Air/Gas Flow Measurement Solutions Handbook

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Executive Summary | Contents

Accurately measuring the flow of air and other gases that travel through a process industry plant is a crucial function for effective and efficient plant operations. In a perfect world, choosing and installing the correct flow meter product would be easy: Flow meters would always be accurate and capture the right calibrations in any plant setting. Reading this handbook will help you prevent problems and instead optimize air/gas flow meters to operate safely and effectively for the long haul with minimal cost.

What you will learn:

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1. 10 Essentials To Specify A Thermal Mass Gas Flow Meter Successfully

Mom and Dad always said to do your homework. That was true then for school and true now for process measurement and control professional responsible for specifying flow instrumentation.

Whether you are working on a plant upgrade, a process improvement or an expansion project, doing your homework on the application and installation will save you time and expense, and ensure first-time right success.

To specify a thermal mass flow meter correctly, there are 10 key questions you will want to understand, consider and then be able to answer. Being ready with the answers to these 10 questions will help you communicate effectively with consulting engineers, manufacturers, and/or their local sales engineering team.

1. What Installed Accuracy Is Needed?
Reviewing the general accuracy statement in the manufacturer's product literature is not enough. The installed accuracy must take into consideration the instrument's basic accuracy capability, plus calibration (refer to actual gas or equivalency section that follows), plus flow profile disturbances, and both the gas and installation temperatures and the instrument's ability to compensate for it.

Is An Actual Gas Calibration Needed, Or Is Equivalency Acceptable?

In all cases, an actual gas calibration performed at process temperature and pressure conditions will always result in best possible accuracy for thermal mass flow meters.*1 When best possible accuracy and repeatability is required, then an actual gas calibration is the solution.

In some situations, however, an actual gas calibration might not be practical, achievable, or economical, and then an equivalency calibration is the only practical answer. These situations might include, but are not limited to, complex gas mixtures or for various safety reasons.

*1, Reference ISO 14511:2019, section 8.2; measurement of fluid flow in closed conduits - thermal mass flowmeters

Furthermore, in applications where less accuracy and repeatability are acceptable, an equivalency calibration, using a surrogate gas (typically air), might be an acceptable, lower cost alternative. Equivalency calibrations are theoretical, and their accuracy is the subject of much debate. When done only for purchase price savings, buyers should beware of equivalency methods. Reputable manufacturers will provide you with an expected accuracy per your specific installation conditions and the calibration process they will apply before you commit to purchase.

2. What Is the Gas Type To Be Measured?
Is the gas type air, inert gas, or hydrocarbon-based gas (Fig. 1)? Is it a single gas or a mixture? If a mixture, what are the proportions of which gases? Could the gas mixture change, and, if so, by what proportions? Is the gas clean or dirty? If dirty, can you qualify and/or quantify it? Is the gas dry, moist or wet? Can you quantify the amount of moisture? Is the fluid corrosive?

Figure 1: Knowing gas type is required to specify a thermal flow meter

Dry, clean gases can be processed by all manufacturers. If it is a moist gas, then constant power technology has been proven to be superior. If liquid droplets or condensation conditions exist within the flow stream, then two manufacturers currently have solutions. One offers a super-heated, 300°C/572°F flow element to flash-off the droplets, while another manufacturer provides a mechanical shunt which prevents liquid droplets or condensate from reaching the sensors.

The measuring principle of thermal mass flow meters involves heat transfer caused by gas flow. Any moisture or condensate in the gas stream that contacts the heated sensor can cause a sudden, momentary change in the heat transfer that can result in a spiked or fluctuating reading, creating inaccurate or unstable flow measurement. Thermal flow meters using the constant ΔT (CT) method are particularly reactive to moisture droplets, while constant power (CP) method meters, because their slightly heated sensor's temperature is elevated above the dew point of the gas are resistant to moisture's effects.

3. What Is the Required Flow Range?
One of the compelling features of thermal flow meters is their wide turndown capability

Figure 2: Know your flow range

(Fig. 2). Typical turndown for most manufacturers is 100:1. Flow range capabilities are a big differentiator between suppliers and technology. Typical CT type technology meters have less range than CP type devices due to sensor power limitations. However, some manufacturers have special techniques to extend their measuring ranges up to 1000 fps [300 mps].

4. What Is the Needed Response Time?
While it might seem like "the faster the response the better" is the correct choice, in flow metering this might not be true at all. If the thermal flow meters will be part of a PID control loop, too fast of a response can create excessive valve responses (chatter) resulting in an inability to achieve stable flow control or premature valve failure. Conversely, if the response is too slow, the control valve action might lag by too much and desired control is not achieved. Furthermore, if the air/gas flow stream has any entrained moisture (e.g., condensation droplets), a fast responding thermal flow meter will produce erratic, unstable readings as water droplets hit the sensors. (Refer to previous section on gas type to be measured.)

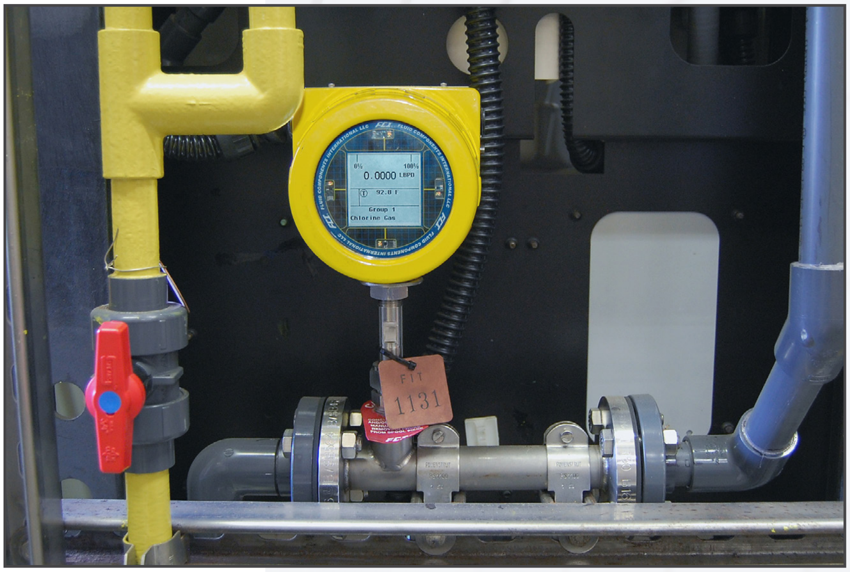

Figure 3, top: Small diameter piping situations can require a different type of connection configuration.

5. In What Type and Size Pipe Will The Meter Be Installed?
Will the installation be in a round pipe or a rectangular duct? What is the diameter, both OD and ID, of the pipe or dimensions of the duct? If an insertion style meter, what is the dimension of the socket (e.g. thread-o-let) and will it be installed through a ball valve? These are important considerations for three reasons: 1) Smaller diameter pipes require use of an inline or spool-piece design rather than an insertion type; 2) If an insertion-type, whether a single-point or multi-point averaging solution is recommended; and 3) to ensure the probe length is correct to achieve the proper insertion depth into the pipe (In single point types, the center of the pipe is the required installation depth.) (Figure 3/3B).

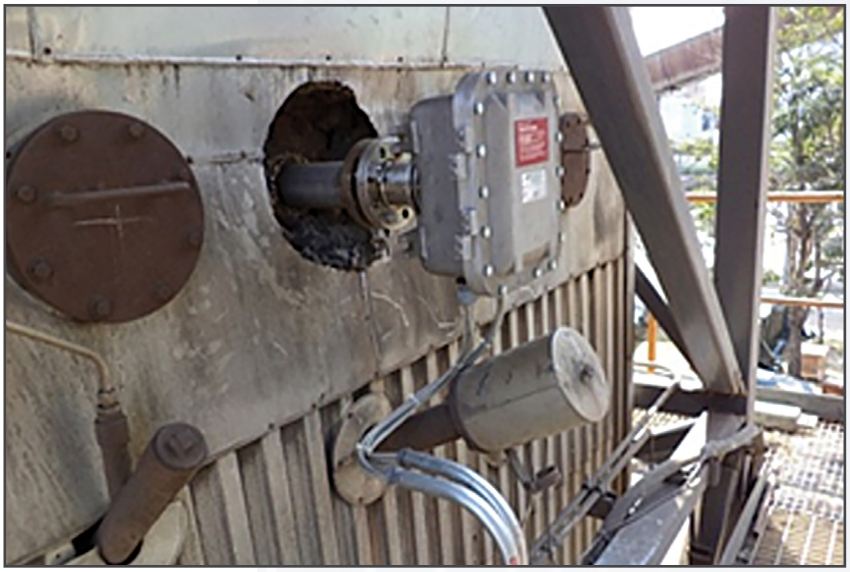

Figure 3B, bottom: Extreme example of very large diameter pipe, high temperature insulation, dusty, outdoor, above ground installation point, and in Div.1/Zone 1 type Ex location that were made clear at the beginning to ensure first time right success.

6. How Much Straight-Run Is Available?
To meet their laboratory calibrated performance specifications in their actual field installation, thermal mass flow meters require a repeatable flow profile. This will naturally occur with 15d to 20d of upstream straight run and 5d to 10d of downstream straight run. These are laws of flow dynamics physics, not subject to

debate. If you do not have enough straight run available, reputable manufacturers will provide information and quantification of the accuracy degradation you could expect. Furthermore, all reputable manufacturers offer some type of flow conditioning technology to produce an accurate, repeatable measurement in installations with inadequate straight run (Figure 4/4B).

7. What Are The Ambient Conditions and Requirements Of The Meter's Installation Area?
Will the instrument be installed indoors, outdoors but under a protective roof, or outdoors completely exposed to all weather conditions (Fig. 5)? Would the installation benefit by remotely locating the electronics from the sensor element? Would a sun shield help shade the transmitter and readout? Does the instrument enclosure's IP or NEMA-type rating meet or exceed the installation condition requirements?

Figure 4: Consider meter flow straight-run requirements and flow disturbers

Will the instrument be exposed to corrosive elements (e.g. seawater) or erosive (e.g. high pressure or steam wash downs)? Will a plastic enclosure survive? Will the paint come off or will the aluminum enclosure exhibit a patina? Will a carbon steel enclosure rust? Would service life be worth the extra investment in a stainless steel enclosure?

Is the process itself running at high temperature where the instrument could be exposed to radiated heat, or does the pipe have a layer of insulation to consider? Should electronics be remotely located from the sensor element to avoid exposure to excessive heat radiating from the process? If insulated, be sure to add its depth in determining the length of the probe and the process connection.

Is the installation subject to explosive gases such that Ex class/zone approvals are required? If yes, what levels? Is the location a Div.1/Zone 1, Class I, Div.2/Zone 2, etc.? If yes, what country's approval standards are required (e.g. FM, ATEX). Does the full instrument (sensor, electronics, and enclosure) carry the matching required approval?

Figure 4B

8. What Type Outputs Are Needed and How Many?
Is a single analog output (e.g. 4-20mA) of the flow rate adequate? If an output of the temperature is also desired, many manufacturers also provide a second analog output channel for this. Some manufacturers also offer pulse or frequency outputs to send to remote readouts or totalizers.

Or, is your process tied to a bus communications based control network requiring HART, Modbus, Foundation Fieldbus, Profibus, BACnet, EtherNetIP or other protocol?

Do you require evidence of these bus comms being registered and certified to better ensure successful integration?

Is there a chance your output needs could change in the future? For example, is the plant considering migrating from traditional analog 4-20mA signals to a digital bus? If yes, ask the flow meter manufacturer if its meter can be upgraded and, if yes, how. For the few manufacturers who offer some migration path, the means will be much different. For some it might mean returning the meter to the factory, while others might have a field upgrade kit available, or, still others will have both analog and digital buses already embedded and selectable by the user in the field.

Figure 5: In outdoor, harsh desert sunlight, know the ambient conditions of your installation location

9. What Type of Process Connection Will Be Used?

How will the flow meter be installed into the pipe and held in place (Fig. 6)? Will the meter be installed in or ever need to be retracted under pressure, and if so, how much? Some manufacturers offer only a limited choice while others offer an extensive selection. What type of fitting is required: threaded, flanged, compression type, NPT or metric? What about the required ratings? Will you need a packing gland or need to hot tap the line for installation? Would adding a ball valve be helpful for maintenance? Consider also that non-standard or special order process connections will increase the cost and extend delivery times.

10. Are Specific Pedigrees, Certifications and/or Documentation Required?

Often overlooked during initial considerations and application suitability are requirements for certifications and qualifications beyond the basic meter performance. This might include such things as pressure tests, certified materials and traceability, positive material identification report, and/or welding pedigree and certificates. If the thermal flow meter is to be used in a safety instrumented system (SIS), is there proof, and preferably independent verification, of SIL compliance (Fig. 7)? If the flow meter will be used in emissions monitoring (CEMS), does it need to have special functions or features added (e.g. calibration check routines) to comply with local regulations (e.g. US EPA, European QAL1, etc.)?

Figure 6: What is the required mechanical connection to pipe?

Conclusions

The proper selection of any flow meter requires the specifying engineer to consider several variables. Thermal mass gas flow meters are no different. Thermal mass gas flow meters are a main-stream technology growing in popularity due to continued improvements in the technology, cost effectiveness, and education on best practices. Specifying engineers prepared with answers to the 10 variables presented here will take less time to identify the best suited product as well as ensure first-time right installation success.

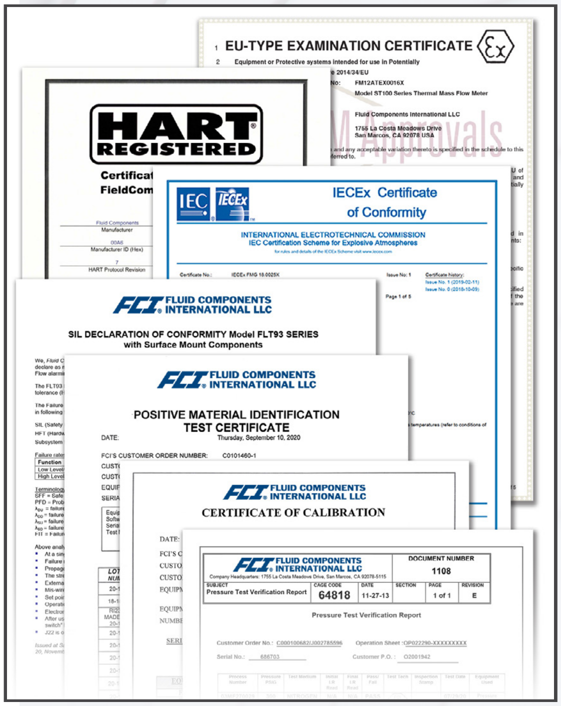

Figure 7: What certification requirements need to be met?

Thermal Flow Meter Success Checklist

- ☐ Accuracy needed
- ☐ Gas type(s) and composition mix %
- ☐ Flow range
- ☐ Response time
- ☐ Size and type of pipe (or duct)
- ☐ Length of straight-run available, upstream and downstream, from meter's installation point
- ☐ Ambient conditions at installation location
- ☐ Type of electronic output(s) needed
- ☐ Process connection
- ☐ Certifications, tests, documentation

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2. 10 Plant Flow Measurement Projects That Lower Costs & Increase Productivity

Accurately measuring the flow and level of the various liquids and gases that travel through a process industry plant is a critical function for effective and efficient plant operations. Plant upgrade or maintenance projects that focus on continuous improvement and automation of flow and level measurement will improve plant productivity and lower overall production and maintenance costs by:

- Optimizing process efficiency and control
- Increasing product throughput and yield
- Decreasing the use of consumables
- Reducing energy costs
- Simplifying maintenance and avoiding unplanned maintenance
- Ensuring employee and community safety
- Complying with environmental regulations

Ten important industrial process plant functions that can benefit from accurate, repeatable and reliable electronic flow or level measurement are:

- Pump protection
- Tank liquid level/interface
- Plant gases distribution
- Fluid additive/injection monitoring
- Compressed air consumption
- Boiler fuel gas and air optimization
- Tank blanketing
- Analyzer flow assurance
- Stack gas monitoring (CEMS,QAL1, MCERTS)
- Flare gas measurement

#1: Pump Protection

Pumping systems are extremely important to the continuous operation and production costs of process industry plants. It's important for plant pumping systems to be 100% operational with minimal downtime. As a result, flow monitoring for reliable and trouble-free pump protection is a necessary requirement to detect dry-running conditions. Failing to detect pump dry-running conditions results in extra maintenance and can shorten the life of a pump, which is typically expensive to replace.

The use of a flow switch, such as FCI's Model FLT93S, rapidly detects declining flow rates, which can provide early warning to operations of the potential for pump run-dry events (Figure 1). Preventative flow monitoring extends the pump lifecycle and increases the intervals between scheduled maintenance. The flow switch is optimally installed in the feed line or discharge line of the pump, and it features two adjustable alarms/relays that are typically set with one as a low flow warning signal and the second as a no flow (indicating an empty pipe), shut-down to avoid costly pump damage.

Figure 1: FCI Model FLT93S flow/level switch protects pumps from dry-running and other operational downtime conditions

#2: Tank Liquid Level/Interface

The reactor is often the central process in chemical and many other types of industrial process plants. Level switches, such as FCI's Model FLT93S, are installed to support various reactor, vessel or tank applications, protecting and ensuring the accuracy of reactor processes. For low level monitoring, the switch is mounted near the bottom of the reactor or a flow switch is installed in reactor discharge line to detect a near empty or empty reactor thereby eliminating contamination between batches.

A level switch is also used for high level detection/alarm to prevent an overfill or spill condition. A thermal dispersion technology level switch is also highly adept as a fast-responding interface sensor, detecting between foam, emulsion or any non-miscible fluids inside a vessel.

#3: Plant Gases Distribution

Many chemical and other process-type plants utilize large amounts of nitrogen, argon, oxygen, hydrogen, and other gases in their processes, plant power and safety systems. Thermal mass gas flow meters, such as FCI's Models ST50, ST75, ST80 and ST100, directly measure mass flow for accurate and repeatable process control and/or inventory purposes.

Where sub-metering is desirable to track individual location or station gas usage and its costs, thermal mass air/gas meters are effective solutions. They measure wide turn-down and are very effective at measuring very low gas flows to detect even the slightest usage or a leakage condition. Furthermore, they have virtually no pressure drop and no moving parts to maintain to achieve lowest installed cost.

#4: Fluid Additive/Injection Monitoring

Liquid and gas additives are frequently injected into processes, including, for example, oil well heads, mercaptan into natural gas, chlorine into water treatment and more. To ensure chemical injection flow is occurring, the ultrasensitive Model FLT93L is an inline flow switch for smaller pipe diameters which can detect gas flows down to 0.6 cc/sec and liquid flows down to 0.02 cc/sec – ideal for virtually all injection processes.

This switch's no-moving-parts flow element design provides outstanding durability and reliability under the harshest process conditions. And, the inherent thermal time delay, available in all FCI flow switch/monitors, prevents false alarms caused by flow pulsation and eliminates the need for auxiliary time delay relays.

#5: Compressed Air Consumption
Compressed air is useful for many industrial processes and plant applications. In compressed air systems, accurate, repeatable flow measurement helps to reduce the consumption of pneumatic air, improves manufacturing, assembly and process plant efficiency, and identifies leakages to eliminate wasted energy. Compressed air flow meters, such as FCI's ST50 with its specially designed FPC-type compressed air sensor design, can measure compressed air accurately and rapidly detect system inefficiencies or expensive leaks.

Compressed air flow meters can measure compressed air accurately and rapidly detect system inefficiencies or expensive leaks.

The installation of air flow meters in large facilities with multiple air compressors allows operators to compare compressor usage and adjust them for optimal efficiencies. The use of mass flow meters at the point of compressed air output also helps to ensure peak performance at a given flow rate.

#6: Boiler Fuel Gas and Air Optimization
Carefully monitoring the natural gas flow fueling plant boilers minimizes fuel consumption, lowers plant energy costs and reduces pollutant emissions. Optimizing the fuel-to-air ratio for boiler control helps to both reduce plant fuel costs and protect the environment. The natural gas flow measurement solution provided by thermal mass flow meters, such as FCI's Model ST80, allows facility engineers to monitor and control the precise amount of fuel needed to run HVAC boilers most efficiently.

The direct mass flow sensing technology of these thermal meters eliminates the need to add temperature sensor, pressure sensor and mass flow computer as is needed with other meter technologies. Eliminating these components, as well as the plant real estate that they occupy and the technician time needed to install and maintain them, reduces plant instrument and operating costs.

#7: Tank Blanketing
Nitrogen tank blanketing is a practice commonly used in the chemical, petroleum refining and other process industry plants to reduce the hazards associated with flammable liquids, improving

the plant's safety in the plant and helping to increase productivity. Blanketing or padding is a process of applying nitrogen gas to the vapor space of a tank or vessel, minimizing the possibility of an explosion or fire. Blanketing also helps decrease product evaporation and protects the tank from structural corrosion damage caused by air and moisture.

Air/gas flow meters, such as the Model ST100 from FCI, help to measure the flow rate of nitrogen more accurately in tank blanketing applications (Figure 2). They provide a repeatable and reliable output necessary for the tank blanketing valve to operate as designed and provide safety and cost savings.

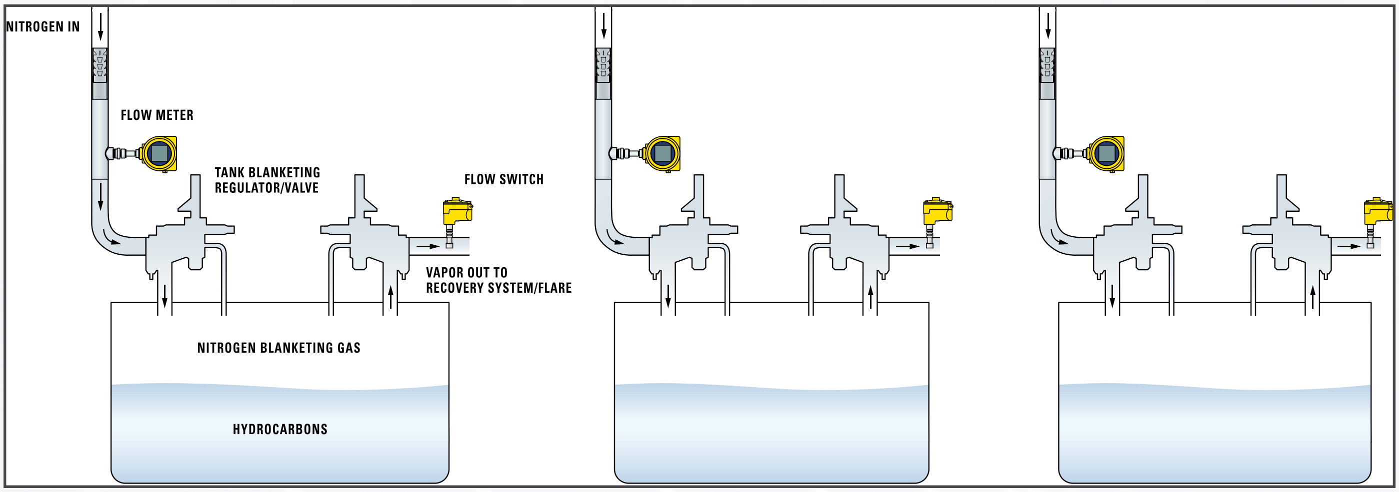

Figure 2: Nitrogen tank blanketing process on refinery tanks

#8: Analyzer Flow Assurance
Gas chromatographs (GCs), mass spectrometers, optical spectrometers and photometers are a few examples of analyzer technologies applied in process and plant systems that need sample flow assurance. It is an accepted industry best practice that sampling systems have some type of flow monitor to assure valid samples and analysis.

Analyzer flow switch/monitors, such as the FCI Model FS10A, are designed specifically for gas and liquid process analyzers and sampling systems (Figure 3). It features a fast responding, highly repeatable sensor that installs easily into a standard tube tee fitting or new SP76 (NeSSI) modular manifold. The instrument's microprocessor-based electronics, onboard keypad and serial I/O computer port provide easy and extensive field adjustability.

Figure 3: FCI Model FS10A in a typical sampling system

#9: Stack Gas Monitoring (CEMS, QAL1, MCERTS)
Flue gases are the general name given to the mixed composition gases that are the by-product of a combustion process. A flue is typically a large pipe, duct, stack, chimney or other venting attached to a process system such as a boiler, furnace, steam generator, oven, etc., through which waste flue gases are exhausted from the combustion process.

Flue gases need to be monitored accurately for process control data and reporting, which is often mandated by environmental and regional air quality regulations. Single- or multi-point air/gas mass flow meters, such as FCI's Models ST80, ST100, ST102A, and MT100, offer accurate and cost-effective solutions to flue gas measurement. Thermal dispersion insertion flow meters provide a cost-effective and accurate solution to flue gas flow measurement.

#10: Flare Gas Measurement
Flaring systems are used to burn-off and dispose of waste, excess or off-gases and as a safety system to protect processes and equipment. They are found throughout the world in oil, gas, petrochemical refining, and other industrial processing plants.

Flare flow meters are a critical component used in these systems that measure, monitor and report these gas flows (Figure 4). Flare flow meters, such as the FCI ST100 Series, provide plant operations with a tool to signal abnormal process changes, early leak detection and report on flared gases to comply with environmental agency reporting regulations for greenhouse gases (GHG's). Flare flow meters are installed in both land-based and offshore platform flare systems throughout the world.

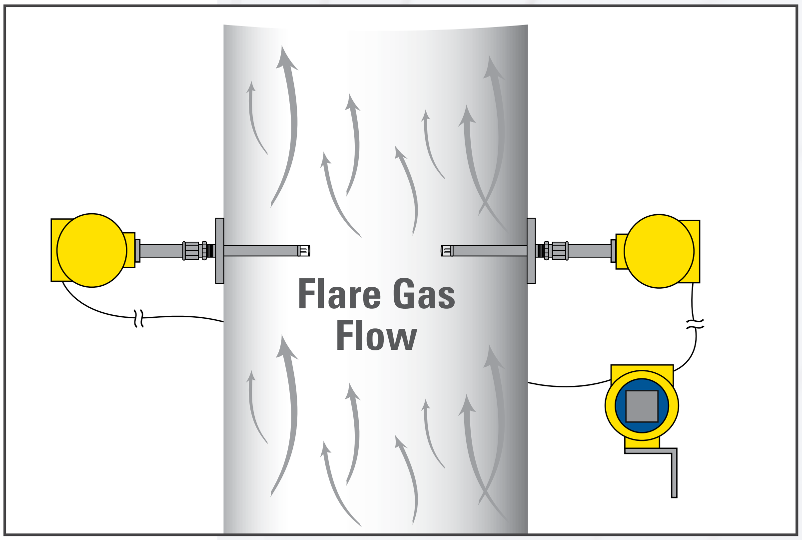

Figure 4: FCI Model ST102A flare flow meter

Furthermore, many flare systems include an assist gas line, such as natural gas, to ensure effective and efficient combustion. Inline-type (spool-piece) thermal flow meters, such as FCI Models ST75, ST80L and ST100L, support flare gas flow control, measure flare gas consumption and flow rate, as well as providing totalized flow data.

Conclusions
Fluid flow and level measurement accuracy and reliability are critical in many industrial process and manufacturing plants. They support efficient and high-quality production operations, protect workers and equipment, ensure compliance with environmental regulations, and reduce total operational costs. Plant upgrades, maintenance projects and process control initiatives that focus on improving the measurement and control of flow ensure that plants continuously operate as efficiently as possible. The various manufacturers of flow and level instruments offer applications expertise and experience across multiple industries. Their factory and field application engineers can provide optimal, cost-effective solutions for most common plant installations and also have the ability to engineer custom measurement solutions to meet unique or challenging plant requirements.

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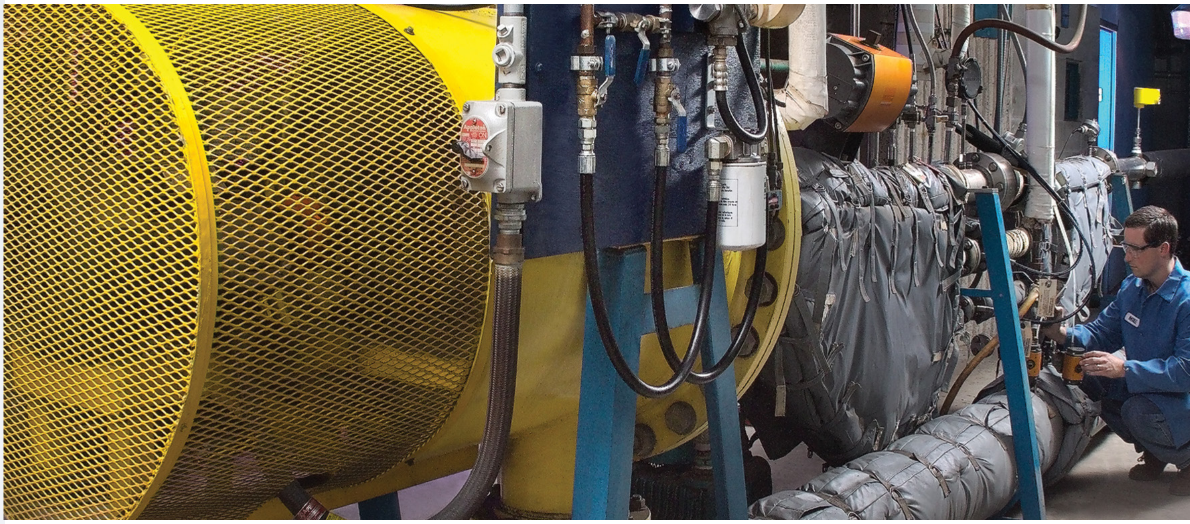
3. Thermal Flow Meter Calibration Safety & Certainty



The Importance of Flow Meter Calibration

Flow meter calibration should never be taken for granted, and thermal mass flow meters are no exception. Flow meters can be built with the highest safety ratings, features, and functions; and the most industrially robust sensor technology, but if the calibration is inaccurate or subject to uncertainty due to an equivalency-based calibration or simulation methods rather than an "actual" fluid calibration, then the device could produce unsatisfactory performance issues.

The results of poor calibration practices can include possible safety exposures and process inefficiencies that might go undetected until the process is running and something goes wrong. Inefficient processes also frequently result in poor product quality and excessive costs which negatively impact the bottom line and competitiveness.

Principle of Operation

All thermal mass flow meters work by measuring the cooling effect of a moving gas along a cylinder. The cooling effects are mostly a function of the gas properties, such as: thermal conductivity, specific heat, density and viscosity (Figure 1). This is true for thermal mass flow meters, regardless of their measuring technique. Additional variations come in with the sensors themselves and how each sensor is affected across its full flow range.

Heat Transfer Path Variability

All thermal flow meter manufacturers need to understand not only the heat input equation and the surface area, but all the heat transfer paths. The variability in the sum of these heat transfer paths will be unique to the flow meter and may differ in the same way fingerprints differ on someone's hands. Just as the right index and left index fingers of your hands appear similar, they are actually different in their details. Similarly, the sensors of thermal mass flow meters, even with tight manufacturing tolerance controls, precision methods of sensor fabrication, and the automation of sensor assembly, are subject to variations. These variations, even if subtle, make a formulary, standardizing gas correction factor inadequate and much more complex than a mere single variable correction factor.

Calibration Laboratory with Traceable Equipment

The capital investment and infrastructure needed to develop and maintain traceable, actual gas flow stands is substantial, particularly for gases that are hazardous or flammable. Additionally, flowing of the specific gas itself, plus the energy required to flow it at specific temperature and pressure conditions, comes at a higher recurring cost. Many thermal mass flow meter manufacturers simply sidestep this investment and evade the higher cost of an actual gas calibration by performing a simulated or "equivalency" quasi calibration.

Not All "Equivalencies" Are Truly Equal

Manufacturers performing equivalency calibrations use a reference or surrogate fluid, typically air, at ambient conditions. To the air flow readings they apply empirically-based calibration parameters that utilize a theoretical, formula-based calculation to set their instrument's gas calibration. At best, this procedure simply infers the fluid's cooling effects on the gas properties such as viscosity, density, specific heat, thermal conductivity, and Reynolds number ranges.

Unlike an actual gas calibration, this inferred equivalency method does not accurately replicate the true thermal heat dissipation of the actual gas. Corrections required for process conditions, such as variations of pressure and temperature extremes, create an even greater uncertainty. As stated and confirmed by ISO Standard 14511, Section 8:

"… the best practice for calibrating thermal mass flow meters is to perform an actual gas calibration, and at actual process conditions, when feasible."

Any critical application where stoichiometric calculations are critical or when measured gas flow rate are essential for safety or efficiency, no simulated calibration method should be considered for thermal flow meters when an actual, "true" fluid calibration is available.

Furthermore, an air equivalency, simulated calibration is not recommended where process conditions are moderately unstable; where flow velocity profiles are potentially in the transitional range, or where there is a potential non-linear relationship between the calibration fluid and the actual service fluid. Therefore, theoretical or equivalency calibrations represent a very limited range of applications. Many flow ranges with turndowns greater than 10:1 extend well beyond a simple linear correction range and a single factor correction as applied by many manufacturers is ineffective due to the non-linear

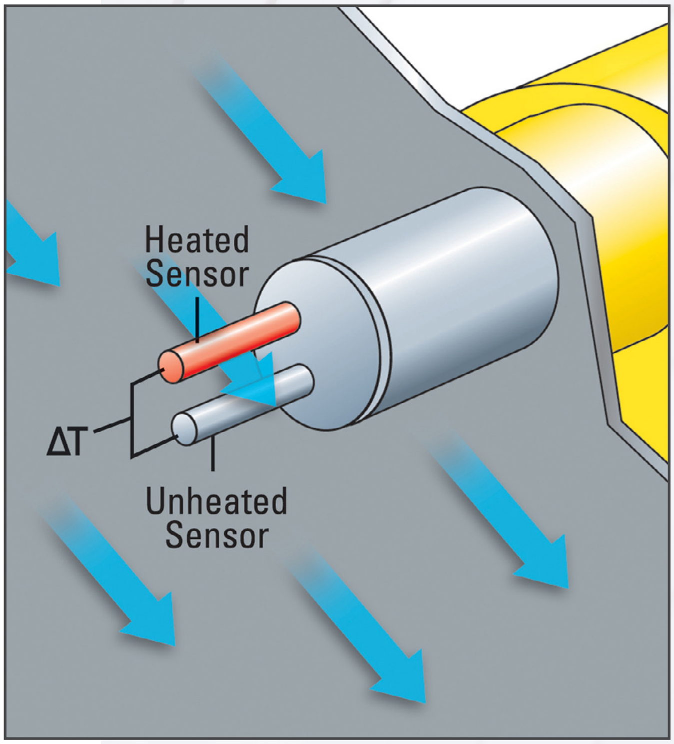


Figure 1: Thermal dispersion principle of operation

Thermal mass flow sensors are comprised of two platinum resistance temperature detectors (RTDs) that are protected within thermowells. One RTD is heated while the other provides a reference by measuring the process temperature. This temperature differential is directly proportional to the mass flow measurement.

> The results of poor calibration practices can include possible safety exposures and process inefficiencies that might go undetected until the process is running and something goes wrong.

relationships between the fluids. This is particularly true with thermal mass flow meters that rely on thermal conductivity and cooling effects as the essential measurement.

The Problem With Simulated Calibrations

To illustrate graphically the measurement uncertainty of simulated calibrations, consider the accuracy performance curves shown in Figure 2. These curves were obtained from a thermal flow meter produced by a leading global, multi-technology flow meter manufacturer, whose meter embedded a user selectable menu of gases. It is alarming to see the extent of the errors.

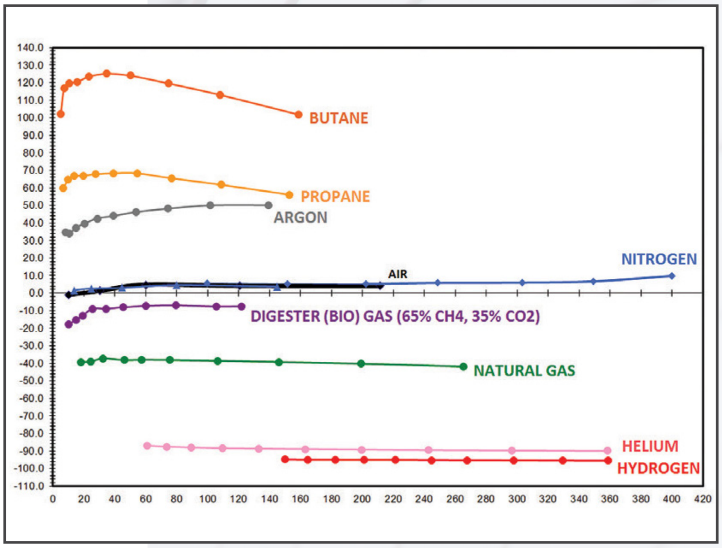


Figure 2: Brand E thermal mass flow meter accuracy performance using selectable gas menu, equivalency. 4" line size, 4-20 mA output signal converted to SFPS at 70 °F [21 °C]. Calibrated range of unit = 10-692,8 SFPS in air.

Clearly, this instrument is not calibrated directly in each of these basic gas compositions but instead applies an inaccurate equivalency algorithm correction factor.

The large errors seem to indicate a simple, single order correction, and the manufacturer does not even attempt to use a polynomial correction for purposes of correcting non-linearities. It is visible through most of the flow range that these corrections, while extremely large in scale, have a certain linearity. As expected, the air and nitrogen curves are relatively close to zero offset because the base calibration is performed in air as the calibration fluid. However, when the instrument has one of the other gases selected, then the additional measurement error after the theoretical correction factor is applied can be as high as ± 100%!

Also detectable is the inability of the algorithm to correct non-linearity for some gases flowing at slightly elevated temperatures. This non-linearity range can vary as much as 30%, which means a correction factor approach, even if accurate, would not apply across the full fluid flow range.

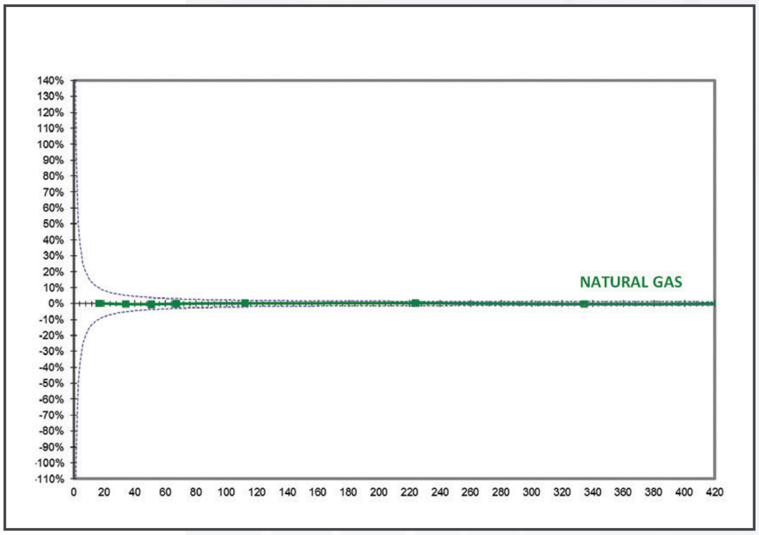


Figure 3: FCI Model ST100 thermal mass flow meter accuracy performance in natural gas using actual calibration. 4" line size, 4-20mA output signal converted to SFPS, at 70 °F [21 °C]

To demonstrate the significant performance improvement obtained by using an actual gas calibration, refer to Figure 3 which shows the accuracy of an FCI Model ST100 using an actual gas calibration for natural gas.

Compare this result with the natural gas plot line in Figure 2, which used an equivalency calibration. The resulting improvement is exceptional.

What You Should Ask and Know

If you're responsible for flow meter performance in critical processes, or for plant safety or environmental compliance, then you have a right to ask manufacturers about their calibration procedures. They should be able to explain and demonstrate how your company's new meters are to be calibrated, on what types of traceable equipment, under what methods and what conditions, and to which specific mechanical, electrical and safety standards.

You should ask to tour the Calibration Laboratory where the work will be performed and to meet with the engineers and technicians responsible for the work. In addition, a flow meter factory representative should be made available to you when necessary to review the application requirements and inspect the actual meter location to ensure a successful installation.

Conclusions

For decades Fluid Components International (FCI) has led the thermal mass flow meter market through the performance integrity and certainty provided by authentic, actual fluid calibrations. FCI has invested in and maintains more than 20 calibration rigs located on three different continents. These flow stands, in various pipe diameters, can flow air, pure inert gases, hydrocarbon gases, and precision mixed-gas compositions with as many as 20 actual gas constituents. All of these stands have the ability to flow the fluids and calibrate in actual temperatures up to 454 °C [850 °F] and in actual pressure ranges from ambient to 34 bar [500 psi].

4. How Flow Conditioners Simplify Meter Installation Requirements

If you need to increase your plant's productivity and reduce its operational costs, focusing on flow measurement can result in significant monetary savings, potential product quality improvements, and even a competitive advantage. The accurate measurement of gases, steam, liquids and slurries is critically important in many plants and processes that produce chemicals, energy and power, food/beverages, pharmaceuticals, pulp/paper, water and more.

Unfortunately, the measurement of flow is often an afterthought—especially in many plant expansions, equipment upgrades, and retrofit projects. The selection and placement of flow switches and flow meters requires careful advance thought. Choosing the wrong flow sensing technology for your application or placing your flow instrument in the wrong location too closely to pumps or valves can not only eliminate potential cost savings, but frequently results in unnecessary replacement or relocation projects.

Carefully planning for new or upgrade flow instrumentation in your plant, however, offers many advantages:

- Lower initial instrument installation costs and faster start-up
- Decreased energy costs to run burners, boilers, fans or ovens
- Reduced consumption of process gases, such as chlorine or nitrogen
- Lower consumption of process water and wastewater
- Less frequent plant maintenance and equipment replacement

The Problems

In a perfect world, every plant would have an instrumentation engineer on staff who is familiar with all the different flow technologies on the market, has experience applying them in multiple processes or industries, has enough budget to buy the best equipment, has a great maintenance team to do the installation, etc. You can stop reading if you're working for this company because this article is for the 95% of you who make up the real world.

Optimizing your flow instrumentation can be summed up fairly simply with the following four broad guidelines to consider:

- Choose the appropriate flow sensing technology for your process media
- Consider the installation and maintenance requirements in advance
- Be careful about installing other equipment around, before, or after flow instrumentation
- Consider adding a flow conditioner or flow straightener

Flow Sensing Technology

When selecting a flow instrument, the first consideration should always be the process media to be measured: air, gas, steam, liquid or slurries. Many flow sensing technologies perform best in one or two media, such as gas or liquids. Some will measure slurries—and some won't at all. The industry's major flow sensing technologies now available include:

- Coriolis (Mass)
- Differential Pressure
- Electro Magnetic
- Positive Displacement
- Thermal (Mass)
- Turbine
- Ultrasonic
- Variable Area
- Vortex Shedding

All of these technologies have their advantages and/or disadvantages, depending on your process and plant. Thinking about the process media, as well as your plant's equipment, environmental or other regulations, maintenance schedules, etc., you will be able to narrow the field to one or two best choices.

Installation Issues

One of the most common problems when installing flow instruments, especially flow meters, is an inadequate straight run upstream and downstream from the instrument. Before specifying any flow meter, you must consult the manufacturer's specification to determine the necessary straight pipe run.

Adding elbows, expansions or reductions, and/or spiral piping in close proximity to instrumentation often further exacerbates the problem of inadequate straight runs. Lots of equipment, not enough space and poor piping layouts—they all work together to alter the process media's tangential, radial and axial velocity vectors. The final result is flow disturbances, including swirl, jetting and velocity profile distortions.

Flow disturbances frequently have a significant impact on the performance of flow meters, pumps and other equipment. For example with flow meters, the irregular flow of process material adversely affects the accuracy and repeatability of many of the most popular flow sensing technologies: differential pressure, turbine, magnetic, thermal, ultrasonic and vortex shedding. Depending on the flow sensing technology, the straight pipe

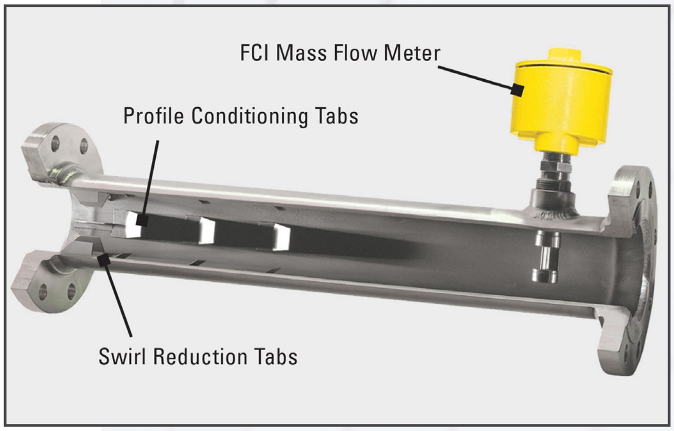


Figure 1. Tab-Type Flow Conditioner with Mass Flow Meter

> One of the most practical ways to optimize flow meter accuracy and/or compensate for adverse installation conditions is the use of flow conditioners.

run requirements for flow meters varies—from 10 to 20 or more diameters.

The Solutions

One of the most practical ways to optimize flow meter accuracy and/or compensate for adverse installation conditions is the use of flow conditioners. Through the use of flow conditioners, it is often possible to increase the accuracy and/or repeatability of a flow instrument by 50% or more.

For example, thermal mass flow meters with the addition of a flow conditioner can be optimized to perform at +1% accuracy instead of their standard +2 % accuracy. That increase in accurate measurement can result in huge savings in controlling expensive natural gas fed burners for plant boilers over a year's period of time.

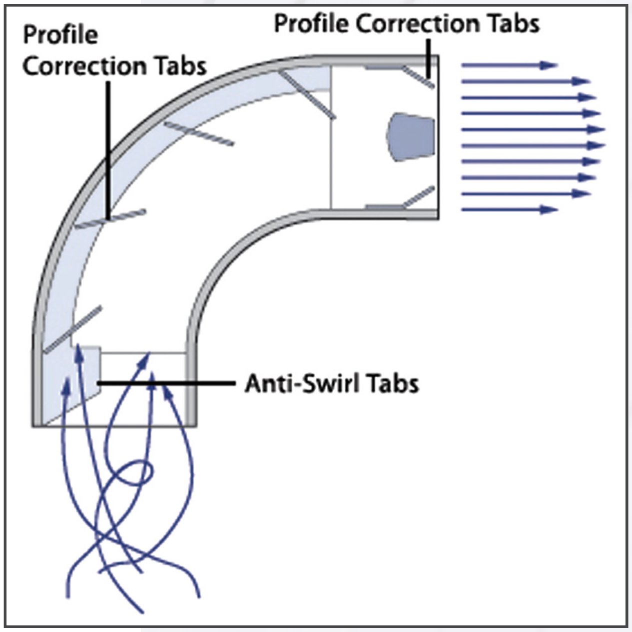
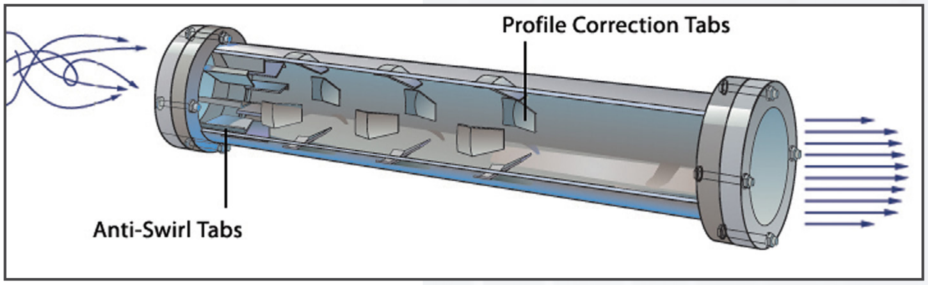


Figure 2: Tube and Elbow Tab-Type Conditioner

There are many types of flow conditioners, including:

- Honeycomb Vane-Type conditioners are popular in HVAC or compressed air handling system applications where they provide air flow profile corrections. Many different designs and materials are available.
- Perforated Plates are frequently selected for application in natural gas pipelines or other clean gases and liquid applications. They are simple to install and require no spool piece, but they can be prone to clogging in dirty gas.
- Tab-Type Flow Conditioners are a good choice in clean or dirty gases and liquids because of the tapered design of their tabs. They provide excellent cross-mixing to remove swirl and correct velocity profiles with minimal pressure-drop (Figure 2).
- Tube Bundles and vanes have been used for decades. Tube bundles are effective at removing swirl but have the tendency to "freeze" the velocity profile and therefore are not as efficient at isolating and correcting flow distortion anomalies.



To choose a flow conditioner, you'll need to follow many of the same guidelines required to specify a flow meter. The process media is especially important. Be sure to consider the viscosity of the process media when selecting a flow conditioner. Some technologies are prone to clogging in slurries, for example, and/or contaminant build-up in dirty gas processes.

Don't forget that in general the more effective flow conditioners are at correcting flow profile distortions, the more pressure drop they may produce. If you're trying to reduce power consumption or pumping costs or you need to speed product throughput, then you'll want to minimize headloss or pressure drop. For example, one flow conditioning technology that has proven itself effective is the tab-type flow conditioner (Figure 1). In its standard straight tube configuration, the Vortab® Flow Conditioner consists of pipe fitted with a short section of swirl reduction tabs combined with three arrays of profile conditioning tabs. Combining the anti-swirl and profile conditioning tabs created a repeatable, flat velocity profile at the outlet of the pipe.

Figure 3: Elbows for Offshore Oil Pumping Station

An elbow flow conditioner also can be configured with the same tab-type flow conditioning technology (Figures 2, 3).

Many different processes and different types of flow instruments can benefit from the installation of tab-type flow conditioners. At an offshore oil pumping station, for example, the process engineering team needed to add a pump to increase capacity. Elbows feeding into the pump consisted of a 20-inch inlet and reduced to a 12-inch section (Figure 3).

The engineer quickly determined there was no room for the pump's required straight run and no way to expand the platform to accommodate the pipe run. By inserting a tab-type elbow conditioner in the elbow itself, the engineer solved the space problem by ensuring a properly conditioned flow entering the pump at a large cost savings and freed real estate for other possible uses.

Figure 4: Electric Power Plant Elbow and Pump

At an electric power facility, the plant team needed to add two identical 14-inch centrifugal pumps to feed water into its main boilers. The pump configuration required that the line size drops from 16 inches at the elbow to 14 inches at the pump inlet. These pumps are powered by 350 hp electric motors.

When installing the pumps, it was found that the indoor facility did not have adequate room for an upstream pipe run into the pumps. Note the proximity of the building's wall in Figure 4. Using a tab-type flow conditioner placed in the elbow compensated for the lack of straight run and provided an equally distributed flow profile entering the pumps.

Vortab flow conditioners are available in straight-pipe runs, a unique 90° elbow, and insertion panel designs for virtually any pipe, tube or duct size.

VEL Elbow

The VEL Elbow is the only true isolating 90° elbow flow conditioner. It can be applied with flow meters and is ideal for use in tight installations with pumps, compressors, and other critical process equipment requiring a stable flow profile and applications where an elbow inlet is typical.

VIS Insertion Sleeve

The Vortab Insertion Sleeve Flow Conditioner (model VIS) is the most cost-effective version of the Vortab flow conditioning products. The VIS can be installed directly into existing pipe or specially designed round, square or rectangular ducts.

VIP Insertion Panel

The VIP (Vortab Insertion Panel) flow conditioner completely neutralizes flow profile irregularities caused by elbows, valves, blowers, compressors, and other flow disturbances that commonly occur in piping and duct runs and cause flow meter inaccuracies. The VIP provides a swirl-free, symmetric and repeatable flow profile that flow meters require for accurate measurement.

VMR Meter Run

The Vortab Meter Run flow conditioner (model VMR) offers a complete, simple pipe section replacement for new and existing piping systems. The VMR is a seven pipe diameter long spool piece comprised of three pipe diameters of Vortab flow conditioning internals and a built-in downstream settling chamber.

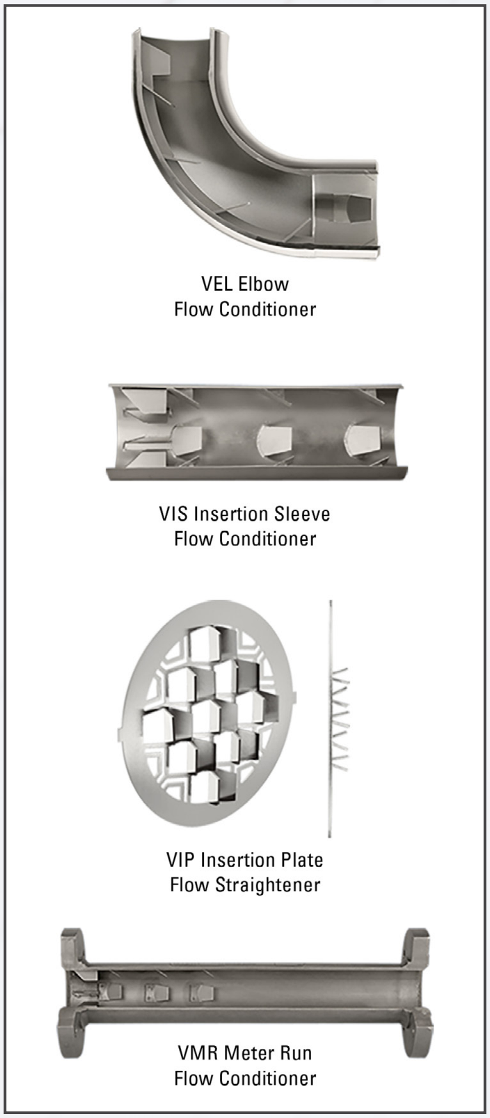


Figure 5: Tab-type flow conditioners

Conclusions

If you're planning a facility expansion or retrofit, be sure to consider the straight run pipe requirements of all the equipment involved in your process. Valves, pumps, compressors, flowmeters — they all can be affected by flow disturbances caused by poor piping layouts. The resulting problems can be costly to fix in terms of poor end-product quality, equipment repairs or failures and even line shut-downs. When you're simply out of room or changing the piping configuration is cost prohibitive, flow conditioners are an excellent solution. There are several different types of flow conditioners — so be sure to consider the characteristics of your process media to avoid maintenance issues with clogging and potential pressure drop problems.

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5. Multipoint Flow Measurement in Large Lines, Ducts & Stacks

Air pollution emissions monitoring and control begins with accurate and reliable gas flow metering. There's an old industry truism that says, "You can't control what you don't measure," and that applies here. Process plants install the world's most sophisticated air pollution control systems, but they can be ineffective if the flow meters they rely on deliver inaccurate or unreliable data.

Flue gases are the mixed composition hydrocarbon greenhouse gases (GHGs) that are the byproduct of an industrial combustion process. A flue is typically a large pipe, duct, stack, chimney, or other venting attached to a process or industrial manufacturing plant system such as a boiler, furnace, steam generator, oven, etc., through which waste gases are exhausted.

Depending on the type of industrial plant, processes, fuel used, and efficiency, flue gases include:

- Carbon monoxide
- Methane
- Nitrogen
- Nitrogen oxide
- Oxygen and water vapor
- Ozone
- Particulates
- Sulfur oxides

Flow Measurement Environmental Standards

For large stack monitoring applications, the U.S. EPA requires a Continuous Emissions Monitoring System (CEMS) or Continuous Emissions Rate Monitoring System (CERMS). For CERMS, the flow meters must perform an automated and on-demand self-checking of calibration drift (CD) at both a low range and a high range flow point.

In the EU, these systems are referred to as an Automated Measuring System (AMS). The flow meters that support them also need to meet the Quality

Assurance Level 1 (QAL-1) standard confirming compliance to EN 15267-1,-2,-3 and EN 14181 standards.

Measurement Challenges

Measuring the flow of stack or flue gas is a challenge (Figure 1). These gases are generally mixed hydrocarbons in terms of their composition. In addition, the volume of gas that is emitted tends to vary based on the products in production, workload schedules and seasonal fluctuations in temperature and humidity. This variability can lead to irregular swirling flows in stacks that are difficult to measure without multipoint sensing.

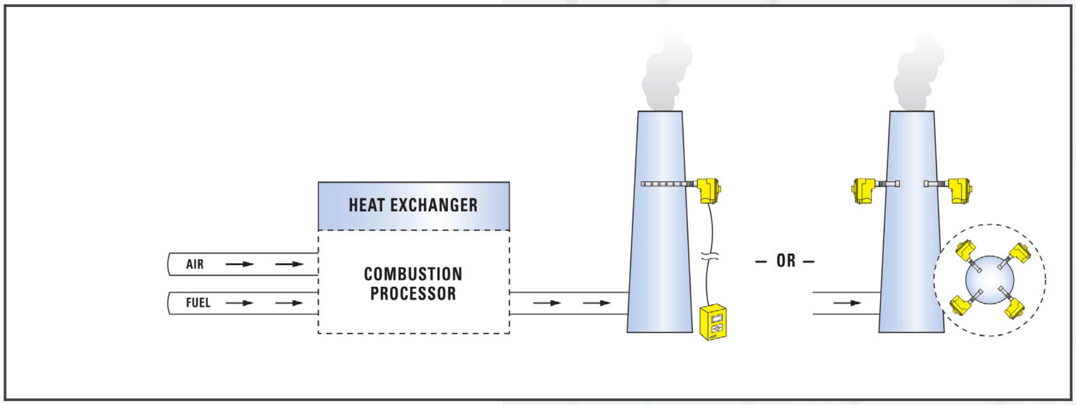

Figure 1: Flow meter installation for flue gas

Large diameter pipes, stacks and ducts present their own unique physical challenges to successful flow meter installation and performance. Installation is complicated by difficult access points, single plane platforms, long cable runs, extra mechanical support and exposure to weather extremes.

Lack of pipe straight-run, distorted flow profiles, low flow rates and wide turndowns rates are common performance challenges for many flow metering technologies. Furthermore, the gas can be dirty and/or at high temperatures, which can result in measurement degradation, clogging and fouling that leads to excessive maintenance procedures or premature flow meter technology failures.

There's an old industry truism that says, "You can't control what you don't measure."

The purpose for gas flow measurement is now increasingly multipurpose: To comply with government regulations and to provide process gas data for scrubbers and flare systems. The combination of these factors results in the need for flow meters that operate accurately and reliably over a wide flow range in rugged environments with distorted and swirling flow profiles.

Evaluating Sensor Technologies

In considering a flow meter for gas monitoring, the first step is always choosing the appropriate flow technology. There are multiple flow sensing technologies available, and the major ones now include:

- Coriolis (mass)
- Differential pressure
- Electromagnetic

- Positive displacement
- Thermal (mass)
- Turbine
- Ultrasonic
- Vortex shedding

All of these technologies have their advantages and disadvantages depending on the type of process fluid (air/gas or liquids). Process engineers must consider limited straight run challenges, dirt and particulates, mechanical installation considerations, high temperatures and moisture entrained in the flow stream, in addition to cost/benefit considerations in meeting accuracy requirements, maintenance and life expectancy of the equipment.

Flue gas monitoring at a cement plant

By looking at these factors as well as the plant's layout, environmental conditions, maintenance schedules, energy cost and ROI, it will soon be easy to narrow the field. The most common flow sensing technologies chosen for flue gas measurement are differential pressure (averaging pitot tubes) flow meters and thermal dispersion mass flow meters. Both technologies have similar accuracy levels when configured with multiple sensing points within the large cross sectional area of a flue gas line.

For swirling flows of hot flue gases, multipoint sensing generally provides more accurate flow measurement than single point technologies.

Maintenance requirements, which drive up operating and lifecycle costs, as well as reducing ROI, are different with these two technologies. Most averaging pitot tube flow sensors require a daily manual cleaning or compressed air back purge system to keep the inlets from clogging. Thermal flow meters, which have no inlets or any moving parts, can require virtually no maintenance for years.

Conclusions

When you examine the viability of the various air/gas flow sensing technologies available for flue gas monitoring and then look at them according to accuracy, installed costs and lifecycle costs, you increase the probability of selecting the best flow measurement solution. If you have a unique problem, contact any of the flow meter suppliers. They see these challenges every day and have probably already solved the same problem for someone else.

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6. Overcoming Wet Gas Measurement Issues

Wet gas is a challenge to measure in a number of industries, including those with combustible gases that represent a safety hazard. In the laboratory, today's air/gas flow sensors and measurement technologies operate at their highest accuracy and greatest reliability in air or gas free of moisture, droplets, particulates, etc. The real industrial world, however, is a much different environment where moisture can be entrapped in one form or another in air or gas flow streams with variable gas compositions and flow rates.

There is no single definition of what constitutes wet gas. It is instead a variable condition that ranges from mild humidity in the pipe to gas that presents itself as a multi-phase flow with for example a 90% volume of gas and 10% volume of other fluid in various forms. At the other end of the spectrum, pollution monitoring systems that measure air/gas flow in large vertical stacks must at times contend with the natural phenomenon of frequent rain in the pipe.

No matter the industry, the application or the pipe size, process engineers need to be able to measure wet gas flow accurately and consistently independent of the fluid composition in the pipe or the weather conditions. Failing to achieve accurate air/gas flow measurement creates inefficiencies in processes, reduces product volume throughput, causes maintenance issues, etc. The result of inaccurate measurement is higher costs and competitive weakness.

Wet Gas Solutions

For entrained moisture, eliminating the moisture from the gas stream is always the preferred, best practice. Common methods for this include the installation of a gas dryer or the installation of a knockout drum or knockout pot upstream from the flow meter's point of installation. Another option is to insulate or heat wrap the pipe to prevent condensation.

While these wet gas mitigation options are often effective and completely solve the problem, there are instances where either the gas composition or the variables in process, installed equipment or piping layout can frustrate the best efforts. If none of these moisture elimination practices are feasible or adequate to solve the problem, then there are several more solutions to consider at the instrument level.

Option 1. Install a standard thermal flow meter using constant power (CP) technology and optimize the installation itself to minimize or prevent condensation from contacting the sensor.

During the flow meter's installation, be sure the meter is angle-mounted in the pipe (Figure 1) so that gravity moves the moisture away from the sensor. If a knockout pot is already employed, the installation of the flow meter as shown (Figure 1) is also the recommended best practice.

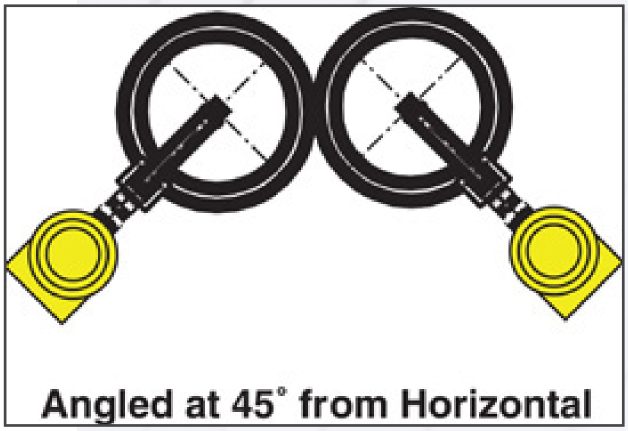

Figure 1: Angle-mounted standard thermal flow meter

Another alternative is to install a ΔT (CT) method meter that is extremely heated, to 300°C (572°F) to "flash off" any moisture. There is an issue, however, with inserting such a high heat source into the flow stream. This could create an unsafe condition, consumes much more energy to operate and can result in a shortened operating life-cycle, accelerated aging and susceptibility to drift and/or premature failure of the sensors.

Option 2. Install a special purpose "wet gas" thermal flow meter, such as FCI's new "wet gas" sensor head. Its innovative design shunts the condensate away and never allows it to reach the sensors. As a mechanical design solution, all safety approvals remain in place, there is no increase in energy consumption to power the instrument and there is no impact on the sensor's service life. Furthermore, there is no de-rating of the instrument's T-rating and the sensor is safe to touch. The recommended installation is side-mounted in either the 90° or 270° position (Figure 2).

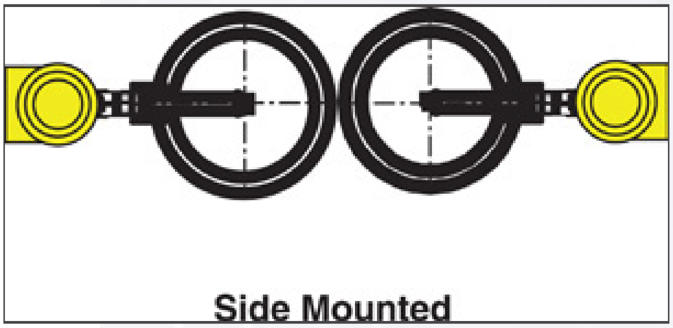

Figure 2: Side-mounted standard thermal flow meter

The Wet Gas Sensor

The most effective of these approaches is the previously mentioned Wet Gas MASSter™ sensor for the ST80 Series Flow Meter. This innovative mechanical design shunts moisture, condensation and water droplets away from the thermal sensor, thus maintaining an accurate gas flow measurement while minimizing errors that occur from a cooling effect on the sensor that could cause a spike or false high reading.

The Wet Gas MASSter can be used in applications that have either moisture entrained in the gas (annular mist) or for protection against rain in larger, vertical stacks. Why is it needed? This new wet gas sensor is designed specifically for use in applications that have a high level of moisture or condensation present in the gas flow stream that cannot otherwise be removed using traditional solutions.

The measuring principle of thermal mass flow meters involves heat transfer caused by gas flow. Any moisture or condensate in the gas stream that contacts the heated sensor can cause a sudden, momentary change in the heat transfer that can result in a spiked or fluctuating output reading, creating inaccurate or unstable flow measurement. Thermal flow meters using the constant ΔT (CT) method are particularly reactive to moisture droplets, while constant power (CP) method meters, because their slightly heated sensor elevates the dew point, are less so (Figure 3).

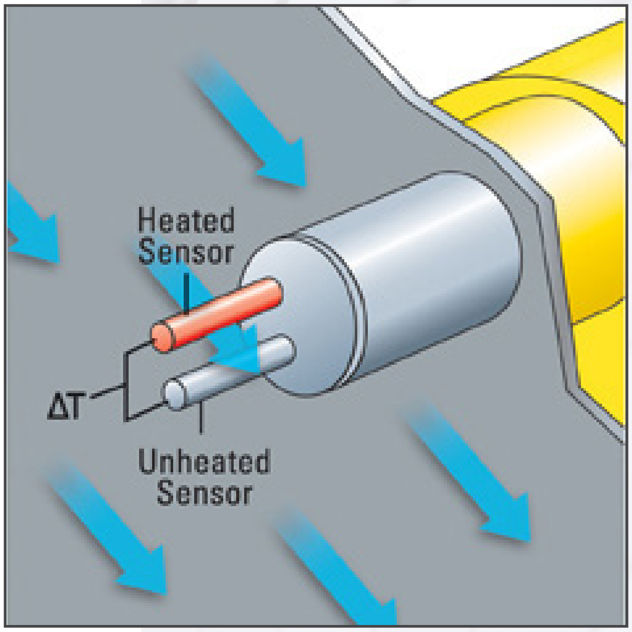

Figure 3: Thermal dispersion principle of operation

Common moist gas applications with condensation droplets are found in biogas recovery systems (wastewater treatment digesters, landfill gas biogas production systems and reactors). Rain droplets are found in open vertical stacks and flues are common in power plants, oil and gas operations, chemical plants and refineries.

The Wet Gas MASSter sensor option for the ST80 meter (Figure 4) is suitable for pipe diameters from 1 inch to 99 inches [25 mm to 2500 mm] and air/gas temperatures up to 850°F [454°C]. These meters are accurate to ± 1% of reading, ± 0.5% of full scale, with repeatability of ± 0.5% of reading for flow rates up to 1000 SFPS [305 NMPS] and 100:1 turndown.

Figure 4: ST80 flow meter; Wet Gas MASSter flow sensor

These meters are available with an extensive choice of outputs and user interfaces to ensure interfacing with virtually any control system and/or set-up or configuration devices. Standard outputs include dual 4-20 mA, NAMUR NE43 compliant analog outputs, HART (version 7), Modbus 485 and a USB port. Foundation Fieldbus or PROFIBUS PA can be optionally added. An intuitive, easy-to-read backlit LCD display provides digital and bar graph readouts of the meter's flow rate and temperature, totalized flow, alarms, diagnostics feedback and a user defined label field is also available. Technicians can easily spot check flow data in person for reliability.

The meter's transmitter enclosure is NEMA 4X/IP67 rated, selectable for NPT or metric conduit port threading and is available in both aluminum and stainless steel and may be remotely located up to 1000 feet (305 m) apart from the flow element. In addition to SIL rating, the instrument with the wet gas sensor also carries full global instrument Div.1/Zone 1 Ex hazardous location approvals of FM, FMc, ATEX, and IECEx.

Conclusions

While wet gas is unavoidable in many industries and processes, solving wet gas measurement challenges can be easier than you think. There are multiple options to eliminate the moisture or to mitigate any interference with flow measurement sensors.

Where possible, choosing the point of measurement and installation of the flow meter downstream from dryers, knock-out pots or knock-out drums is the traditional and best possible solution. If that doesn't work, then angle-mounting the meter in the pipe helps isolate the flow sensor from the fluid in the pipe.

The newest option is the wet gas sensor designed for the ST80 thermal meter, which mechanically shunts moisture away from the sensor head to ensure accurate, repeatable measurement. Its unique construction eliminates affects from both moisture in the pipe and is suitable for use in large open stacks where rain fall is an issue.

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7. Installation Best Practices for Thermal Dispersion Flow Meters

Installation Recommendations for FCI Single-Point Thermal Dispersion Flow Meters

- Straight-run situations and recommendations
- Installation orientation options for various fluid conditions
- Overcoming limited straight-run and flow obstructions using flow conditioners
- Optimizing accuracy and repeatability

Optimizing flow meter installation ensures performance and instrument accuracy.

All flow meter technologies have recommended installation and engineering practices to ensure they meet their published specifications and provide optimal performance, accuracy and repeatability. Flow meter users are frequently challenged with wide variations in their actual field conditions and installation constraints that are much different from the ideal conditions under which their flow meter was calibrated. In fact, the most common installation constraint for almost all flow meter installations is inadequate straight-run. Flow meter users expect their flow meter suppliers to provide engineering recommendations and solutions to overcome real world application conditions to obtain expected flow meter performance to specifications. This guide provides recommended engineering practices with diagrams and specifications for straight-run, installation orientation and depths, as well as use of flow conditioners as an engineering solution for FCI single-point, thermal dispersion flow meters.

FCI's AVAL Software Makes Proper Sizing and Instrument Selection Easy

FCI's exclusive AVAL software tool is designed to make proper sizing and selection of thermal dispersion flow meters simple and effective. Since process parameters, fluid compositions and installation constraints can limit ideal performance, FCI AVAL software will ensure you are fully aware of process conditions that can potentially produce installed uncertainty. AVAL application evaluation software is a proprietary FCI service designed from years of fluid testing and installation experience. Using AVAL software, FCI models an installation with straight run variations and obstructions. When a complete evaluation is performed, an output report clearly defines expected "installed" accuracy or offers recommendations for improvement. FCI relates laboratory calibrations to true installed field performance. The configuration software matches specific process conditions and makes appropriate configuration recommendations for each flow meter application. Contact FCI or your local sales representative to run AVAL for your specific application.

FCI Offers Multiple Solutions to Limited Straight-Run Conditions

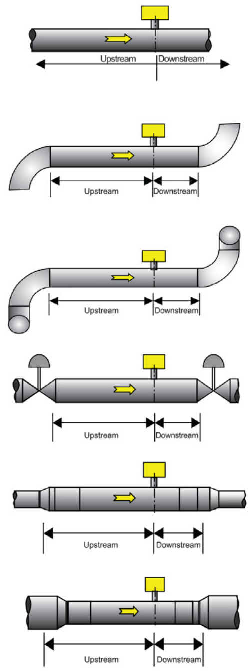
Straight-run is one of the most significant variables to consider in your flow meter installation to ensure accurate and repeatable flow measurement. Inadequate straight-run or the presence of flow disrupters are the most common real-world constraints to proper flow meter installation.

Figure 1 provides recommendations and engineering practices for commonly found conditions and line sizes to ensure an installation supports the meter's published specifications. When possible, installing the flow meter within these recommendations will ensure proper performance with the least installed cost. Figure 2 shows samples of the effects on flow meter accuracy of obstructions.

Recognizing the straight-runs specified in Figure 1 are not always possible, FCI offers four solutions which can be applied by themselves or in combination to overcome installation constraints:

- Vortab® Flow Conditioners to develop flow profile and negate obstructions with up to 70% reduction in straight-run needed
- Customized calibration set-ups that simulate the actual field installation conditions
- In-situ field calibration service and instrument adjustment
- Multiple sense point flow meters

Figure 1: Straight Run Recommendations



Default Recommendation for Required Straight-runs with Undefined Obstructions

Pipe Size	Upstream	Downstream
< 6 inches [150 mm]	20 x Pipe ID	10 x Pipe ID
≥ 6 inches [150 mm]	15 x Pipe ID	7.5 x Pipe ID
with Vortab flow conditioner	6 x Pipe ID	2 x Pipe ID

Recommendation for 45° or 90° Elbows in Plane

Pipe Size	Upstream	Downstream
< 6 inches [150 mm]	15 x Pipe ID	7.5 x Pipe ID
≥ 6 inches [150 mm]	10 x Pipe ID	5 x Pipe ID
with Vortab flow conditioner	6 x Pipe ID	1 x Pipe ID

Recommendation for 45° or 90° Elbows OUT of Plane (Swirl Effect)

Pipe Size	Upstream	Downstream
< 6 inches [150 mm]	20 x Pipe ID	10 x Pipe ID
≥ 6 inches [150 mm]	15 x Pipe ID	5 x Pipe ID
with Vortab flow conditioner	6 x Pipe ID	2 x Pipe ID

Recommendation for Flow Controlling Valves Upstream or Downstream

Pipe Size	Upstream	Downstream
< 6 inches [150 mm]	20 x Pipe ID	10 x Pipe ID
≥ 6 inches [150 mm]	15 x Pipe ID	5 x Pipe ID
with Vortab flow conditioner	9 x Pipe ID	2 x Pipe ID

Recommendation for Pipe Adaptor Upstream or Downstream

Pipe Size	Upstream	Downstream
< 6 inches [150 mm]	20 x Pipe ID	10 x Pipe ID
≥ 6 inches [150 mm]	15 x Pipe ID	5 x Pipe ID
with Vortab flow conditioner	9 x Pipe ID	2 x Pipe ID

Recommendation for Pipe Reducers Upstream or Downstream

Pipe Size	Upstream	Downstream
< 6 inches [150 mm]	15 x Pipe ID	5 x Pipe ID
≥ 6 inches [150 mm]	10 x Pipe ID	3 x Pipe ID
with Vortab flow conditioner	6 x Pipe ID	1 x Pipe ID

Recommendations shown are for general reference only as actual application conditions can vary and multiple effects are possible. FCI flow meter performance guarantees are only available following completed AVAL software-based application evaluations. Contact your local FCI sales representative for a comprehensive evaluation.

Figure 1: Straight run recommendations

Figure 2: Sample of Effects on Accuracy with Flow Obstructions Before and After Installation Point of Single-Point, Insertion Flow Meter

With Pipe ID < 6 inches [150 mm]

Distance From Flow Meter	19D	17D	15D	13D	11D	9D	7D	5D	3D	1D	FLOW METER	1D	3D	5D	7D	9D
Obstruction Type:																
90° Elbow	0%	0%	<1%	1%	1%	2%	3%	4%	5%	5%		4%	3%	2%	1%	0%
Two Elbows (with 4D between them)	1%	1%	2%	2%	2%	3%	4%	6%	8%	9%		5%	4%	3%	2%	1%
Gate Valve	1%	2%	3%	4%	5%	6%	8%	10%	17%	20%		15%	13%	8%	3%	1%

See Vortab discussions below on how to eliminate effect and improve accuracy.

With Pipe ID ≥ 6 inches [150 mm]

Distance From Flow Meter	19D	17D	15D	13D	11D	9D	7D	5D	3D	1D	FLOW METER	1D	3D	5D	7D	9D
Obstruction Type:																
90° Elbow	0%	0%	0%	0%	0%	<1%	2%	3%	4%	5%		4%	2%	<1%	0%	0%
Two Elbows (with 4D between them)	0%	0%	<1%	2%	2%	2%	4%	5%	6%	8%		4%	3%	<1%	0%	0%
Gate Valve	0%	0%	<1%	2%	3%	4%	6%	8%	15%	20%		15%	5%	<1%	0%	0%

See Vortab discussions below on how to eliminate effect and improve accuracy.

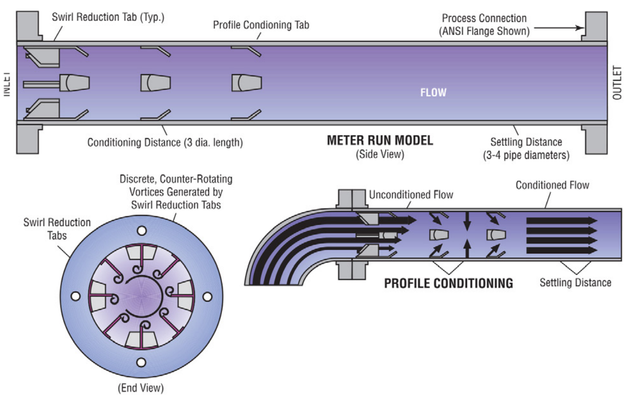
X% : Application not recommended.

Figure 2: Sample of effects on accuracy with flow obstructions before and after installation point of single-point, insertion flow meter

Vortab Flow Conditioners Reduce Straight-Run

In installations with inadequate straight-run, Vortab flow conditioners provide a solution that will ensure flow meter performance in as little as just 7 diameters upstream. This patented technology is the flow conditioner most recommended by flow and process control experts to eliminate the flow swirl and profile distortions which adversely affect flow meter measuring accuracy. Further, because Vortab achieves results with the least pressure drop, it actually saves significantly on energy costs over alternate techniques. FCI is the only authorized supplier of Vortab flow conditioners for use with thermal dispersion technology flow meters. Vortab are available as a spool-piece meter run section, an insertable sleeve and as a field weldable kit to accommodate a variety of installation needs.

Figure 3: Vortab Flow Conditioning Removes Swirl and Creates Uniform Flow Profile



Swirl Reduction Tabs – The swirl reduction tabs remove swirl by generating small vortices (swirls) opposite to the main swirl. These cumulatively cancel the larger main swirl.

Profile Condition Tabs – Three sets of profile conditioning tabs produce vigorous cross-stream mixing which rapidly mixes faster velocity regions with slower regions. This mixing quickly produces a homogeneous (i.e., conditioned) velocity profile. In addition, uneven particulate distributions or temperature profiles are made more uniform through this process.

Settling Distance – 3-4 pipe diameters of settling distance between the flow conditioner and flow meter installation location are required to fully condition the flow stream.

Figure 3: Vortab flow conditioning removes swirl and creates uniform flow profile

Figure 4: Pipe Installation Orientation Options for Insertion Style Flow Meters

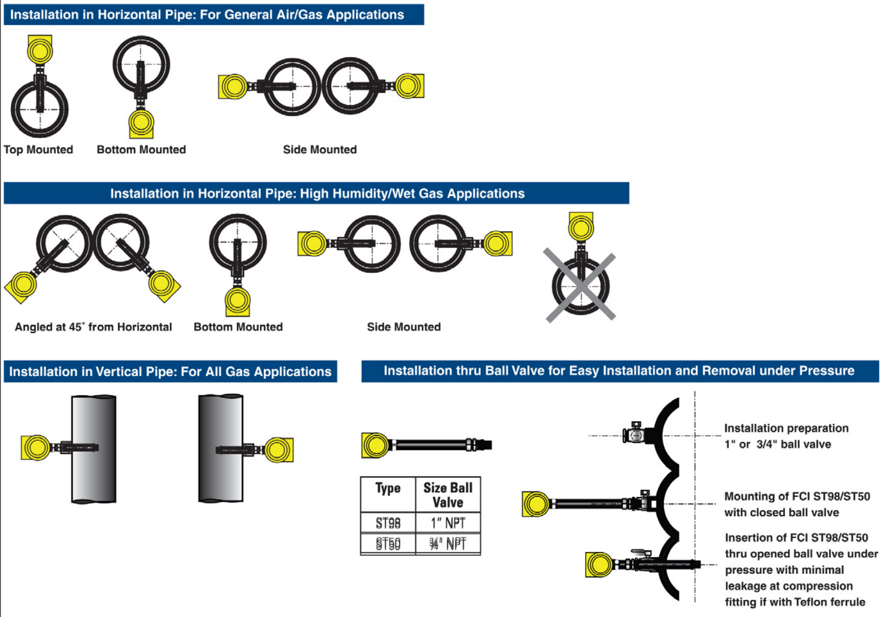


Figure 4: Pipe installation orientation options for insertion style flow meters

8. FCI: The Innovator in Air/Gas Flow Measurement

Fluid Components International (FCI) has met the demanding requirements of industrial process and manufacturing plants for accurate air/gas flow measurement with its patented thermal dispersion flow measurement technologies for over five decades. Based on its long, extensive R&D efforts, rigorous engineering, field experience know-how, quality manufacturing and the world's largest installed base of thermal dispersion instruments, you can count on FCI to know your application and have the proven solutions ready to go. Our goal is to provide the flow data you need while saving time and expense.

From off-the-shelf products to custom engineered products and systems, FCI has the selection and an unequalled record of engineered solutions to supply the optimal flow instrument for your application. We solve measurement problems: from line sizes ¼" to the largest of stacks and ducts, from basic air flow to complex mixed or variable flare gas compositions, from dry gases to wet/dirty gases, along with survivability under the harshest of temperature and pressure conditions. FCI products deliver superior accuracy, repeatability, long-term reliability, superior service life, and safety at the lowest lifecycle cost that represents true value.

R&D Commitment

As a pioneer in thermal dispersion measurement technology, FCI thermal mass flow meters, and thermal flow switches are the industry's most recognized and installed, throughout the world. FCI has developed and is the market leader in constant power technology, has innovated techniques such as equal mass sensor and AST™, an FCI patent pending hybrid thermal flow meter drive technology combining both constant ΔT plus constant power techniques, and is the sole provider of the industry's Vortab® tab-type flow conditioners.

FCI's extensive product lines with a vast selection of both mechanical and electronic options ensure a solution matched to your application requirements. If you need something special, know that FCI loves a challenge and has engineered custom solutions for thousands of customers—so please ask us. Our team of applications and sales engineers has solved thousands of unique flow measurement problems over the years—the chances are we have seen your application before and can provide a cost effective, high performance solution.

Manufacturing, Certifications & Calibration

FCI instrumentation is made in the USA and comes with global industry pedigrees and certifications that meet or exceed the industry norms and the application conditions. FCI is ISO 9001 and AS 9100 certified manufacturer. Our flow measurement products carry hazardous area and industry certifications that include: ATEX, CE Mark, CSA, CRN, CPA, CCoE, FM, FMc, EAC/TR CU, IEC/IECEx, Inmetro, Kazakhstan MPA and NEPSI. Other industry certifications and compliances include: CEMS, Foundation Fieldbus, HAF604 (Nuclear-China), HART, QAL 1, PROFIBUS, NQA-1 (IEEE-Nuclear) and SIL.

Our calibration laboratory operates with 19 different flow stands, all with NIST and ISO/ IEC 17025 traceable equipment. It is unmatched by any other manufacturer of thermal flow meters in offering the safety and certainty of providing actual gas calibrations matched to your specific application versus the typical air equivalency method of calibration.

Where You'll Find Us

You'll see our flow measurement products and technologies hard at work in processes around the globe on nearly every continent wherever people live and are employed in diverse industries. FCI's air/gas flow meters set the standard for performance in a wide range of industries, including: chemicals, electric power generation (conventional, renewable and nuclear), food and beverage, industrial machinery and equipment, oil and gas, marine vessels, metals and materials, pharmaceuticals, pollution control, pulp and paper, solid waste management, and water and wastewater treatment.

The flow data and control that our products provide are more than meets the eye. Beyond simple process measurement needs, our air/gas flow measurement products frequently support plant safety requirements, reduce energy consumption, and assist in assuring clean air and water. We're committed to being a responsible corporate partner that helps protect the planet and operates ethically in all that we do for customers, employees and business partners.

Sales and service support for FCI thermal dispersion products is unequaled. With more than 50 local, sales representative organizations throughout the world and more than 600 sales engineers with extensive factory training and who are armed with custom tools like AVAL, FCI's flow meter sizing and application optimizer, to ensure the best engineered and recommend solutions for your applications.

In additional to headquarters in USA, FCI has subsidiaries in Europe and China which can provide post-sales service assistance, perform depot level service/repair, and can deploy credentialed field service technicians almost anywhere in the world.

Get additional information on FCI's capabilities:

Click here to see video of FCI's capabilities and operations
Click here to get an FCI product line brochure
Click here to see video of FCI's world-class calibration lab
Click here to get FCI calibration lab brochure