

Technical White Paper



6 THINGS TO CONSIDER IN FLARE AND COMBUSTOR GAS MEASUREMENT:

APPLICATIONS, REGULATIONS, AND CHALLENGES

A TECHNICAL WHITE PAPER FROM FOX THERMAL

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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 in the Oil & Gas, Industrial, and agricultural sectors. Use these 6 considerations to guide you through the process to choose a flow meter technology right for your specific flare gas application.

#1: TYPE OF FLARE GAS 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 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

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.



off excess combustible gas from a system. For instance, flaring may be a precaution to keep pressure at safe levels in a system, 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.

Flow meters for flares or combustors will need to measure the flow of gas to it at the time when burn-off of the waste gas occurs. The flow may fluctuate between very high and very low velocities before, during, and after burn off of the gas.

#2: CONSIDERATIONS FOR COMMON FLARE GAS APPLICATIONS

OIL & GAS PRODUCTION

Both on and offshore, crude oil extraction wells have been exhausted through vertical drilling. To increase production in existing

wells, the “fracking” method of horizontal drilling and hydraulic fracturing in the shale rock formations deep underground has taken over the industry. Fracking increases access to oil and gas reserves from fewer access points and extends production capacity dramatically at each well site.

Shale formations are made up of a porous rock material holding vast amounts of trapped methane and hydrocarbons deep underground. Bore holes at well sites must be drilled deeper than traditional oil wells to reach shale. To release the trapped resources, the shale must be fractured by a powerful electric charge. The charge causes fissures to open and a pressurized water/sand/chemical slurry is pushed down into the crevices. The sand collects in the fissures allowing the slurry to pass through and mix with the oil and gas trapped in the shale. This mixture is pumped to the surface as “flowback” that is harvested at the well head. The flowback must go through a separation process to isolate the components

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.

of solids, water, oil, gas, and other matter. Flares and combustors are used at well sites to burn off vapors from the drilling, collection, and storage of the gases produced in this process. Any storage tanks must be vented or flared as new product is injected.

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. Flares are used to make room in storage tanks when new product is injected.

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. After trapping and collecting digester gas, it can be used as fuel 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 decomposes 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.

#3: 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 OOOO (Quad O). 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 $\pm 5\%$. 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 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 combustion devices to cut down on the



Fox model FT4X thermal mass flow meter and temperature transmitter.
Flow Accuracy, air: $\pm 1\%$ of reading, $\pm 0.2\%$ of full scale;
Flow Accuracy, other gases: $\pm 1.5\%$ of reading, $\pm 0.5\%$ of full scale
Turndown ratio: up to 1000:1
Available in insertion, inline, and remote styles.



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.

COMPLIANCE WITH BLM 3175

Public lands leased for use in oil & gas production are governed by the Bureau of Land Management (BLM). Oil & gas activities on leased lands must conform to BLM 3175 which defines gas flow meter accuracy and features for determining royalty payments. Data from the flow meter is used for this royalty determination. This includes the gas composition, gas density, and the gross heating value. A highly accurate measurement of the flow of gas in daily totals must be recorded with storage of that data over time.

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.

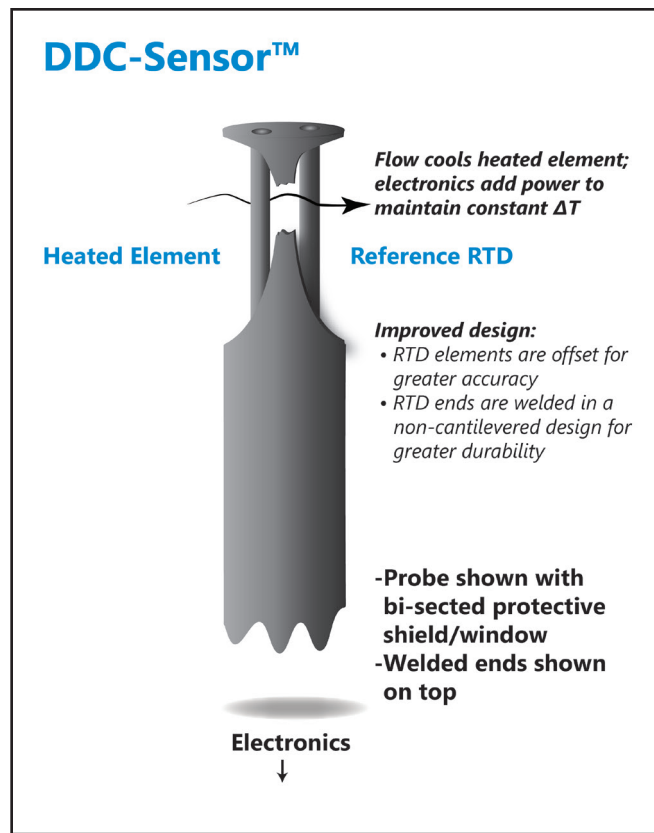
Low Installed Cost

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

#4: OVERCOMING 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 ratio between the minimum and maximum flow values 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 also important for flare and combustor gas measurement, especially when there are



Fox DDC-Sensor™ sensor illustrating the thermal mass flow meter principle of operation.

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. Likewise, a method of verifying the calibration of a meter at periodic intervals allows operators to be confident that they are collecting the most accurate information at each site.



A Fox Thermal flow meter in a remote configuration used to measure flare gas at an offshore drilling rig.

#5: CHOOSING THE RIGHT TECHNOLOGY: THERMAL MASS FLOW

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	MODEL FT4X THERMAL MASS FLOW
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 the Model 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!



A portable Fox Thermal flow meter kit used at oil and condensate storage tanks for emissions requirements.

#6: CHOOSING A MANUFACTURER: BENEFITS OF USING FOX THERMAL MASS FLOW METERS

Fox Thermal has been a leader in thermal mass flow innovation for over 20 years; Fox Thermal was the first manufacturer to offer a thermal mass flow meter using an onboard microprocessor. The Fox Thermal model FT4X was designed specifically with flare and combustor gas monitoring for the Oil & Gas industry in mind. The model FT4X is a state-of-the-art flow meter offering direct mass flow measurement, exceptional low-flow sensitivity, fast response, and low maintenance requirements.

ADVANCED DDC-SENSOR™ DESIGN

The DDC-Sensor™ sensor, a Direct Digitally Controlled sensor, is unlike other thermal flow sensors available on the market. Instead of using traditional analog circuitry, the DDC-Sensor™ is interfaced directly to the meter's microprocessor for more speed and programmability.

The DDC-Sensor™ provides a technology platform for calculating accurate gas correlations. The correlation algorithms allow

the meter to be calibrated on a single gas in the factory while providing the user the ability to select other gases in the Gas-SelectX® gas menus.

Competitors' sensors utilize fragile, cantilevered elements, whereas the sensor elements of the DDC-Sensor™ are welded to the sensor window at both ends for extra stability and strength. This enhanced design eliminates the sensor element vibration - found most often at high flow rates - which can potentially lead to metal fatigue and failure.

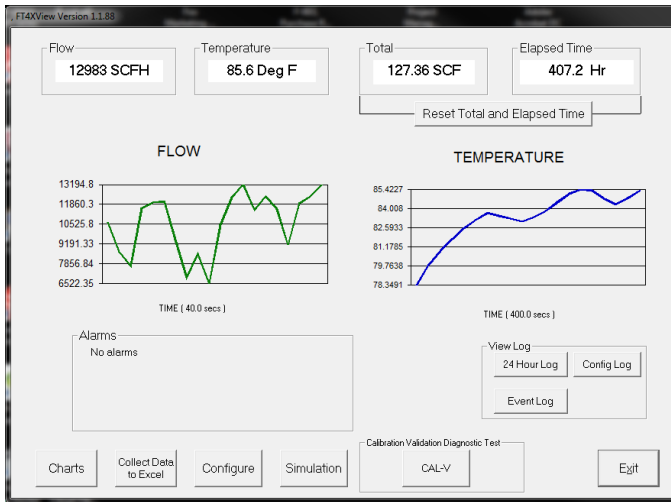
The sensor elements are in direct contact with the process flow. In applications where slag, ice or other foreign particles are traveling down the pipe, cantilevered elements are subject to damage requiring factory repair.

GAS-SELECTX® GAS SELECTION MENU

The model FT4X offers three gas menus to choose from. Users can choose from over 11 gases in the Pure Gas menu or create a custom gas mix through the combination of gases available in the Mixed Gas and Oil & Gas Menus.

Gases can be mixed in 0.1% increments to create a truly custom gas mix to fit the gas composition on-site. This action can be performed on demand and in the field for optimum convenience and to avoid sending the meter back to the factory for a re-calibration service.

For flare and combustor applications, this is especially valuable as the composition of the gas can vary quite substantially between sites and over time. Operators can change the programmed gas mix using the configuration panel on the display or by using the FT4X View™ software whenever the results of gas sample analysis shows a change in gas composition.



Sample screen view of the FT4X View™ software tool used to configure the model FT4X Thermal Mass Flow Meter & Temperature Transmitter.

ADVANCED DATA LOGGER

Every Fox Thermal model FT4X comes equipped with an intrinsic Data Logger for advanced record-keeping and data retention. The Data Logger records flow rate totals and other events and alarms.

The advanced features of the model FT4X Data Logger include:

- 40 daily totals (24-hour totals)
- Settable Contract Time defines Contract Day
- Time/date stamped alarm & event logs; 7 year history
- Power off totalizer; power failure creates event log entry

The logs in the model FT4X Data Logger also give information about the meter's settings and functionality:

- View the meter's gas or gas mix composition
- View the meter's configuration and other meter settings
- View Calibration Validation historical test data
- View and print logs of events and alarms

The Data Logger can be accessed with a MODBUS RTU (RS485) communication option and the free FT4X View™ Software.

ACCURACY, SIZING, AND INSTALLATION

The model FT4X is very accurate at low flow rates and at high velocities – up to 60,000 SFPM - with a turndown ratio up to 1000:1 and a flow accuracy of $\pm 1\%$ of reading and $\pm 0.2\%$ of full scale for air ($\pm 1.5\%$ of reading and $\pm 0.5\%$ of full scale for other gases).

The model FT4X is available in insertion, inline, and remote styles. The insertion meter is easily installed with a weld-o-let and compression fitting with the option of a retractor assembly. The inline model is available in $\frac{3}{4}$ -inch to 6-inch sizes and includes built-in flow conditioners that eliminate the need for long, straight pipe runs. Fox Thermal flow meters can be ordered to fit almost any application, even large pipes or complex mixed gases.

RUGGED, RELIABLE PERFORMANCE

The model FT4X is a rugged instrument with a dual-compartment, explosion-proof enclosure housing the instrument electronics. An standard on-board 2 line x 16 character backlit display includes a configuration panel for field configuration of the meter's settings. Settings such as 4-20mA and pulse output scaling, pipe area, zero flow cutoff, flow filtering or damping, diagnostics, alarms, and data logs may be accessed via the configuration panel.

COMMUNICATION OPTIONS

Fox offers a free software interface, FT4X View™, to connect via a USB port to a laptop or computer. This software provides complete configuration and remote process monitoring functions allowing the user to adjust meter configuration, evaluate transmitter alarm conditions, collect process data, and view measurements from your PC or control station. HART and Modbus RTU (RS485) are available communication protocols with all digital communication isolated for EMI immunity.

CALIBRATION VALIDATION		
TYPICAL REQUIREMENTS OF COMPETITIVE MODELS	OTHER THERMAL FLOW METERS	FT4X 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 auxiliary test equipment and/or test gases to flow meter		

CALIBRATION

All Fox meters are calibrated with NIST traceable flow standards. 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 FT4X offers Calibration Validation with CAL-V™ to verify that the calibration of the meter is still valid. Providing a Pass/Fail result, CAL-V™ can help to reduce the added cost and inconvenience of annual factory calibrations. If these tests are initiated using the free Fox FT4X View™ software tool, CAL-V™ Calibration Validation Certificates can be produced at the conclusion of the test. This feature is of particular value for compliance with emissions monitoring applications where periodic calibration validation is mandated.

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 FT4X meets and exceeds these requirements with its high accuracy, Calibration Validation feature, and advanced Data Logger.

Direct mass flow measurement, exceptional low-flow sensitivity, fast response, and low maintenance requirements distinguish the Fox Model FT4X. Virtually immune to changes in temperature and pressure, the flow meter delivers 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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Fox Model FT4X Thermal Mass Flow Meter

- Measures gas mass flow rate and temperature
- DDC-Sensor™ state-of-the-art sensor technology
- Gas-SelectX® gas selection feature
- Advanced Data Logger
- Equipped with CAL-V™ Calibration Validation feature
- 2 line x 16 character backlit LCD display
- Housing: NEMA 4X Indoor/Outdoor
- Standard Outputs: 2 x 4-20mA for Flow and Temperature, Pulse Output
- USB port standard
- Communication Options: HART or Modbus RTU (RS485)
- Approvals:
CE, FM, FMc, ATEX, IECEx

See FT4X Datasheet for more product information.



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