



FOX WHITE PAPER



FLARE AND COMBUSTOR GAS MEASUREMENT: APPLICATIONS, REGULATIONS AND CHALLENGES

A TECHNICAL WHITE PAPER FROM FOX THERMAL INSTRUMENTS

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PURPOSE

To provide a convenient and easy to follow method of finding the right flow meter technology for flare and combustor gas flow measurement.

FLARES VS COMBUSTORS

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 combustors; the differences between the two are slight (see 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 off excess combustible gas from a system. For instance,

FLARES VS COMBUSTORS	
FLARES	COMBUSTORS
Open flame	Flame enclosed
Lights up the night sky	Flame hidden, less 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.



flaring may be a precaution to keep pressure in a system at safe levels, or it may be to remove gas that cannot be processed from a storage vessel that must make room for the inflow of more oil. If the waste gas is not burned off, it could be vented directly to the atmosphere, which adds large quantities of unburned hydrocarbons, a leading contributor to global climate change.

FLARE AND COMBUSTOR GAS FLOW MEASUREMENT - COMMON APPLICATIONS

CRUDE OIL PRODUCTION

Some crude oil extraction wells have been exhausted through vertical drilling alone. For this reason, a new method using horizontal drilling and hydraulic fracturing in the shale rock formations

has helped to pull oil and gas from these tapped wells which extends their life and production capacity dramatically. The shale formations are very porous and have vast amounts of methane and other hydrocarbons trapped inside these pores. By fracturing these formations and pushing a water/sand/chemical slurry down into the crevices created, oil and gas can be harvested. The majority of the slurry mixture is removed during well completion and the flowback must go through a process to separate the components of water, oil, gas and other residue. Flares and combustors are used at these well sites to burn off vapors from the drilling, collection, and storage of the gases produced in this process. Most notably, the storage tanks must be vented or flared as new product is injected.

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.

Source: Wikipedia

STORAGE TANKS / TANK BATTERIES

Volatile Organic Compounds (VOCs) are the primary emissions from storage tanks used in oil & gas production. The reduction of these emissions is now being regulated by the US EPA as they are considered hazardous air pollutants (HAP). These emissions happen from venting (flash gas) due to pressure or temperature changes and the introduction of more product.

NATURAL GAS PRODUCTION

Although most natural gas production happens onshore at gas plays such as Barnett, Haynesville, and Marcellus, some occurs in conjunction with

oil drilling on rigs in the US Gulf of Mexico. Flaring is a necessary part of the process in order to maintain a safe production facility and comply with environmental regulations.

NATURAL GAS PROCESSING

When hydrocarbon gases are extracted, especially from hydraulic fracking, it is necessary to process it further to achieve pipeline quality natural gas. The natural gas must be separated from the water and other hydrocarbons. This is part of natural gas processing. This may be done at a processing plant or on a skid-mounted processing system. A VRU (vapor recovery unit) may be used to capture gas for delivery to a pipeline. Flares are often used in these processes.

BIOGAS FROM DIGESTERS AND LANDFILLS

Organic materials from methane-producing facilities like wastewater treatment plants are placed in digesters that trap organic matter and allow it to decompose in the absence of oxygen. During this process, a biogas mixture (usually about 60% methane and 40% carbon dioxide) is produced. Natural gas primarily consists of methane, so this biogas is an important energy source. By trapping it in the digester, it can be collected and used as a fuel gas instead of allowing it to accumulate in the atmosphere causing a greenhouse effect.





Dairy and swine operations are beginning to turn manure, a plentiful by-product of the animals, into a valuable resource by substituting biogas for natural gas or propane as fuel for their generators. Landfill waste produces significant amounts of methane as it composes under the capping soil layer. There are efforts being made to collect this gas and burn it to produce electricity. Flares are often needed as a part of these biogas digester and landfill gas systems.

COMPLIANCE WITH REGULATORY AGENCIES FOR FLARE MONITORING

EPA REGULATIONS ON FLARE MONITORING

Flares must be monitored to be compliant with a number of EPA regulations: most notably, 40 CFR Part 98 and 40 CFR Part 60 Subpart 0000 (referred to as Quad 0). These regulations cover

emissions from various parts of the Oil & Gas Industry and other industrial emitters.

40 CFR Part 98 requires that emissions be measured, recorded, and reported in categories such as refineries, offshore drilling rigs, natural gas plants, landfills, and other sources. Specifically, 40 CFR Part 98 Subpart W requires the emissions from both onshore and offshore petroleum and natural gas production sites. Monitoring devices used for these purposes are required to have an accuracy of 5%. Subpart W includes the monitoring of emissions from processing plants, storage, transmission, and distribution. Since this ruling was published in 2010, a mass of CO₂, CH₄, and N₂O emission data has been collected and published. This data reflects emissions from equipment leaks, vented sources, and flare gas emissions.

Perhaps due to the overwhelming data amassed from these reports, the EPA has begun to regulate the amount of emissions allowed in certain



*Fox Model FT3 thermal mass flow meter and temperature transmitter.
Flow Accuracy: $\pm 1\%$ of reading, $\pm 0.2\%$ of full scale
Turndown ratio: up to 1000:1
Available in both insertion and inline styles.*



industries. Recently, the Natural Gas Production industry has been required to reduce their emissions by 95% in some cases in order to comply with the Quad O regulation. This 2012 ruling requires that waste gas be recovered using Vapor Recovery Units (VRUs) or combusted using flares, combustors, or other combusting devices to cut down on the loss of these gases to the atmosphere. The hope is that these gases can be recovered and sold to cover the costs of complying with the regulation. As part of this ruling, flares or combustors used to reduce emissions must include monitoring instruments that have an accuracy of $\pm 2\%$ or better.

COMPLIANCE WITH EU DIRECTIVES

The European Union introduced the Emissions Trading Scheme (ETS) in 2005 as part of an overall climate change policy. The ETS requires that emissions be reported to the Environment Agency each year. The European commission allocates carbon credits to participating countries (spread across many installations) which allow for a predetermined amount of CO₂ to be released into the atmosphere. At the end

of each year, there may be a surplus of allocated credit or the emissions may have exceeded the allocation. Surplus credits may be sold and over-emitters must buy excess allocations from other installations with surplus credits. Each year, when the credits are distributed, the credit allocation is reduced which allows time for industries to make small improvements each year to reduce their emissions. Over time, this results in the gradual reduction of harmful gases and emissions, not a drastic and expensive overhaul of processes all at once.

Flow meters used to report emissions for this purpose must operate at a Tier 3 accuracy level which means that they must measure at $\pm 7.5\%$. It is also mandatory that the measuring device be validated for calibration accuracy at periodic intervals.

Thermal Mass Flow Meter Benefits

Direct Mass Flow Measurement

Fox flow meters do not require pressure or temperature compensation.

Outstanding Rangeability

Fox flow meters' low-flow sensitivity improves measurement accuracy over a wide range of conditions.

Rugged, Low-Maintenance Design

Fox flow meters' no-moving-parts design makes them relatively immune to oils and particulates and reduces service requirements.

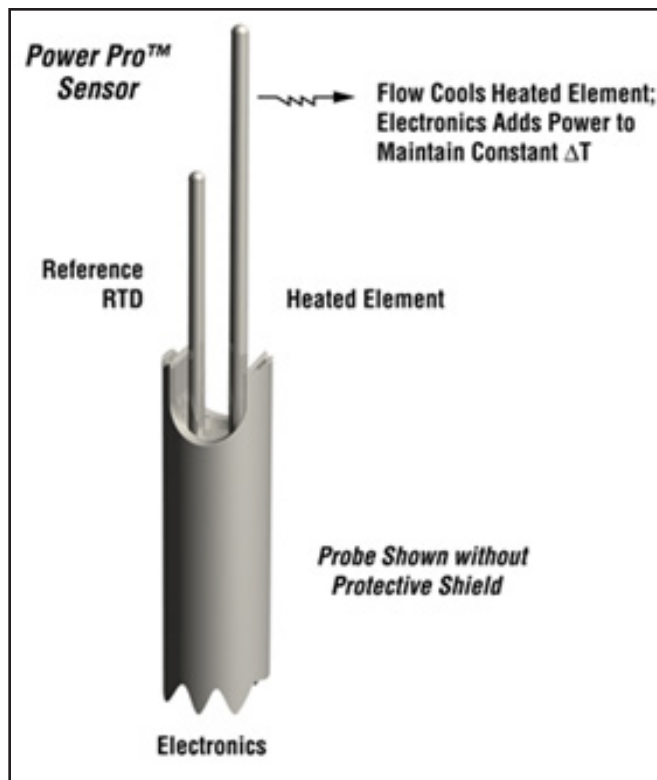
Low Installed Cost

Fox flow meters are available in both insertion and inline versions to suit and application.

CHALLENGES OF MONITORING FLARE AND COMBUSTOR GAS

Flare and combustor gas is generally waste gas that must be evacuated at high flow rates and at various intervals. This abrupt change, or upset condition, has always proved difficult for most flow meter technologies to measure. In order to measure accurately, the meter must be able to measure very low flow rates while the flare or combustor is in normal operation, and measure just as accurately when the flow increases to a very high flow rate. The flow range difference between these two minimum and maximum flow rates is called the “turndown ratio”. When the difference between them is quite large, as in flare or combustor gas measurement, the turndown ratio is wide, for instance 800:1. When considering what meter to use in your flare application, the turndown ratio must be high enough to account for these upset conditions.

Accuracy over such a wide flow range is



Fox PowerPro™ sensor illustrating the thermal mass flow meter principle of operation.

also important for flare and combustor gas measurement, especially when there are regulations that require the meter meet a certain accuracy spec. Most flow meter technologies operate more accurately at the higher end of their flow range, but errors increase at the low range. The average flare or combustor will operate at the lower end of its flow range for most of its life, so the need for accuracy at the low end is critical when choosing the flow meter technology to use.

Gas composition is another challenging aspect of flare and combustor gas. The variability in gas composition makes it imperative that the flow meter be calibrated to measure the mixture of flare/combustor gas constituents at each site. If the flow meter manufacturer offers actual gas calibrations, the accuracy of measurement is



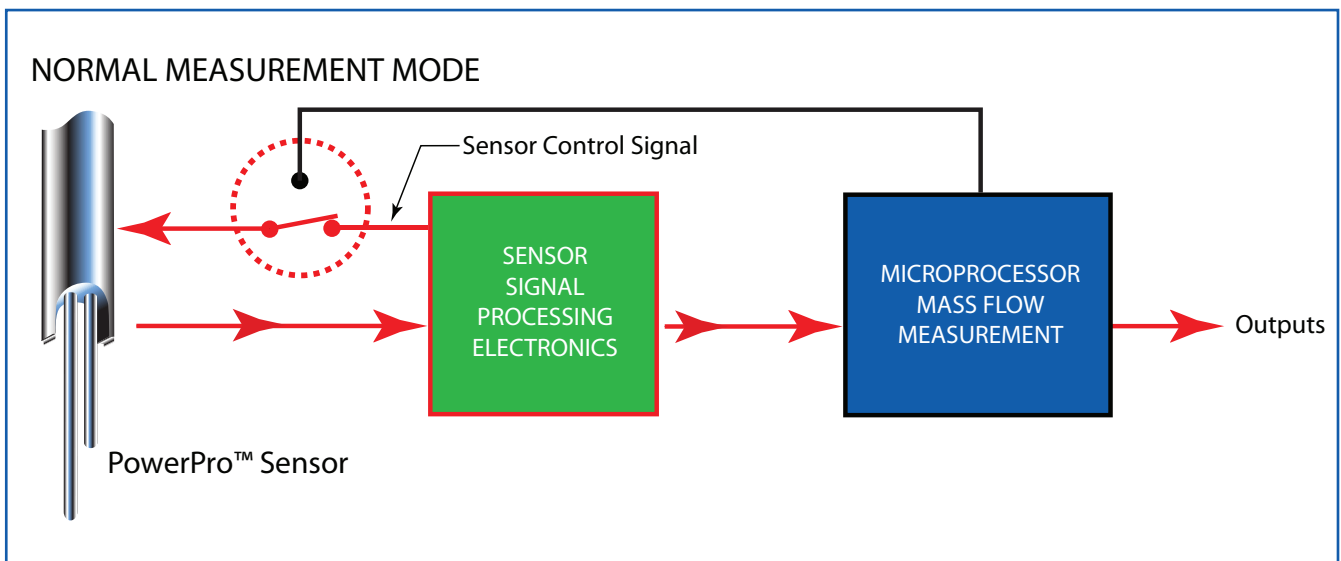
Fox Model FT3 in a remote configuration used to measure flare gas at an offshore drilling rig.

increased dramatically. Likewise, a method of verifying the calibration of a meter at periodic intervals helps operators feel confident that they are collecting the most accurate information at each site.

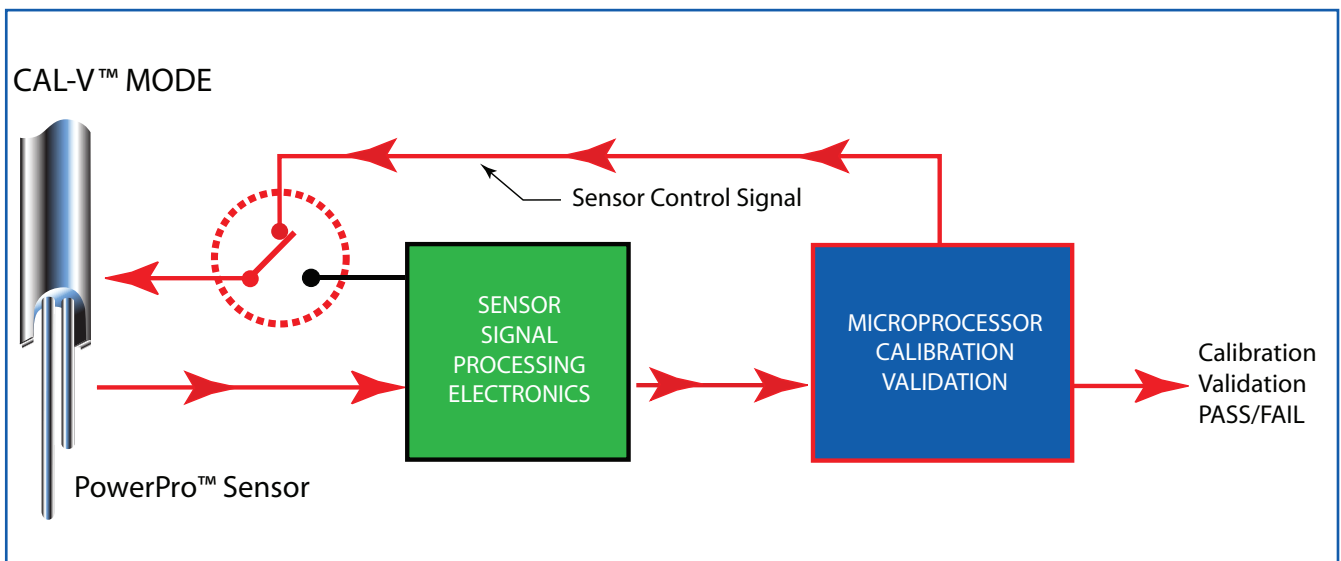
Thermal Mass Flow Technology

Thermal mass flow meters (TMFMs) operate under the constant temperature differential method and provide a direct mass flow rate without the

need for temperature or pressure compensation. Using two RTD sensors, one heated and the other sensing the temperature, TMFMs' sensors are in direct contact with the gas in the pipe. As the gas passes over the sensors, the flow of gas molecules pulls heat from the heated sensor. The second RTD sensor measures the temperature of the gas passing by and detects that the equilibrium is disrupted. The circuit makes up for the loss in heat by sending more current to the heated sensor. The power required to maintain the temperature of



In normal measurement mode the signal processing electronics control the sensor.



In CAL-V™ mode, the microprocessor controls the sensor and determines the resulting electrical characteristics.

CALIBRATION VALIDATION

TYPICAL REQUIREMENTS OF COMPETITIVE MODELS	OTHER THERMAL FLOW METERS	FT3 WITH CAL-V™ & ZERO CAL-CHECK™
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 auxiliary test equipment and/or test gases to flow meter		

**When using a retractor assembly for Zero CAL-CHECK™*

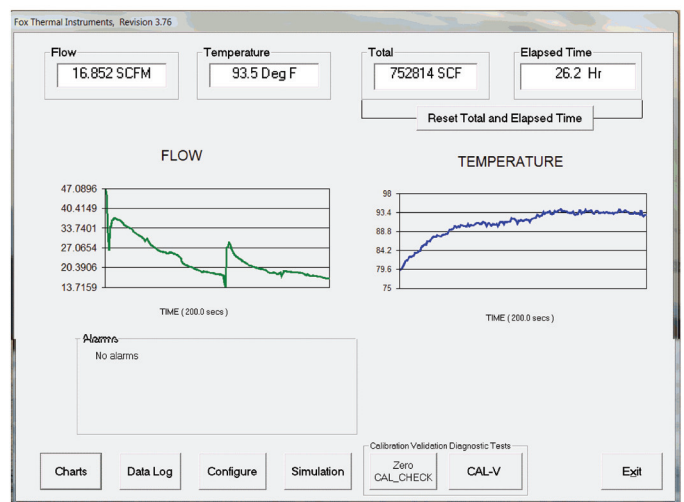
the heated element (constant ΔT) is proportional to the flow of gas in the pipe. There is no need for external temperature or pressure devices or additional calculations to determine the mass flow rate when using TMFMs.

BENEFITS OF USING FOX THERMAL MASS FLOW METERS

Fox Thermal Instruments has been a leader in thermal mass flow innovation for over 20 years; Fox was the first manufacturer to offer a thermal mass flow meter using an onboard microprocessor. The Fox Model FT3 was designed specifically with flare and combustor gas monitoring for the Oil & Gas industry in mind. The Model FT3 is a state of the art flow meter offering direct mass flow measurement, exceptional low-flow sensitivity, fast response, and low maintenance requirements.

Using the Fox PowerPro™ sensor, the FT3 operates at a higher power level than competitors' sensors resulting in improved response time and a wider turndown. The PowerPro™ sensor is

very accurate at low flow rates and also at high velocities – up to 60,000 SFPM (30,000 MSCFD in an 8" pipe). The turndown ratio can be up to 1000:1 with a flow accuracy of $\pm 1\%$ of reading and $\pm 0.2\%$ of full scale. The Model FT3 is available in both insertion and inline models. The insertion meter is easily installed with a weld-olet and compression fitting. The inline model is available in 1/4-inch to 6-inch sizes and includes built-in flow conditioners that eliminate the need for long, straight pipe runs. Fox flow meters can



Sample screen view of the FT3 View™ software tool used to configure the Model FT3 Thermal Mass Flow Meter & Temperature Transmitter.



A portable Fox Model FT3 kit used at oil and condensate storage tanks for emissions requirements.

be ordered to fit almost any application, even large pipes or complex mixed gas calibrations.

RUGGED, RELIABLE PERFORMANCE

The Model FT3 is a rugged instrument with a dual-compartment, explosion-proof enclosure housing the instrument electronics. An optional on-board 2 line x 16 character backlit display is available with a configuration panel for field configuration. Using either the mechanical or infrared (IR) buttons, the meter's settings may be manually accessed. Settings such as 4 to 20mA and pulse output scaling, pipe area, zero flow cutoff, flow filtering or damping, display configurations, diagnostics and alarm limits may be accessed via the configuration panel.

COMMUNICATION OPTIONS

Fox offers a free software interface, FT3 View™, to connect the Model FT3 via a USB port to a laptop or computer. This software provides complete configuration and remote process monitoring functions that allows the user to adjust meter configuration, evaluate


transmitter alarm conditions, collect process data, and view measurements from your PC or control station. HART and RS485 Modbus are available communication protocols with all digital communication isolated to provide immunity from electrical interference.

CALIBRATION

All Fox meters are calibrated in actual gas customer conditions and performed with NIST traceable flow standards. For flare and combustor applications, this is especially valuable as the composition of the gas can vary quite substantially between sites. The Fox Calibration Lab employs a wide range of gases, mixtures, temperatures, pressures and line sizes to simulate actual fluid and process conditions. This approach improves accuracy and minimizes measurement uncertainty in the field.

CALIBRATION VALIDATION

The Model FT3 offers Calibration Validation consisting of two tests: CAL-V™ and Zero CAL-CHECK™. Used in succession, these tests can be performed at regular intervals to verify that the calibration of the meter is still valid. Providing a Pass/Fail result, these tests can help to reduce the added cost and inconvenience of annual factory calibrations. If these tests are initiated using the free Fox FT3 View™ software tool, CAL-V™ and Zero CAL-CHECK™ Calibration Validation Certificates can be produced at the conclusion of the tests. This feature is of particular value for compliance with emissions monitoring applications where periodic calibration validation is mandated.

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CAL-V™ CERTIFICATE CALIBRATION VALIDATION			
CAL-V™ Performed on:	9/13/2012	15:04:46	CAL-V™ Results: PASS
Firmware Version:	v 3.65		CAL-V™ Value: 21.76
Fox Meter Serial Number:	16505		CAL-V™ Verify: -0.01
Tag #/Meter location:	Compressor #528		
Test performed by:	John Doe		
Additional Comments:			
Calibration Table Stored in Flow Meter Compare the below Calibration Table to the original Calibration Certificate			
Data Point	Input Volts	NMPH at 0 C 760 mmHg	
2	0.27050	0.00	
3	0.35040	900.18	
4	0.38040	1816.74	
5	0.42240	3520.52	
6	0.44610	5416.31	
7	0.47040	7809.88	
8	0.49610	11373.89	
9	0.52370	16125.43	
10	0.54560	20961.04	
11	0.56900	27173.59	
12	0.59250	34886.99	
13	0.61320	43118.28	
14	0.63140	51203.31	
15	0.64980	60252.02	
16	0.71200	99355.28	
17	0.79930	179203.87	
18	0.90009	359874.00	
19	0.97028	542034.85	
20	1.00977	721034.58	
	1.04768	1027627.17	
CAL-V™ is an in-situ calibration routine that validates the flow meter's calibration accuracy by testing the functionality of the sensor and its associated signal processing circuitry. At the conclusion of the test, the meter will display a pass/fail message and the CAL-V™ data. A "pass" result confirms the meter is measuring accurately.			
<small>1. The CAL-V™ test is valid for checking the calibration accuracy of flow meters installed in the application for which it was calibrated, including the gas/gas mixture, calibration range and pipe size shown on the Calibration Certificate. 2. For applications with temperature exceeding 200°F (121°C), CAL-V™ test results may vary.</small>			

If using FT3 View™, a free PC-based software tool, to conduct the Calibration Validation tests, a CAL-V™ calibration Validation Certificate can be printed at the conclusion of the test.

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, landfill 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.

CONCLUSION

Flare and combustor gas flow monitoring requires a flow meter that meets the accuracy and periodic calibration verification requirements set by local environmental agencies. The Model FT3 meets and exceeds these requirements with its high accuracy and Calibration Validation feature.

Direct mass flow measurement, exceptional low-flow sensitivity, fast response, and low maintenance requirements distinguish the Fox Model FT3. Virtually immune to changes in temperature and pressure, the flow meter delivers repeatable, accurate mass flow measurement under varying loads.

Disclaimer: Fox Thermal Instruments 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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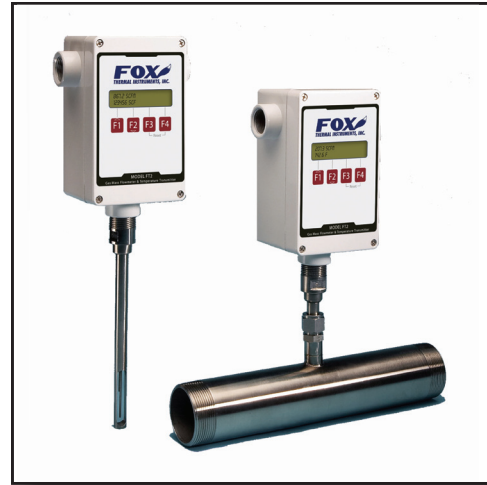




Fox Model FT3 Thermal Mass Flow Meter & Temperature Transmitter

- Measures gas mass flow rate and temperature
- Equipped with CAL-V™ and Zero CAL-CHECK™ tests - Calibration Validation feature
- 2 line x 16 character backlit LCD display
- Housing: NEMA 4X Indoor/Outdoor
- Standard Outputs: 2 x 4 to 20mA for Flow and Temperature, Pulse Output
- USB port standard
- Communication Options: HART or RS485 Modbus
- Approvals: CE, FM, FMc, ATEX, IECEx

See FT3 Datasheet for more product information.



Fox Model FT2A Thermal Mass Flow Meter & Temperature Transmitter

- Measures gas mass flow rate and temperature
- 2 line x 16 character backlit LCD display
- Housing: NEMA 4X Indoor/Outdoor
- Standard Outputs: 2 x 4 to 20mA for Flow and Temperature, Pulse Output
- USB port standard
- Communication Options: BACnet MS/TP, RS485 Modbus, Profibus-DP, DeviceNet or Ethernet Modbus TCP
- Approvals: CE, FM, FMc

See FT2A Datasheet for more product information.



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