Method for Assessing the Impact of Calibration Gas Uncertainty on Fiscal Risk During Energy Billing

A crucial component of fiscal energy measurement is the determination of physical properties from the measurement of natural gas composition using a gas chromatograph (GC). One of the main driving forces behind accurate physical property determination is the selection of a well-designed, high-quality calibration gas with low uncertainty levels. However, the critical importance of high-quality calibration gases with assigned low uncertainties to ensure the highest level of confidence in total metered energy, is not well-understood, and so, often overlooked. Choosing calibration gases with very low uncertainties will minimise financial risk during custody transfer. The gas industry offers a wide variety of calibration gases with defined uncertainty levels that typically range from 0.1 – 5%.

EffecTech has developed a method which can be used to demonstrate the impact of different quality calibration gases on financial risk, focussing on a hypothetical natural gas export meter transferring gas from an LNG terminal to a national transmission system (NTS). The approach adopted here can be applied to any high-pressure metering system being used for custody transfer.

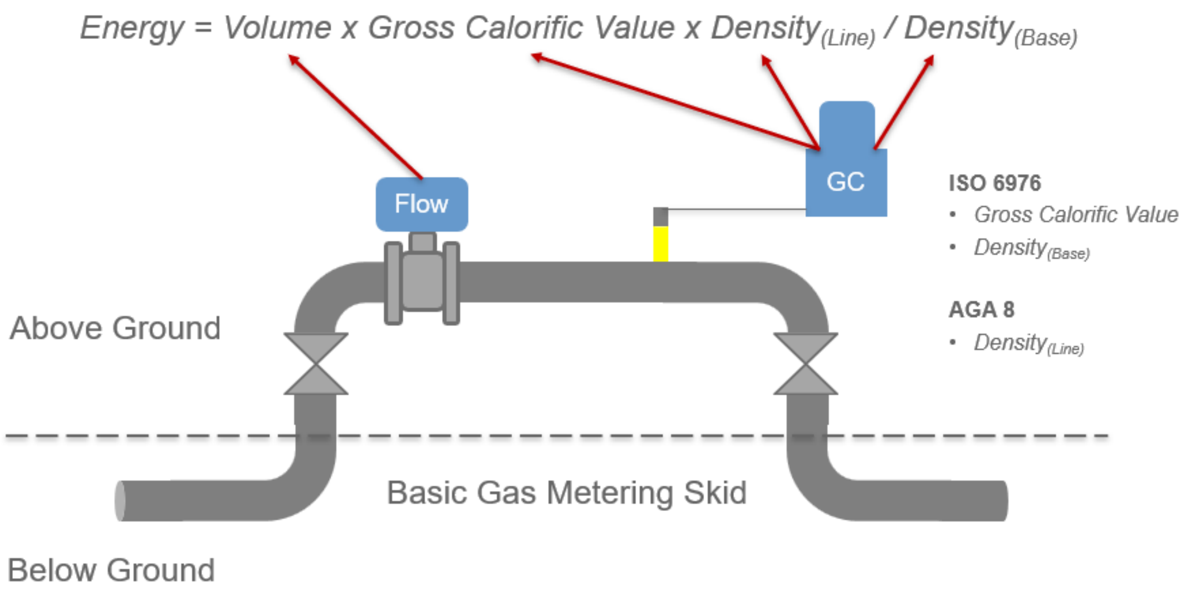

Figure 1 – Energy Calculation

The measurement of gas quality and volume are prerequisites for determining total metered energy. Figure 1 shows a fiscal metering system consisting of a flow element and a natural gas chromatograph (GC). Combining the measurements from both the flow and composition elements results in a total energy output described by the equation in Figure 1.

Gross Calorific Value (GCV), Base Density (at standard conditions as defined in ISO 6976) and Line Density (the density at line conditions calculated by the AGA 8 method) are all determined from gas composition, illustrating the importance of an accurate and reliable measurement from the GC.

In the EffecTech method we have developed an offline model for a typical GC operating on the UK NTS. The offline model can then be used to simulate how the GC would respond to a whole range of different gas compositions This typical GC is operating in Type 2 mode (single point calibration) and meets the acceptable criteria for maximum permissible error (MPE) and maximum permissible bias (MPB) on Gross Calorific Value of 0.1 MJ/m^3 and 0.02 MJ/m^3 respectively. This means that the typical GC is operating normally, within the parameters defined by the NTS, and can be expected to provide reliable and accurate gas measurements.

The industry standard for assessing the performance of a GC to check if it is operating within its parameters is an ISO 10723 performance evaluation. This evaluation models the relationship between what the instrument thinks is correct and what is truly correct, allowing the errors in mismeasurement due to non-linearity, to be assessed.

The EffecTech offline model follows the ISO 10723 methodology by running a set of 7 reference gases with known composition through the GC to evaluate the non-linearity of the GC response to the measurement of each component for each reference gas. Following the method outlined in ISO 6143, polynomial equations up to 3rd order are developed to more accurately describe the response required from the GC to reflect the true composition of each reference gas. In practice the results from an actual ISO 10723 performance evaluation of a real GC have used to develop the EffecTech method.

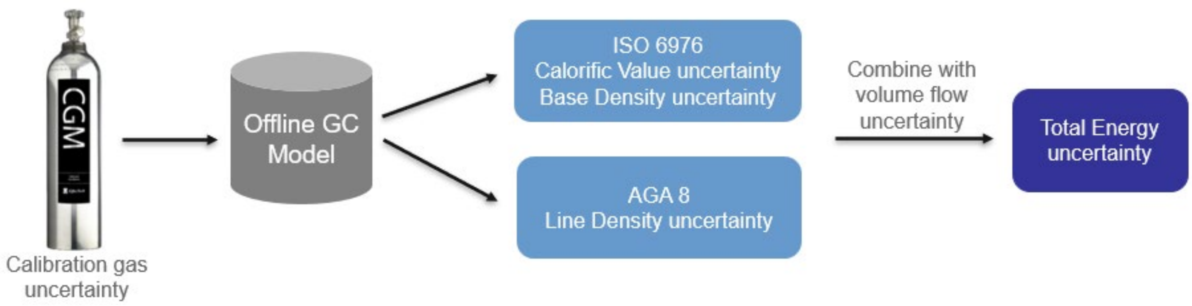

Figure 2 - Modelling Calibration Gas Uncertainty Propagation

Once the offline GC model has been developed it is then possible to propagate a calibration gas uncertainty through to total energy uncertainty, as shown in Figure 2. To demonstrate the impact of calibration gas uncertainty, it is the only parameter that we change. Simulation range, calibration gas composition and flow uncertainty remain constant.

The EffecTech method then uses in-house bespoke software utilising a Monte Carlo simulation to generate 10,000 real calibration gas compositions to model the various compositions the GC might be expected to measure. Parameters are set in the software to ensure that the calibration gas compositions generated reflect real natural gas compositions. For each calibration gas composition, the uncertainty is derived based upon an EffecTech ISO 17025 Calibrated Gas Mixture with uncertainties based on our schedule of accreditation, and a typical industry Gas Mixture (GM), with an expanded uncertainty of 2%. Table 1 illustrates the simulation range for each natural gas component and shows the relative expanded uncertainty for a single calibration gas compositions for an EffecTech CGM and the industry GM.

Simulation ranges			***Calibration gas composition***		
	amount fraction (%mol/mol)			***relative expanded uncertainty***	
component	***min***	***max***	***amount fraction (%mol/mol)***	***CGM***	***GM***
nitrogen	0	10.0000	4.4940	0.26%	2.00%
carbon dioxide	0	7.0000	3.3135	0.18%	2.00%
methane	78	100.000	80.378	0.04%	2.00%
ethane	0	12.0000	7.0430	0.25%	2.00%
propane	0	7.0000	3.3290	0.30%	2.00%
iso-butane	0	1.00000	0.49990	0.30%	2.00%
n-butane	0	1.00000	0.50160	0.30%	2.00%
neo-pentane	0	0.15000	0.10957	0.82%	2.00%
iso-pentane	0	0.35000	0.11031	0.63%	2.00%
n-pentane	0	0.35000	0.10964	0.55%	2.00%
n-hexane	0	0.35000	0.11060	1.08%	2.00%

Table 1 – Simulation Range and Calibration Gas Composition

For each of the 10,000 simulated calibration gases, GCV and Base Density are then calculated along with their associated uncertainties using the methods described in ISO 6976. Calculating of Line Density is more complicated, so here we use the industry recognised AGA 8 method. This approach requires a Monte Carlo simulation, where for each of the 10,000 simulated calibration gases an additional 10,000 sub-compositions are generated. This allows the Line Density and uncertainty to be estimated from the standard deviation of the entire population of AGA 8 values.

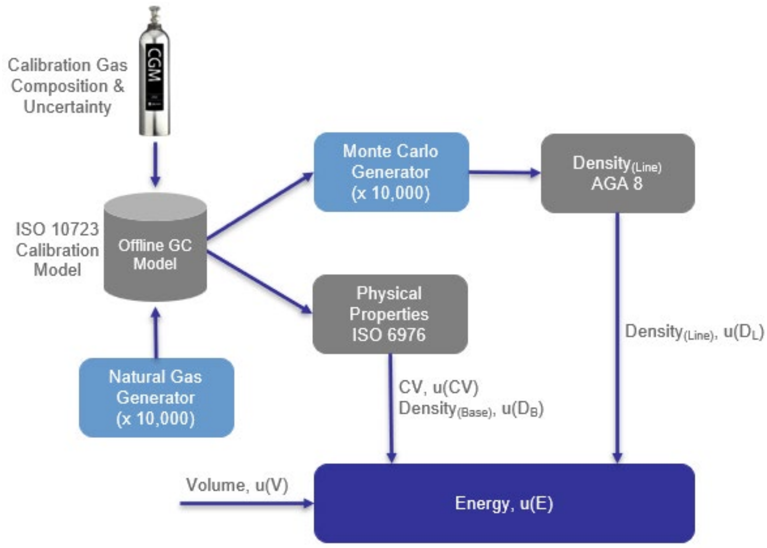

Figure 3 – EffecTech Model of the Evaluation of Energy Uncertainty

Figure 3 provides an illustration of the complete EffecTech model for estimating the uncertainty in Energy measurement from calibration gases with different expanded uncertainty, which is this case are an EffecTech CGM and an industry GM with an expanded uncertainty of 2%.

For the flow element of the model, we have assumed a value of 30 Million m^3/day, which would be a typical value for a medium sized LNG terminal exporting gas into a NTS. The approach adopted here can be applied to any high-pressure metering system being used for custody transfer. We have assumed a flow meter measurement uncertainty of 0.2% (k=2).

The final output from the EffecTech model is to plot the GCV for each of the 10,000 calibration gas compositions against the associated daily billing risk for both the CGM and the GM. Figure 4 shows this information plotted in the form of performance envelope for EffecTech CGMs and industry GMs. Taking a gas with a GCV of 38 MJ/m, the industry GM could represent a maximum financial risk of over / under billing in the region of $7,500 per day, whereas using an EffecTech CGM this drops to $3,000 per day. However, for the EffecTech CGM, the billing uncertainty is dominated by the flow meter uncertainty (0.2%). If we remove this flow meter uncertainty and assume 0%, we see the billing uncertainty for the EffecTech CGM dropping to circa $1,700, see Figure 5.

This clearly shows the financial benefit of purchasing a well-designed, high quality, low uncertainty CGM.

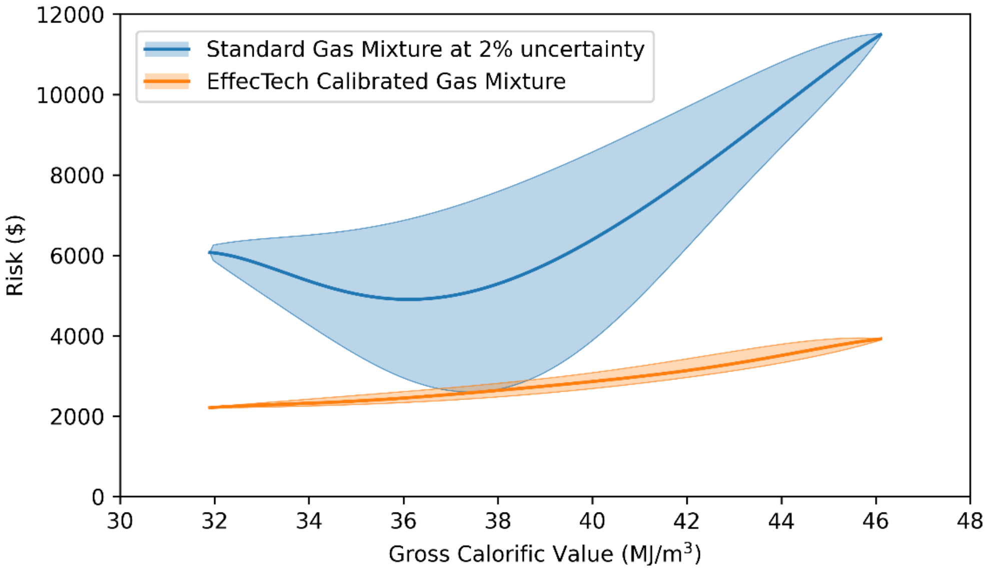

Figure 4 – Performance Envelope for EffecTech CGM and Industry GM

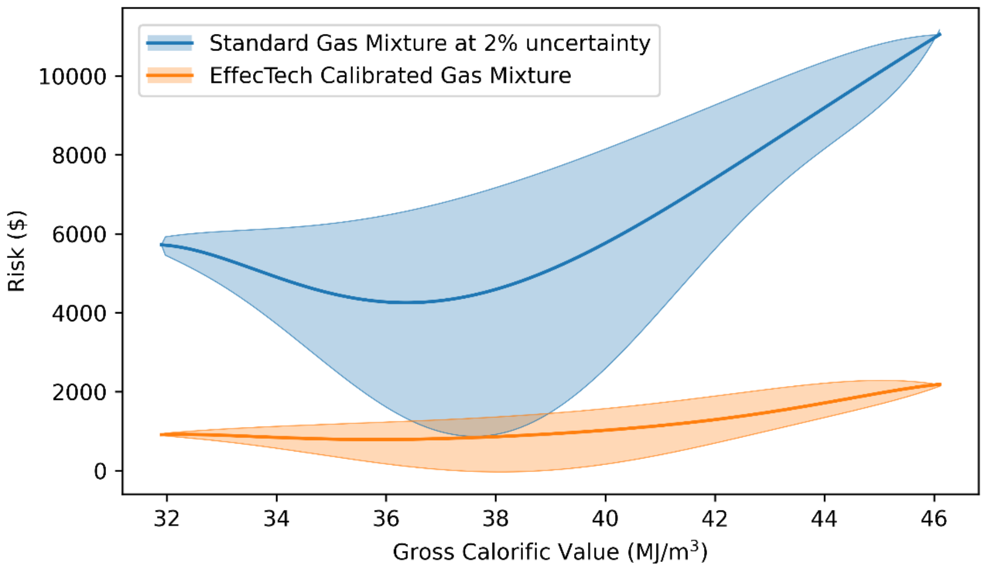

Figure 5 – Billing Uncertainty with Flow Meter Uncertainty Removed

Conclusions

The EffecTech method clearly demonstrates the benefits of using a well-designed, high quality calibration gas, with low uncertainty levels to minimise the billing risk during custody transfer. Whilst the purchase price of a typical industry gas mixture may be lower than an EffecTech CGM, this saving is quickly outweighed when compared to the daily billing risk from using a poorer quality calibration gas.

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