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Reducing Measurement Uncertainty in Process Gas Quality Measurements
Class # 5330.1

Charles Cook
Vice President
Mustang Sampling LLC, Houston, TX

Ken Parrott
President
K2Controls, Inc. .Houston, TX

Uncertainty is an ever-present and universal flaw in observation. Any statement of measurement uncertainty should be free of subjective terms and should not require interpretation but rather it should only require understanding. This paper will not be able to state a quantification of uncertainty but rather it will offer suggestions to aid users in avoiding uncertainty.

Natural gas is billed for its economic equivalent to its flowing energy.
See formula below:
*MMBTU = Q'*BTU/Ft3*
Where:
MMBTU = Flowing energy value
MM=1,000,000
Q'= Flow Rate
BTU = British Thermal Unit
FT3 = Cubic Ft. as a quantity of gas volume

In addition, flow measurement is corrected by AGA 8 using measured component data. Liquids measurements are more often stated by mass. But the relationship of flow with any other property reflects the same equivalence. In the formula the MMBTU is made up of the multiplication of two terms. Each term is just as important in resultant quantitative outcome as the other. Thus users are advised arithmetically to pay as much attention to gas quality during the design phase as to flow measurement design. But many, if not most designs fail to meet all factors necessary to reduce uncertainty even to acceptable terms.

Note to users: Safety must be the premier concern in the selection, installation and operation of measurement equipment. During this discussion the reader and writers may disagree on safety practices. This paper is not meant to suggest to anyone that their own company standards, practices or common sense should not be used.
The writers wish to thank those serving on API and GPA who have poured time and effort into the reduction of uncertainty in gas measurement and in their ability to offer concise recommendations on flow measurement and also analysis methods including sampling. In addition to engineering staff, it is important for technicians to learn about sampling so field technicians can recognize ways to routinely reduce uncertainty.

The following lists some facts and choices for reducing uncertainty among the following topics; Spot sampling, Composite sampling, and On-Line analysis. All three methods are similar but the improved results will be seen for any one method over another.

Spot Sampling
Spot sampling of natural gas involves taking a sample cylinder to a specific point on the pipeline and drawing a representative sample at one point in time.

It is important to recognize that the spot sample is representative only of the natural gas flowing at the sample point at the specific moment of time the sample is taken, and cannot account for changes in gas quality that might occur. While the very nature of spot sampling produces uncertainty if the sample is applied to a larger volume of gas or sample period, spot sampling is necessary in several instances.

1. Where flowrates are low and the cost of a composite sampler or online analyzer cannot be justified.
2. Where an estimate of typical gas quality information is required (well test).
3. To confirm gas quality at a certain point in time. (validation of online analysis).

Note: Some users make use of monthly mobile laboratory analysis. Their efforts to reduce uncertainty must include the following:

1. Choice of a regulator and probe that will maintain the phase of a sample.
2. Heated tubing is required for most all situations.
3. Proper purging of the sample system on the mobile analyzer.

Because spot sampling is necessary for these and perhaps other reasons, it is important to note ways to reduce error by implementing best practices. It is important to refer to current industry standards such as GPA 2166 "Obtaining Gas Samples for Analysis by Gas Chromatography". Procedures are included in this standard that provides various methods for spot sampling natural gas. Among these procedures are commonly used methods such as Fill and Empty, and Helium Pop which are both effective in spot sampling natural gas. In either method it is important to address the following issues:

1. Insure the presence of a sample probe, which is inserted into the pipeline sufficiently to avoid free liquids which may be present along the pipe wall. These liquids if introduced into the sample will invalidate the sample.
2. Use a sample apparatus that will allow for elimination of any aerosols that may be in the flowing stream. Even with a sample probe there could be liquids that are in aerosol form that could gain entry into the sample system. It is important to select a sample point that is not near items which can cause aerosols such as bends in pipe, or valves. In the event aerosols might be present, consideration of a *phase separation membrane* that is incorporated into the spot sampling apparatus. Other means to separate liquid from gas may be employed but many home made devices employ techniques that add excessive volume that must be purged and heated to avoid sample distortion.
3. If using the "Fill and Empty" method of spot sampling the sample cylinder will be filled to pipeline pressure and emptied to a pressure slightly above atmosphere numerous times depending on line pressure. It is important to use a length of tubing commonly referred to as a "pig tail" to move the valve controlling the emptying of the cylinder a sufficient distance from the sample cylinder so that any liquids condensed by the Joule-Thompson cooling effect caused by the differential pressure across the valve will not contaminate the volume in the sample cylinder.
4. As with all methods of determining gas quality, hydrocarbon dew point is critical to the accuracy of the sample. Spot sampling typically involves a reduction of pressure as the natural gas fills the spot sample cylinder. By adding sufficient heat the sample should not reach its hydrocarbon dew point. Adding temperature to the sampling system can be done with a cylinder type heater where the sample cylinder is enclosed in a capsule which has been previously heated.

Composite Sampling

Composite sampling is the process of mechanically removing a small volume of natural gas from the pipeline, during a specified sample period and depositing into a sample cylinder. Like Spot Sampling it is important to be familiar with the current industry standard API - Chapter 14.1 of the Manual of Petroleum Measurement Standards, "Collecting and Handling of Natural Gas Samples for Custody Transfer". Included in this standard are methods which will decrease the uncertainty associated with the composite sample such as:

1. The standard covers only the sampling of natural gas and not two phase fluids. Therefore, as with all sampling application, insure the presence of a sample probe which is inserted into the pipeline sufficiently to avoid free liquids which may be present along the pipe wall. These liquids if introduced into the sample will invalidate the sample.
2. Choosing the correct sample point where free liquids and aerosols will be inhibited. It is important to note that in some applications liquids or aerosols can be present and a method of separating these from the gas phase should be applied. One method is to use a sample probe that includes a *phase separation membrane*.
3. The sampling system should be located as near to the pipeline (preferably on the pipeline) so that the sample point is as close as possible to the sample point.
4. The sample should always be taken in a flow proportional mode, meaning that the sample frequency should cease when there is no flow in the pipeline and increase in direct relationship with the flowrate. This will require a flow signal to be connected from the flow measurement device to the natural gas sampler controller.
5. Again, as with all sampling systems, hydrocarbon dew point is the important issue. [How about this: Sufficient temperature must be present to prevent condensation that will distort the sample: as opposed

to the following?.] Temperature should be placed on the system including the sample cylinder so that the sample does not reach its hydrocarbon dew point.
6. Because the sample cylinder will be removed and replaced at the end of the sample period, properly purging the sample system, including the cylinder, when the sample cylinder is changed is critical. When using the Fill and Empty Method, the use of a pigtail is required (API 14.1).

On-Line Analyzer Sample System

1. Become acquainted with API 14.1 and its guidelines. It is a document originated for the purpose.
2. Location of the sample extraction point. Proper meter tube design provides thread o' lets
3. Location of analyzer building or enclosure should be as close as possible to sample point.
4. Sample point – a means to extract the sample without changing its phase from gas to liquid or liquid to gas before analysis.
5. Tubing must be sized and heated to meet sample lag requirements. The extracted sample must not change phase. Sample compatibility and metallurgy must be evaluated to provide a non-reactive means to transport.
6. Sample route to analyzer must be planned and built with good craftsmanship. Dips and dead volumes must be avoided.
7. A means to regulate the sample for on-line analysis as stated by analyzer manufacturer.
8. An oven or enclosure that maintains heat to ensure sample phase control.
9. A sample return or safe exit-vent for analyzed sample and/or analyzed sample.

Gas Chromatograph installation considerations
1. A building, shelter or enclosure may be required to meet manufacturer, operation specifications.
2. Not all GC sample systems are equipped to maintain sample phase.
3. GC shelter or enclosure may be heated.
4. Gas Chromatograph must be specified for an analytical cycle time sufficiently fast to match gas flowing velocity in measurement.

Calibration gasses and Carrier Gasses
1. Calibration gas may require heat to prevent condensation and permanent distortion of certified contents when flow is allowed during interims of condensation.
2. Manufacturers specify the term of certification. Historic cylinder comparisons to resulting calibration response factors are advisable.
3. Transportation of calibration gasses to analyzer may need to be heated unless other design conditions may allow.

Gas Quality Analyzers
In addition to attaining a heating value measurement stations often need analyzers to provide gas quality measurements such as moisture, H2S, CO2 and Hydrocarbon Dew Point.

1. It may be advisable to mount GQ analyzers as close to the sample point as possible.
2. For moisture analyzers the tubing most often requires heat tracing. The Accurate LASER Detectors now in wide use to measure moisture, H2S and CO2 require large volumes of sample. Such high volumes of flow mean prolonged exposure of the sample to Stainless Steel tubing. Without heat tracing, moisture will absorb into the walls of the tubing and perhaps the laser cells constructed of stainless steel resulting in distortions and false readings. Note: it is not advisable to had heat trace to laser cells but rather use a heated enclosure.
3. H2S can react with moisture so in unheated tubing distortions are likely. Coatings of tubing are in common use to prevent wall-absorbance and unwanted reactions.

Selection of Sample Regulators

Regulators are a most common source of sample distortion. Gas gains heat when compressed and loses heat when expanded. In addition liquid can contain dissolved gasses and if pressure is high it liquid increases in density. If temperature decreases density also decreases resulting in entrained gas bubbles that represent distortion. Calculation software is available to the user to allow the understanding of sample phase behavior. Too often users fall back on legacy standards and practices as opposed to use of modern tools to design process or pipeline sample systems.

Types of Sample regulators

1. Single stage; stainless steel – for use with a sample probe. The seat of the regulator - where the pressure reduction is made – is exposed to ambient temperature unless heated.
2. Single stage insertion, stainless steel – no sample probe is required. The pressure cut is made within a pipeline or vessel.
3. Single stage heated; stainless steel - for use with a sample probe. The seat of the regulator is in proximity to a 'cartridge-shaped" heater so heat-loss is negated by voltage.
4. Multi-stage regulators – Newer method where fixed seats gradually lower the temperature in each chamber of up to three chambers while a final adjustable seat can be adjusted to meet analyzer manufacture specifications without heat.
5. Multi-stage regulators can be heated if pressure becomes to high for unheated multi-stage design.
6. Portable regulators are available for spot sampling or analysis. They are available in heated or un-heated designs. They are equipped with safety features designed to allow insertion regulators to be both installed through valve assemblies while pressurized and removed for maintenance.

Conclusion

Uncertainty may exist in places that have not been discussed here. But proper analysis can never be possible unless proper sample design is in place that will prevent condensation in gas and entrained bubbles in liquid. Attending special classes like ISHM and other short courses as well as NGSTech, a bi-annual event to acquaint people with the latest sampling devices and data is a sure way to reduce uncertainty.