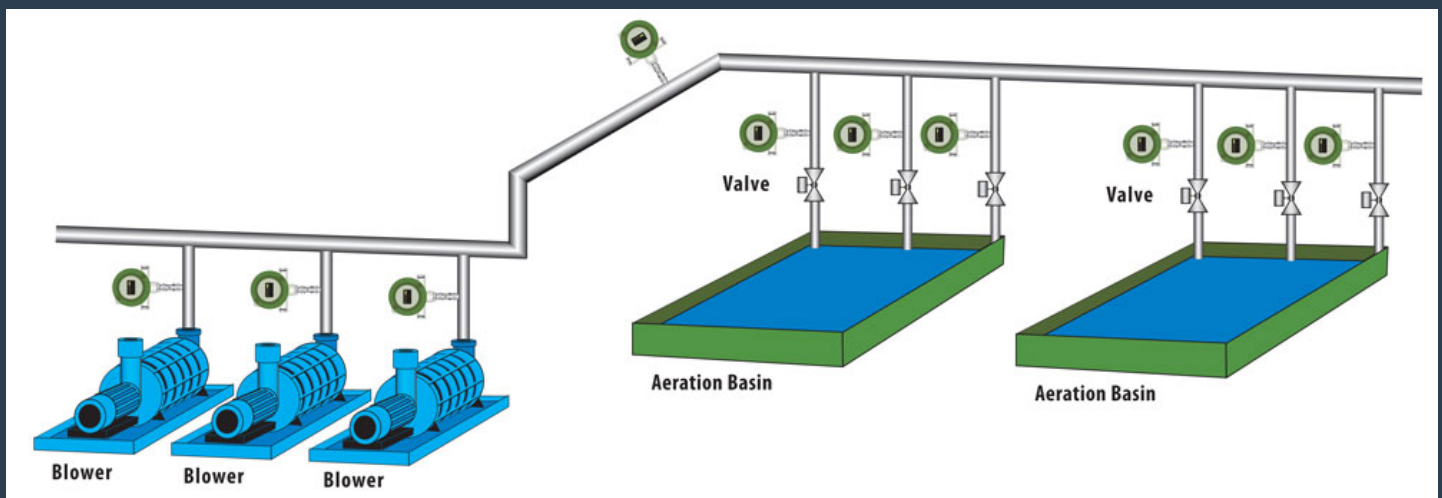


Figure 15: Aeration Basins and Blowers

In other cases, the total flow of *all* aeration basins is measured. The thermal mass flow meters may be installed in the main header to measure the total air flow from the blower/compressor. In this case, there is no control of the air flow to each basin; the meter is merely monitoring air flow to check the blower's performance. However, we can achieve better control by measuring and controlling the air flow to each zone of the aeration basin, reducing energy usage. In this case, a flow meter is on each branch line leading to an individual basin where the flow meter is used for balancing the air flow between basins or, in some cases, controlling the flow to each aeration basin.

#### Thermal Mass Flow Meters in Aeration Flow

Three technologies are commonly used to measure aeration airflow: orifice plates, vortex shedding, and thermal mass flow meters. The thermal mass flow meter is the preferred device to measure airflow at wastewater treatment facilities. The meter requires less maintenance, is easier to install, has lower pressure drop, saving energy over the other technologies. As older aeration systems become upgraded, thermal mass flow meters are replacing vortex and orifice meters.

The thermal mass flow meter's accuracy and repeatability serve the aeration process well. The thermal meter can measure over a wide flow range (high rangeability), making it accurate in changing operating conditions. Thermal mass flow meters also measure mass flow, so pressure and temperature measurement devices are not needed, unlike other metering options. The insertion-style flow meter is easy to install through a single tap point. The small sensor creates a minimal pressure drop, allowing the blowers to run at lower power levels and reduce energy consumption.

If an aeration system lacks sufficient straight run, flow conditioners may eliminate flow profile distortions. Because there are no moving parts, there is nothing to clean, repair, wear out, or clog. The thermal mass flow meter provides excellent reliability and long-term maintenance-free operation. Also, Sage Prime and Paramount meters can have their calibration verified while in the field without stopping the process or removing the meter from the pipe.

### Advantages of Sage Thermal Mass Flow Meters in Aeration Air

A remote style meter permits the operator to view the air flow from a convenient location.

Figure 16: A remote style meter permits the operator to view the air flow from a convenient location

The benefit of thermal mass flow meters in this application is:



Figure 16

- Mass flow measurement without the need for temperature and pressure measurement devices
- Easy to install an insertion probe directly into the pipe
- High rangeability
- Creates minimal pressure drop
- Excellent reliability provides long-term maintenance-free operation



### Recommended for Aeration Air

**Prime™** –The Sage Prime offers exceptional performance with an economical insertion-style and remote-style meter.

## Digester Gas

Sludge from the primary and secondary treatment stages is a byproduct of wastewater treatment. The slurry further breaks down in the absence of air with anaerobic digesters. It produces digester gas (biogas), a mixture of methane and carbon dioxide with small amounts of other components, including hydrogen sulfide, nitrogen, and trace amounts of other gases. Digester gas is wet and dirty. The ratio of the gases varies but typically is 65% methane and 35% carbon dioxide.

In situations where gas composition changes, like digester gas, some thermal mass flow meter manufacturers offer innovative software to resolve the issue. The Sage Metering SageCom permits the user to enter a new gas composition, and the Sage Paramount flow meter automatically corrects the flow measurements for the new gas composition.

The digester gas can be used as a fuel to produce energy for the facility. If a facility lacks the engine to generate the energy or too much digester gas is created, the digester gas is sent to a flare to burn off. Measurement of the biogas flow rate indicates both the digester's and the engine's operation.

Many different flowmeter types have attempted to measure digester gas flow. One challenge, of course, is that digester gas often has a low velocity, and many flow meters cannot accurately detect this low flow. Another problem is that meters with moving parts, such as the positive-displacement rotary gas meter often used in this application, become plugged with buildup and create ongoing maintenance difficulties.

Due to condensed moisture in the gas, install the flow meter downstream of the moisture knock-out pots.

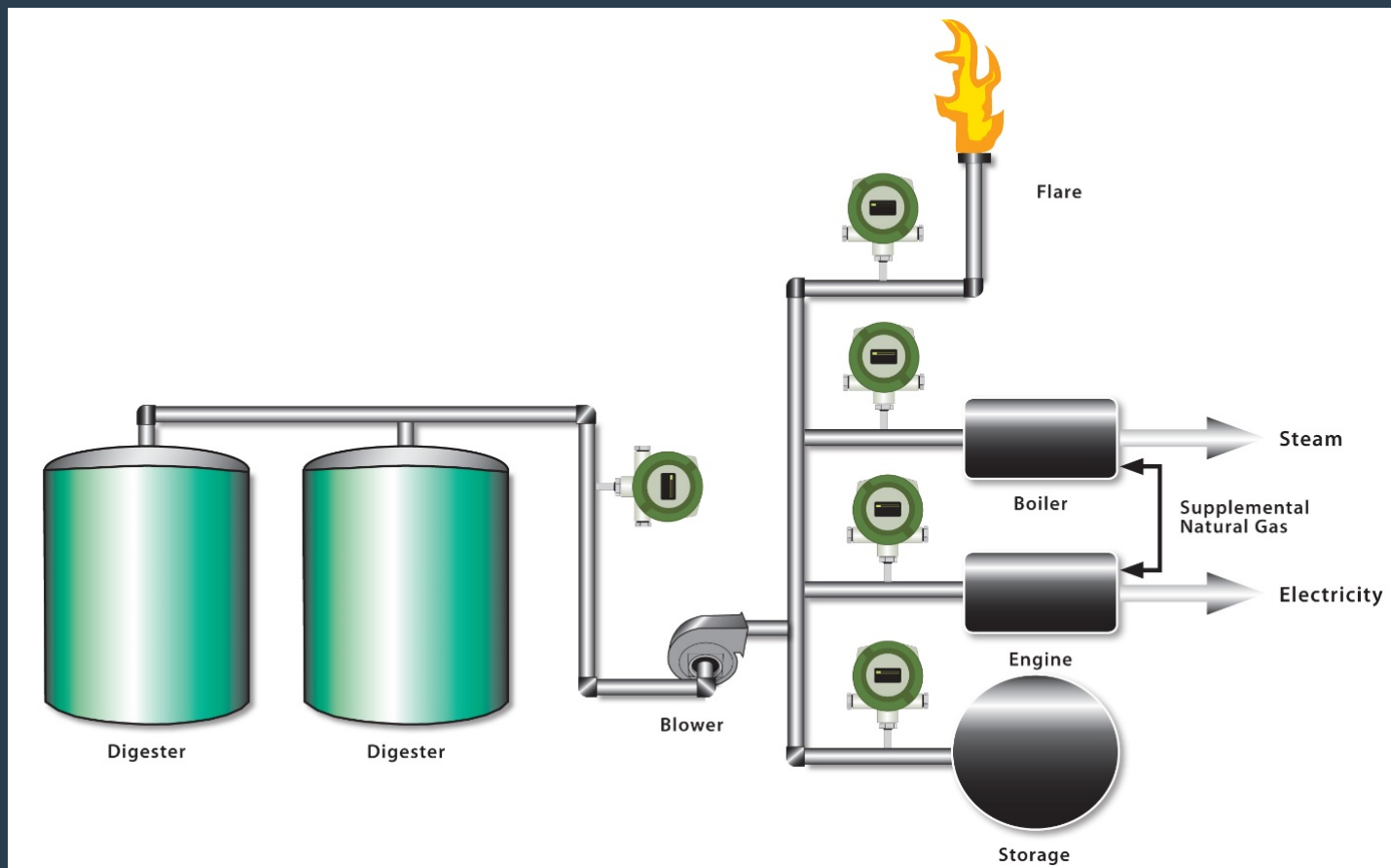


Figure 17: Within a contemporary wastewater treatment process, there are many opportunities to use thermal mass flow meters to measure digester gas flow or flare gas flow.

#### Applications for using thermal mass flow meters for digester gas include:

- Monitor the digester process performance
- Process control for cogeneration systems that use digester gas as an energy source
- Flaring to convert methane (GHG) to less harmful CO<sub>2</sub>
- Generating data for GHG reduction and carbon credit programs
- Comply with environmental regulations to report greenhouse gas emissions

#### Advantages of Sage Thermal Mass Flow Meters in Digester Gas Applications



- Easy in-situ calibration verification method to verify the accuracy and operation of the sensor and transmitter
- Permits the user to change the gas composition in the field when using SageCom software
- Mass flow measurement without the need for temperature and pressure correction
- Gas from the digester is often low pressure and low flow rates, so the meter requires excellent low flow sensitivity and negligible pressure drop
- Approved for use in hazardous areas (Class I Div 2 is standard with Div 1 optional on the Sage Paramount)
- No moving parts reduce maintenance; advantageous over commonly used positive displacement flow meters or turbine meters
- Calibrated for digester gas composition
- Probe retraction device for easy removal for maintenance
- Wide turndown for precision measurement at a low or high flow
- Temperature compensation for accuracy and repeatability with changing process and ambient temperatures

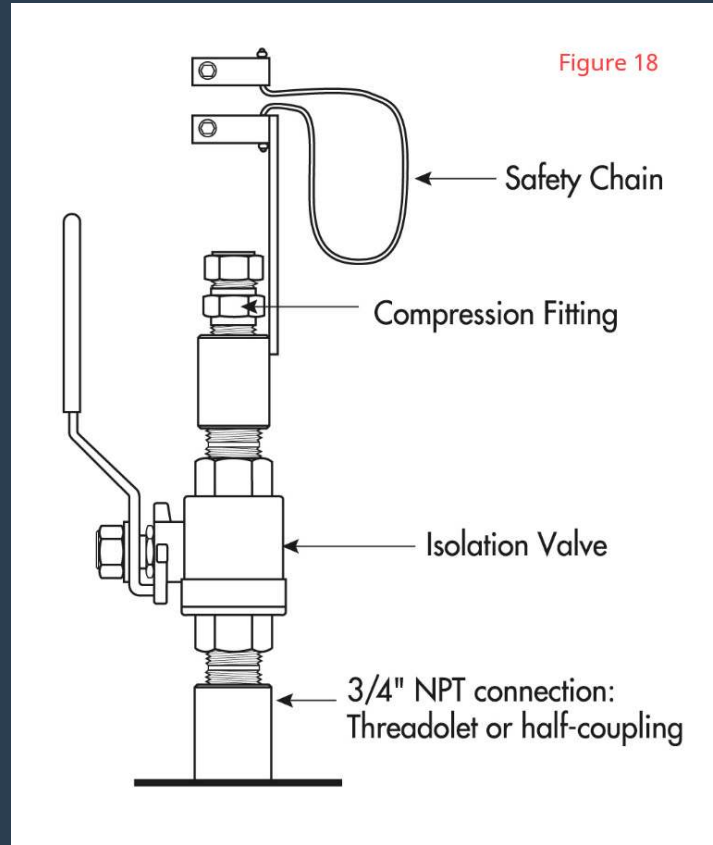


Figure 18: Sage Prime and Paramount meters can perform the in-situ calibration check as long as a "no-flow" (0 SCFM) condition occurs. "No flow" is easily created using an isolation valve assembly (pictured) with the insertion meter style

## Recommended for Digester Gas



**Paramount™** –When used with the SageCom software (complimentary with Paramount purchase), the user can change the gas composition while still in the field. The flow meter automatically corrects the flow measurements for the new gas composition. Additionally, the Paramount comes standard with CI I Div 2 rating with an optional Div 1 class.

## Odor Control Systems

Wastewater treatment plants produce odor, especially in the initial stages of the process. Since some wastewater facilities are near residential areas, odor reduction systems are installed. These systems may involve covering equipment such as the raw sewage influent pump station, raw sewage clarifiers, aeration basins, and sludge thickeners. The odorous gas containing hydrogen sulfide is pulled through ductwork, to a fan, through a treatment device, and discharged into the atmosphere. The treatment device may be a carbon filter, wet scrubber, or similar equipment.



Figure 19



Flow meters are used in each ductwork section to ensure that sufficient odorous air is removed from each unit and that the total flow rate does not overload the primary odor control device.

## Advantages of Sage Thermal Mass Flow Meters in Odor Control Applications

For all these wastewater treatment plant applications, thermal mass flow meters offer:

- Mass flow measurement provides consistency with varying pressure and temperature
- Easy installation in pipe or ductwork
- Remote mount available for local display of flow rate
- Thermal mass meters can detect and measure very low flow rates; at velocities less than many other flow meters
- An insertion-style meter can easily be removed from the duct for cleaning and maintenance using a suitable retraction device (if required)
- Virtually no pressure drop
- High rangeability
- Linear output signal

## Recommended for Odor Control Applications



**Prime™** –The Sage Prime offers exceptional performance with an economical insertion-style and remote-style meter.

# Municipal Solid Waste

Accurate measurement of landfill gas flow throughout the system is needed, whether the objective is landfill gas to energy projects, monitor the process for optimization, or GHG emissions reporting.

## What is a Landfill?

A landfill is an engineered terrain where trash is deposited and remains. Landfilling is an obsolete way of handling waste, though it remains a primary way to dispose of trash and garbage. Modern landfilling is also known as "municipal solid waste." Landfills contribute to enormous environmental problems such as climate change, toxic air emissions, and groundwater contamination.

## Landfill Methane Gas Composition

The natural bacterial breakdown of organic waste at municipal solid waste (MSW) landfills generates landfill gas (LFG). This gas contains approximately 50% methane, with the remainder being mostly carbon dioxide, with smaller amounts of water vapor, nitrogen, oxygen, and trace amounts of other contaminants. The gas can be wet and also considered dirty.

## Landfill Gas to Energy and Flare LFG

Gas is removed from the ground at individual wells and collected through a series of headers or manifolds. Equipment, such as sumps, knock-out pots, compressors, are used to bring the landfill gas to flare or recover it for landfill-to-energy facilities.

Throughout the processes, accurate gas flow measurement is needed from the landfill extraction to the destruction or cogeneration, whether for optimizing the process or GHG emissions reporting to environmental agencies.

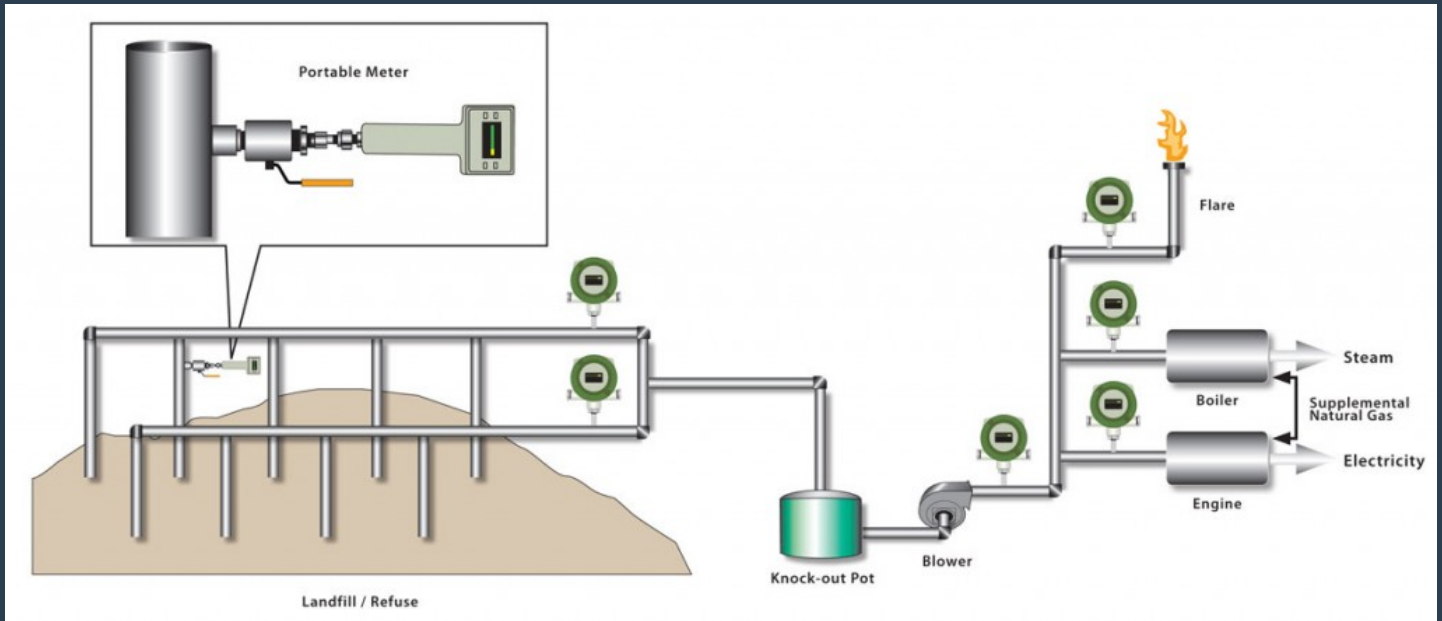


Figure 20: Accurate analysis of landfill gas is needed throughout the system whether the objective is monitoring, LFG to energy or recovery, or GHG emissions reporting.

## Local Municipality

Some local municipality landfills cannot implement landfill-to-energy projects. In these cases, the landfill gas is often collected and delivered to a privately held co-gen facility usually located on the property and used to produce electricity. During periods when the co-gen facility does not need the gas, it is flared. In either case, gas flow meters need to measure LFG flow to the co-gen or the flare.

The measurement of landfill gas demands performance from any flow meter due to challenging integral conditions:



- Gas and ambient temperatures variations
- Gas flow rates vary
- Potentially hazardous/explosive locations
- Landfill gas is wet and dirty
- Low-pressure systems

## Advantages of Sage Thermal Mass Flow Meters in Landfill Gas Applications

Consider the following standards when selecting a flow meter to measure LFG:

- Calibrated for landfill gas composition, a mixture of methane and carbon dioxide
- Mass flow measurement without the need for temperature and pressure correction
- No moving parts reduce maintenance; advantageous over positive displacement flow meters or turbine meters
- Permits the user to change the gas composition in the field when using SageCom software
- An insertion-style meter easily removes from the duct for cleaning and maintenance using a suitable retraction device
- Temperature compensation for accuracy and repeatability with changing process and ambient temperatures
- Wide turndown for precision measurement at a low or high flow
- Excellent low-flow sensitivity
- Minimal pressure drop
- Approved for use in hazardous areas (Class I Div 2 is standard with Div 1 optional on the Sage Paramount)
- Graphical displays of flow rate totalized flow and temperature
- Easy in-situ calibration verification method to verify the accuracy and operation of the sensor and transmitter to comply with environmental regulations

## Recommended for Landfill Gas Applications



**Paramount™** –When used with the SageCom software (complimentary with Paramount purchase), the user can change the gas composition while still in the field. The flow meter automatically corrects the flow measurements for the new gas composition. Additionally, the Paramount comes standard with CI I Div 2 rating with an optional Div 1 class.

The Sage thermal mass flow meter, whether in-line or insertion body style, is ideal for landfill gas collection or flare gas systems. The Sage meters meet and exceed the selection considerations for measuring landfill gas flow in flare and landfill gas to energy applications. Sage Metering is the only manufacturer offering an uncomplicated, in-the-pipe method to verify that the meter is accurate and that both the sensor and transmitter are clean and operational. The Sage meter is compliant with EPA strict calibration requirements when measuring greenhouse gases.

## Chapter 3: Steel

Steel production uses many different gases, including natural gas, oxygen, argon, and nitrogen. A central facilities department may want to submeter the gases to charge the various operations or identify and conserve gas consumption throughout the mill. Thermal mass flow meters are suitable for this use. In many

applications, the process requires a minimum amount of gas flow, and lower gas usage can affect the product. A flow meter can measure the gas flows in these cases, ensuring the optimum flow of gas.



Figure 21

Figure 21: Very hot steel pouring in steel plant.

### Basic Oxygen Furnace

The basic oxygen furnace (BOF) takes the pig iron from the blast furnace, mixes it with scrap, and then adds oxygen to reduce the carbon content. The reaction of oxygen and carbon releases heat and waste gases [carbon monoxide (CO) and carbon dioxide (CO<sub>2</sub>)] from the BOF. The CO-rich gas can be a fuel source for a waste heat boiler or combusted and flared. The steel from the BOF can then be refined further. Argon may be used for gas shrouding of the tuyeres, and argon and nitrogen can be used for bottom stirring to increase mixing. Some steels have specifications on acceptable nitrogen levels, thus requiring the use of argon in these instances.

## Electric Arc Furnace

Electric arc furnaces (EAF) are in mini-mills. Here, scrap metal is loaded into the furnace. Electrical power applied to the electrodes creates heat and starts the melting process. In addition to the electrical energy, chemical energy is also provided by injecting oxygen into the molten steel. Here, the oxygen reacts with various metals in an exothermic reaction to produce additional heat and create metal oxides. The metal oxides end up in the slag. Oxygen lancing into the molten steel also generates heat. It reduces the carbon content when the oxygen reacts with carbon to produce CO. After achieving the right composition, the molten steel is transferred to a ladle where it goes to the continuous caster or for further refining for high-quality steel.

## Ladle Preheat

Ladles move molten steel between steps in the steel-making process. The ladles are preheated to a temperature above the melting point of steel using combustion from natural gas to avoid solidifying the molten steel. As with any combustion operation, measuring the flow of natural gas improves efficiency.

## Argon-Oxygen Decarburization (AOD)

The steel used for stainless steel or other high-grade alloy requires further reduction of the oxygen content. This process is completed in an argon-oxygen-decarburization (AOD) vessel. Additional oxygen, mixed with argon, is injected into the AOD through a lance and the tuyere in the vessel's side. The presence of argon combined with oxygen enhances the reaction of carbon with oxygen, promoting carbon removal.

## Bottom Stirring

Bottom stirring is typically used on electric arc furnaces and accomplished by injecting an inert gas into the lower part of a vessel containing molten steel. This process boosts the stirring action, accelerating the reaction speed and the heat transfer in the melt, resulting in energy savings. Also, the increased interaction between slag and melt raises the liquid metal yield. Argon is used for those steels which specify a maximum nitrogen content.

## Tundish

A tundish is a refractory-lined vessel that sits on top of a continuous caster and regulates molten steel's flow to the caster. A ladle is used to pour molten steel into the tundish. Depending on the type of steel, argon may provide an inert environment around the continuous caster's connections. For some grades of steel, argon may also be injected through diffusers in the tundish bottom. In both instances, a flow meter ensures the proper amount of argon usage.

## Tundish Preheat

When using the tundish, heat is lost. Thus, it is necessary to replace the tundish periodically with a new heated unit. The cooled tundish is taken to the tundish preheater, where a combustion system using natural gas heats the tundish.

## Annealing

Some grades of steel are annealed to reduce internal stress and increase its workability. The steel is heated and then slowly cooled under controlled conditions. For gas annealing, the steel is covered and maintained under a nitrogen atmosphere to prevent oxidation. A nitrogen/hydrogen blend decreases annealing time as hydrogen has a high heat capacity. For some grades of steel, annealing occurs with 100% hydrogen.

## Furnaces

In addition to the electric arc furnaces (EAF) or basic oxygen furnace (BOF), there are multiple furnaces in a steel mill used for various operations. These may include process heaters, reheat furnaces, annealing furnaces, and tempering. These heating devices are usually fired using natural gas. There are many reasons why the measurement of the natural gas flow rates to these combustion sources is desirable, including efficiency determination and energy reduction programs.

## Ingot Casting Line

High-grade quality steel is subject to oxidation when exposed to air. The ingots may be cast in an inert gas environment to avoid oxidation. Argon is preferred over nitrogen since nitrogen levels must be minimized in some quality steel.

## Flare

The waste gases from the coke oven, blast furnace, and converters (EAF, BOF, and AOD) are frequently fuel gas. The gas from the coke oven typically consists of hydrogen (50 to 60%), methane (15 to 30%), and a small percentage (10 to 20%) of carbon monoxide, carbon dioxide, and nitrogen. The gas from the blast furnace and converters is carbon monoxide rich. These gases can be burned in an engine to produce supplemental power for the steel mill. In other cases, the gases may flare. The EPA requirement for greenhouse gas emission reporting from a flare in a steel mill is the same as required for petroleum refineries.



## Chapter 4: Other Industries at a Glance

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While this eBook has focused on three significant industries, there are many industries where thermal mass flow meters serve various uses. The following are worthy of mention.

### Automobile Manufacturing

Within the automobile manufacturing industry, there is a focus on facility management and the efficient and effective use of services. Thermal mass flow meters help the industry in natural gas submetering applications for process efficiency and process accounting, compressed air monitoring to identify compressor efficiency and costly leaks that could impact the environment, and the measurement of vent air.

### Chemical and Petrochemical Industries

There are four main areas that thermal mass flow meters assist within the chemical and petrochemical industries, including flare gas and flue gas monitoring, scrubber balancing, and nitrogen blanketing.

### Food & Beverage

Food and beverage manufacturers use boilers, ovens, furnaces, and much natural gas to process and package products. They also move masses of air around its facilities. Thermal mass flow meters help the food and beverage industry in applications that include tank blanketing, dryer air flow, carbonation, compressed air, and leak detection.

## Industrial Compressed Air

Compressed air is a vital energy source for various industries worldwide. Just about every industry uses compressed air to fuel air-tools, pneumatic conveying equipment, and spray painting. Large electric motors or expensive diesel-powered generators must produce compressed air, and they need substantial energy to operate. For these reasons, compressed air is costly to make, use, and more expensive than most manufacturing processes.

Thermal mass flow meters help compressor manufacturers, compressor distributors, and manufacturers using compressed air in different ways:

- Facilities monitoring, submetering, and billing
- Leak detection
- Compressor optimization and situation audits
- Compressor performance testing

Some industries using compressed air include those previously mentioned (automotive, chemical, food and beverage, pharmaceutical) and aerospace, electronics, general manufacturing, hospitals/medical, mining, plastics, power generation, wood products, and others.

## Pharma and Biotech

Thermal mass flow meters support the pharmaceutical and biotech industries in measuring air flow, nitrogen gas, ammonia gas, and emissions monitoring.

# Conclusion

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The thermal mass flow meter has been beneficial in many other industries not covered in this paper, including industrial compressed air, pharma, biotech, and food and beverage. Like any metering technology, there are advantages and disadvantages, and no technology is perfect. To achieve accurate gas measurement, the purchaser must consider the equipment where the strengths outweigh the weaknesses.

Thermal mass flow meters measure the mass flow based on heat transfer from a heated element. The only other meter that measures mass flow directly is the Coriolis meter. Both the thermal meter and Coriolis do not require additional pressure and temperature correction. The thermal meter provides acceptable accuracy and excellent repeatability without the substantial upfront cost of the Coriolis. Additionally, the thermal mass flow meter is easy-to-install and has negligible pressure drop.

Thermal mass flow meters have excellent low-flow sensitivity and can measure some gas flows that the Coriolis meter cannot because the gas density may be too low. Coriolis flow meters become much more expensive as the pipe size increases, and even though they are available in sizes up to 12", they are rarely used above 4". The insertion thermal mass flow meter easily installs in virtually any size pipe, and the price is not dependent on pipe size.

With thermal mass flow measurement, there is a need for sufficient upstream and downstream straight run to achieve a fully developed flow profile. Sage Metering offers flow conditioners to create a uniform flow profile when sufficient straight run is a challenge.

The AGA does not approve the thermal meter for natural gas custody transfer. However, the meter satisfies natural gas flow monitoring applications within natural gas distribution and many applications for measuring natural gas, air, and other gases.

Lastly, the user of the thermal flowmeter must know the gas composition to measure it accurately. However, there may be applications where the user is more interested in repeatability and chooses to sacrifice the accuracy to save substantial upfront costs over other meter alternatives.

### About Sage Metering

**Sage Metering** is a manufacturer of thermal mass flow meters. The meters measure and monitor gas mass flow for various industrial, environmental, and municipal applications. The company headquarters is in Monterey, California. In 2003, the firm introduced the first hybrid-digital thermal mass flow meter in place of the traditional Wheatstone bridge technology. It provided improved resolution and reproducibility. Sage Metering was the first thermal flow meter manufacturer to offer a unique and easy-to-invoke on-site calibration verification. This breakthrough made it possible to use thermal mass meters in environmental applications to report greenhouse gas emissions (GHG) per EPA regulations and quantify carbon credits per US carbon credit protocols.

### About Bob Steinberg



Bob Steinberg is the founder, president, and CEO of Sage Metering. He has over 40 years of instrumentation experience. Before forming Sage Metering in 2002, Mr. Steinberg managed thermal mass flowmeter sales at Kurz Instruments, Sierra Instruments, and Eldridge Products. While at Weston Instruments, he was a product marketing engineer. He has a BSEE and a BA from Rutgers University.

## Want More Info?

To find out more about how your business can benefit from using Sage Metering thermal mass flow meters in your industrial application, [message us](#).

Or learn more about our revolutionary new Sage Paramount and the SageCom software.

[Learn more](#)



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