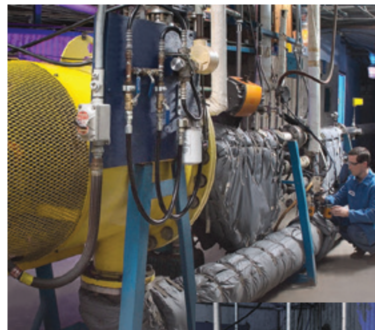
Best Practices: Safety and Certainty With Actual Gas Calibration of Thermal Mass Flow Meters

The Importance of Flow Meter Calibration

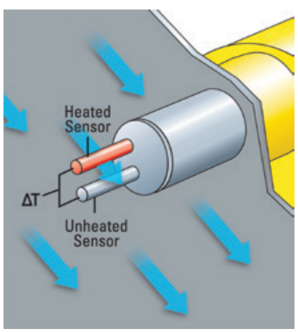
Flow meter calibration should never be taken for granted, and thermal mass flow meters are no exception. Flow meters can be built with the highest safety ratings, features and functions, and the most industrially robust sensor technology, but if the calibration is inaccurate or subject to uncertainty 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. 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 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 1*. 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. 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.

<u>Figure 1</u>

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

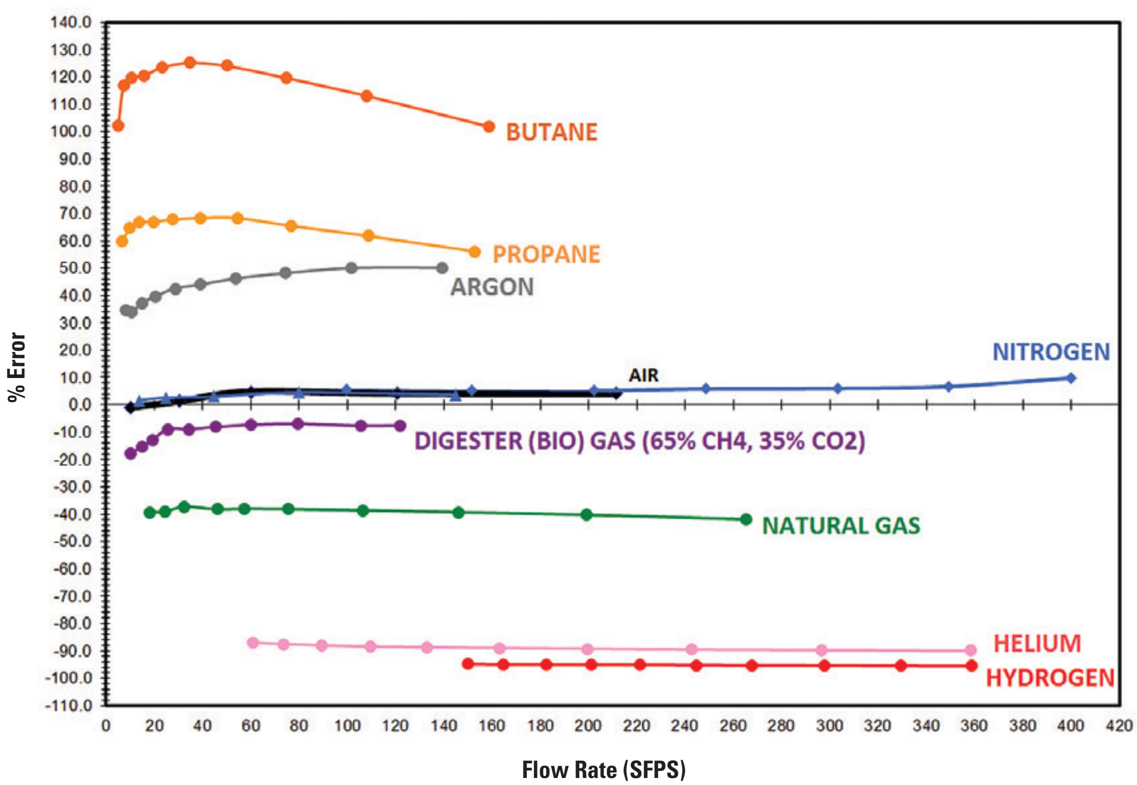
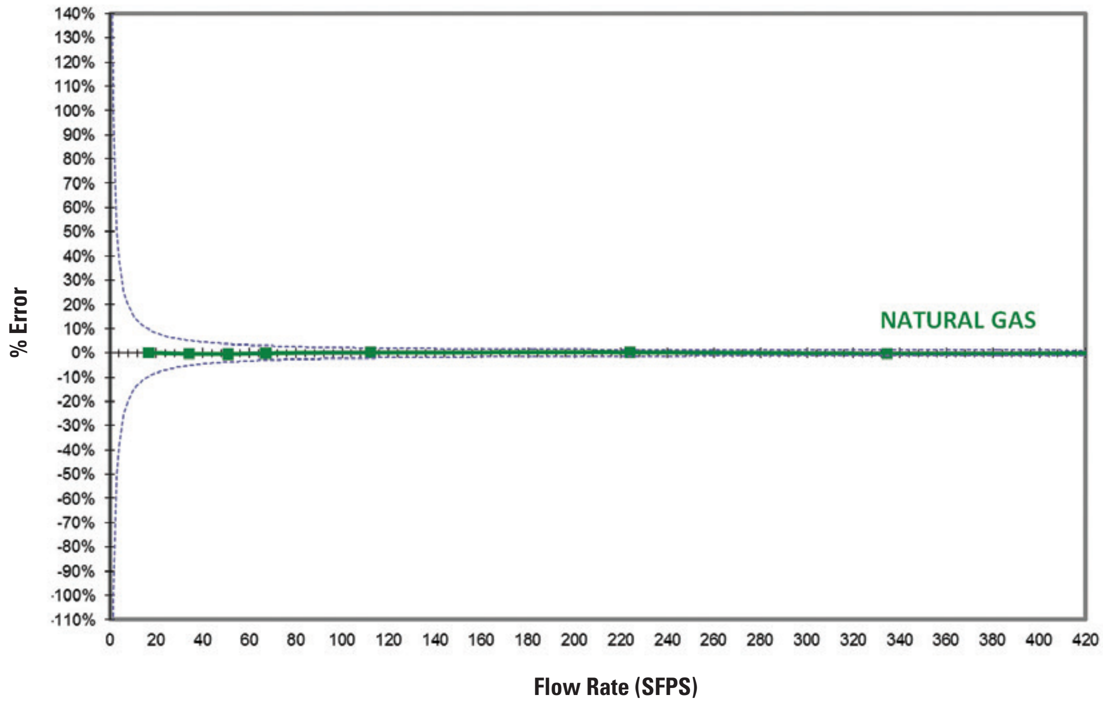


Figure 2

FCI Model ST100 Thermal Mass Flow Meter Accuracy Performance in Natural Gas Using Actual Gas Calibration

4" line size, 4-20 mA 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 2* 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 1*, 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].

FCI Models ST100, ST75V, and ST51

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