CASE STUDY

3 Flow Meter Assessments for Natural Gas Usage:

Case Study on Thermal Flow Meter Calibration for Natural Gas Service

A Study of the Importance of Calibration Affecting Errors in Reading

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FOX™ THERMAL

SUMMARY

Errors associated with the calibration of flow meters for natural gas service can be costly but can also be mitigated using an advanced flow meter design that allows field-adjustment of the natural gas composition without loss of accuracy.

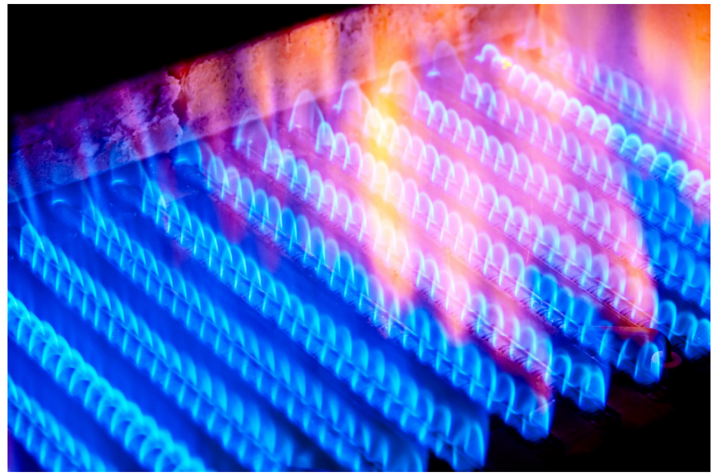
NATURAL GAS COMPOSITION

Even the most experienced instrumentation and process control engineers specify "natural gas" as the fluid in their thermal flow meter specifications. In contrast, only a small handful of specifications include the actual composition of the flowing natural gas. This often leads to the misconception that natural gas composition does not change - regardless of location. Gases such as argon, helium, hydrogen, nitrogen, and oxygen are well-defined pure gases, conversely natural gas does not have a uniform composition.

Natural gas is a product of nature whose composition, density, and heating value vary from location to location (see "Notes on Natural Gas Composition" below). The implications and potential problems associated with flow measurement of natural gas apply to most (if not all) metering technologies, albeit in different ways.

APPLICATION AND FLOW METER SELECTION

Natural gas is colorless and odorless, so natural gas processors and transporters add odorant to the gas so it can be identified downstream by smell. Odorization systems typically require independent measurements of the amount of natural gas odorized and the amount of odorant consumed.



Pipeline sizes in these applications ranging from 1.5 to 8 inches and a preference for installation without shutting down the pipelines suggested applying insertion flow meters. The desire to measure gas flow accurately over a wide range of flow rates without the need for pressure and/or temperature compensation suggested the application of thermal mass flow meter technology. Therefore, insertion thermal mass flow meters were selected to measure natural gas flows in the odorization systems.

In these applications, odorant is added in proportion to the natural gas flow rate. A natural gas flow meter measuring high will over-dose the system and waste odorant. For example, a natural gas flow meter that measures approximately 10 percent high will increase odorant consumption (and operating cost) by approximately 10 percent. In an odorization system that consumes approximately $40,000 USD of odorant per year, locating and correcting an existing flow meter error of this magnitude would reduce operating costs by approximately $4,000 USD per year. Implementing

Notes on Natural Gas Composition

The North American Energy Standards Board (NAESB) suggests composition ranges of various components in natural gas. A typical analysis contains approximately 94.9 percent methane, 2.5 percent ethane, 1.6 percent nitrogen, and 1.0 percent other components (see table).

It is reported that over 10 percent ethane can be present in natural gas obtained from horizontal drilling. In contrast, significant amounts of heavier hydrocarbons may be present in natural gas from other sources. These types of differences in composition can adversely affect flow meter performance.

The table on the next page contains natural gas compositions provided by individual flow meter users at various measurement locations (note the cited regions) and the flow measurement errors resulting from calibrating with the typical NAESB gas composition.

Even within the U.S.A., different natural gas compositions in different locations within the same state can result in flow measurement errors that exceed the measurement error associated with the flow meter.

Chemical Compositions of Natural Gas (in mole percent)								
Gas Components	NAESB Range	NAESB Typical Analysis	USA (TX)	USA (WY)	USA (TX)	Nigeria	Canada	Italy
Methane	87.0 - 96.0	94.9	93.1	92.8	89.3	86.5	85.8	85.6
Ethane	1.8 - 5.1	2.5	3.0	4.2	8.2	7.2	4.8	7.7
Nitrogen	1.3 - 5.6	1.6	0.1	0.2	2.4	0.1	4.6	3.1
Carbon Dioxide	0.1 - 1.0	0.7	2.1	0.8	0.0	0.7	2.2	1.3
Propane	0.1 - 1.5	0.2	0.8	1.2	0.1	3.5	2.3	1.7
Iso-Butane	0.01 - 0.3	0.03	0.2	0.2	0.0	0.8	0.1	0.2
Normal-Butane	0.01 - 0.3	0.03	0.2	0.2	0.0	0.8	0.1	0.2
Oxygen	0.01 - 0.1	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Iso-Pentane	Trace - 0.14	0.01	0.12	0.09	0.00	0.23	0.01	0.12
Normal-Pentane	Trace - 0.14	0.01	0.08	0.06	0.00	0.15	0.01	0.06
Hexanes Plus	Trace - 0.06	0.01	0.24	0.24	0.00	0.11	0.01	0.05
Hydrogen	Trace - 0.02	Trace	0.00	0.00	0.00	0.00	0.00	0.00
% Thermal flow meter error vs. NAESB typical analysis	N/A	0.0	+4.0	+4.5	+6.6	+7.9	+9.8	+10.1

these fixes over tens or hundreds of odorization systems in a sizable natural gas transmission system can yield substantial ongoing operating cost savings.

DISCOVERING THE PROBLEM

Odorization systems are often installed upstream or downstream of custody transfer flow meters, so it was possible in this case for the natural gas transporter to discover that some recently-installed flow meters were not performing properly in various pipelines. Some of the meters reportedly exhibited flow measurement errors in excess of 10 percent. By way of example, natural gas in north, south, and central Italy comes from Russia, Africa, and elsewhere respectively, with each source having different compositions and exhibiting different flow measurement errors.

The existing flow meter settings were examined, and the programmed gas density was discovered to be different from the actual density of the natural gas composition flowing in the pipe. Initial investigation revealed that the composition was set to a default natural gas composition similar to the typical NAESB analysis (see "Notes on Natural Gas Composition" feature on page 2). However, the flowing natural gas contained significant amounts of heavier hydrocarbon components, so its actual composition was materially different than the default assumption of NAESB natural gas settings.

Further investigation at the factory confirmed the composition of the gas used to calibrate the flow meters was not representative of the actual flowing natural gas. This

Fox Thermal model FT4A thermal mass flow meter and temperature transmitter.

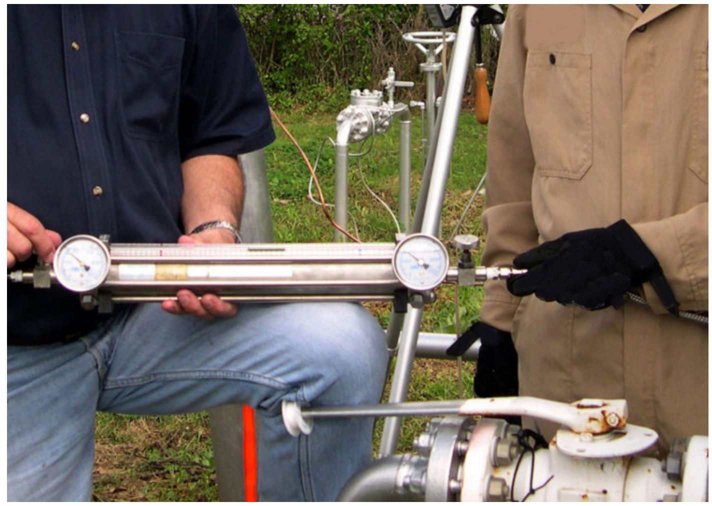
mismatch needed to be addressed, but the gas transporter also expressed a desire to set the gas composition in the field to reflect the actual gas composition based on region, all without sending the flow meter back to the factory for calibration. The user wanted to fix the identified problem, then later be able to periodically update for natural gas composition changes likely to occur over time.

NATURAL GAS CALIBRATION — THE DIRTY LITTLE SECRET

Thermal flow meter calibration for natural gas service is typically performed with (1) a surrogate gas mixture representative of natural gas like the NAESB's typical composition, or (2) with a well-defined pure gas using correlations to correct for the thermal properties of natural gas relative to the well-defined gas. Using a surrogate gas representative of the flowing natural gas is generally considered more accurate than using correlations, but the effectiveness of technological advancements in the latter technique are challenging this presumption.

Flow meter manufacturers can calibrate their natural gas flow meters using their own factory-standard natural gas surrogate. Calibrating with a surrogate representative of a typical NAESB analysis would seem appropriate, but some flow meter manufacturers reportedly calibrate or have calibrated their flow meters using surrogates containing 95 to 100 percent methane plus small percentages of ethane and/or nitrogen.

Note that each flow meter manufacturer can have its own



Sampling natural gas from the source is the best way to determine the gas composition.

factory-standard surrogate natural gas mixture. Therefore, calibrations of the same flow meter performed by different manufacturers using their different surrogate gases will measure differently in operation, where the measurement variation depends on differences in the thermal properties of the different surrogate gases. For example, the flow measurement error associated with calibrating in pure methane versus calibrating in the typical NAESB natural gas mixture is approximately 3 (three) percent — an amount that can be larger than the performance specification of the flow meter if left uncorrected.

Notwithstanding that calibrations of the same flow meter specified for the same fluid service (natural gas) will be different when performed using different surrogate gases, calibrating using a surrogate gas with thermal properties sufficiently similar to those of the actual flowing gas should not pose a significant measurement problem. However, an overwhelming majority of users have never considered nor confirmed whether the composition of their actual natural gas reasonably approximates the surrogate gas used for calibration. Without knowing, they could be experiencing significant flow measurement errors on a continuing basis.

Actual natural gas analyses can be obtained from natural gas suppliers. With that information, the flow meter manufacturer can confirm whether the calibration gas and the user's natural gas are reasonably similar. Better yet, users should include their actual natural gas analyses in flow meter specifications when purchasing, allowing their flow meters to be factory-calibrated using an appropriate surrogate mixture. Even if the factory's surrogate gas cannot be changed, the calibration can be corrected to account for a different mixture in the application.

The Importance of NIST Calibrations

Meet NIST-traceable Flow Standards
Calibrations performed on flow meters must meet MIL-STD-45662A requirements.

Ensure Reliable Flow Meter Performance
Calibration equipment subject to a meticulous metrology program that includes the selection, usage, calibration, control, and maintenance of measurement standards.

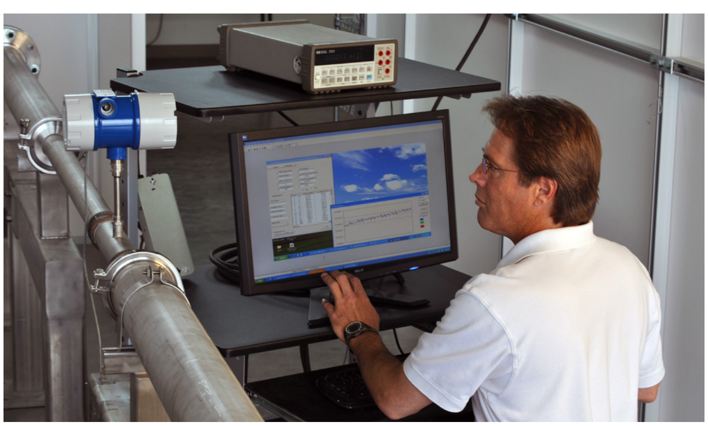
Automated Calibration Procedures
Automated systems in calibration flow labs maximize calibration accuracy and repeatability as well as output and efficiency. Results are consistent and calculating measurement uncertainty simplified.

Gas-SelectX® Feature				
FT1 Gas-SelectX® Menus		FT4A & FT4X Gas-SelectX® Menus		
Pure Gas	Gas Mixture	Pure Gas	Gas Mixture	Oil & Gas
Air		Air	Air	Methane (C1)
Argon		Argon	Argon	Ethane (C2)
Butane		Butane	Butane	Propane (C3)
Carbon Dioxide		Carbon Dioxide	Carbon Dioxide	Iso-Butane (C4)
Ethane		Helium	Ethane	Normal-Butane (C4)
Helium	Mixture of any 5 gases in first column. Mixture must total 100%	Hydrogen	Helium	Pentanes (C5)
Hydrogen		Methane	Hydrogen	Hexanes (C6)
Methane		Natural Gas*	Methane	Heptanes (C7)
Natural Gas*		Nitrogen	Nitrogen	Octanes (C8)
Nitrogen		Oxygen	Oxygen	Nonanes+ (C9+)
Oxygen		Propane	Propane	Carbon Dioxide
Propane				Nitrogen

*Choosing Natural Gas sets the NAESB average in a pre-programmed mix of methane, ethane, propane, nitrogen, and carbon dioxide. This composition can be changed by the user in the field with no loss of accuracy.

The "dirty little secret" of natural gas flow measurement is that failure to calibrate with a gas sufficiently similar to the gas encountered in the field can result in significant and sometimes large undetected flow measurement errors, and those errors will more than likely be present during the entire life of the flow meter.

An alternative technique to calibrate a flow meter for natural gas service is to calibrate using a well-defined gas and then use mathematic correlations to accurately correct the measurements in natural gas. One advantage of this technique is that problems associated with the "dirty little secret" are mitigated because the actual natural gas composition can be entered directly into the electronics, completely eliminating the need to use surrogate gas mixtures. Further, the thermal flow meter itself can automatically update the density calculation of the natural gas and its thermal content to reflect the new composition.



Calibration Technician performing an actual gas calibration in the flow laboratory.

This alternative technique offers the user, representative, and manufacturer more flexibility. The actual natural gas composition can be obtained, entered, and changed both after installation and during operation, without loss of accuracy and without returning the flow meter to the factory for calibration. Similarly, these flow meters have the flexibility to adapt to completely different applications by entering the composition for a new process, again without loss of accuracy and without returning the flow meter to the factory for calibration.

SOLUTION

As previously mentioned, the existing flow meters were configured for a natural gas composition similar to the NAESB's typical analysis and calibrated using the factory-standard surrogate natural gas. The composition of the actual natural gas was significantly different than surrogate, varying by site and likely to change over time. The transporter wanted the capability to configure the actual composition of its natural gas in the field without returning the flow meters to the factory for calibration, all without loss of accuracy. This information was relayed to the thermal flow meter manufacturer's representative who informed the flow meter manufacturer.

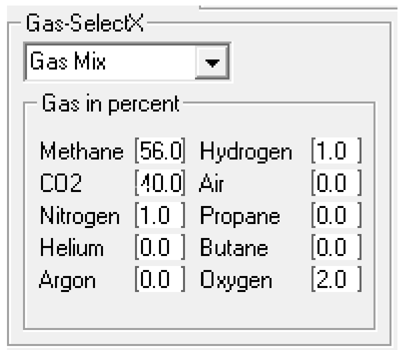
The manufacturer used the actual natural gas compositions to perform calculations that confirmed the flow measurement errors were similar to those experienced by

the transporter. The traditional approach to resolve this problem would be to return the flow meters to the factory for recalibration with various surrogate gases representative of the various natural gas streams. This was not acceptable to the transporter in the short term and would have made compensating for future composition cumbersome in the long term.

Fortunately, the existing flow meters were factory-calibrated in a well-defined gas, to which correlations were used to measure natural gas using the alternative method previously described. Using this technology, each component in the natural gas could be configured in 0.1-percent increments in the field to measure the flowing natural gas with no loss of accuracy.

The existing flow meters could have been used if the actual

natural gas largely contained components present in the typical NAESB analysis, albeit in different proportions. However, the actual flowing natural gas contained significant quantities of numerous heavier components, and the transporter wanted the flexibility to set those heavier components directly in the field, both for simplicity and to achieve the best accuracy. Therefore, the existing flow meters were upgraded to a model that not only allowed more components, but also included additional gases relevant to the gas industry that were determined to be present in the actual flowing natural gas.



Gas-SelectX® allows the user to choose gases in 0.1% increments to create a custom gas mix.

3 ASSESSMENTS AND OPERATION CONSIDERATIONS

In general, both new and existing natural gas flow meter installations can be affected by this "dirty little secret" and can cause measurements to be inaccurate for decades. Such operation can be costly over the life of the flow meter in applications such as odorization. One problem for most users is that they need to trust their natural gas flow meters because they do not have reasonable means to verify their flow measurements are accurate. This transporter was the exception because custody transfer flow meters were available to check accuracy.

Nonetheless, there are actions that the typical user (without the ability to verify accuracy) can take to assess the performance of flow meters and to ensure accurate natural gas flow measurement.

ASSESSMENT #1

For existing flow meters calibrated with a surrogate gas at the factory, users should compare the actual flowing natural gas composition (typically available from the utility) with the gas mixture used to calibrate the flow meter at the factory. The manufacturer can then estimate the measurement error and offer suggestions to correct for the actual flowing composition. Sometimes, flow meter settings can be modified to compensate for the estimated error, but factory calibration using a more representative surrogate gas mixture may be needed for more accurate measurement.

Repeat periodically to determine if the actual natural gas composition has changed sufficiently to warrant modifying the correction and/or recalibrating the flow meter at the factory.

ASSESSMENT #2

For existing flow meters calibrated with a well-defined gas at the factory, users should configure the actual flowing natural gas composition (typically available from the utility) in the flow meter.

Repeat periodically to determine if the actual natural gas composition has changed sufficiently to warrant updating the flow meter composition configuration in the field.

ASSESSMENT #3

For new installations, users should include their natural gas analysis in their specifications and strongly consider purchasing flow meters that are calibrated with a well-defined gas in the factory, allowing the actual flowing natural gas composition to be set in the field, with no loss of accuracy, to mitigate the effects of the "dirty little secret" altogether.

CONCLUSION

Huge financial losses can occur in some applications when natural gas flow meters are not measuring flow accurately. Conversely, large cost savings can be realized when the performance of existing flow meters is scrutinized and corrected.

The initial choice of a natural gas flow meter is a critical moment. Ask the flow meter manufacturer about their strategies for mitigating the effects of gas composition changes in natural gas flow before making a purchasing decision.

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