

TECHNIQUES OF NATURAL GAS SAMPLING AND COMPOSITE SAMPLING SYSTEMS

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Introduction

In today's up and down, sometimes struggling but always competitive market, a producer of natural gas must strive to maximize their market value and achieve the highest return of invested income. The fluctuations seen recently in pricing make this an increasingly important goal. In order to accomplish this goal they must ensure they are receiving full value for the natural gas products they produce. In addition to the producer, it is extremely important for the other stakeholders, whether they be government, gathering system operator, processor, or transporter to do their due diligence to ensure they are also receiving or properly accounting for the true and full value of the natural gas products that pass through their systems. Royalty rates, transportation levies and processing fees are based on the value of the natural gas being commercially bought and sold, processed or transported.

Sampling and analysis when properly implemented can ensure that everyone's needs and product expectations are met.

This paper will discuss issues that must be considered to obtain a good representative gas sample through continuous composite sampling.

Why Natural Gas Sampling...

There are many reasons why natural gas sampling is and should be undertaken. Wells may be owned by different companies and may flow into a common gathering system. There may be lean wells as well as rich wells, sweet wells, or sour wells. The gathering system may then transport the combined flows to a common gas plant for processing. The challenge for the production accountant is to ensure that every stakeholder will be compensated correctly based on the volume and quality of the gas that they produced.

Gas allocation is made up of two components; the volume of natural gas and the compositional make up of the gas or heating value (BTU) of the gas. Analysis may also be done to determine any recoverable liquids and to identify potential contaminants in the gas stream. The key to successful allocation can only be accomplished through the precise measurement of these values and that measurement depends on the ability to accurately determine and analyze the gas composition.

Raw natural gas is composed of many different components. These components typically include methane, nitrogen, carbon dioxide, hydrogen sulfide, as well as a variety of different hydrocarbons and inert compounds. Some of these components such as nitrogen and carbon dioxide have no commercial heating value while the hydrocarbon components not only have heating value but will have different heating values depending on their molecular structure. So again, the total heating value determination of a natural gas stream is dependent on the accurate compositional analysis of the stream.

Industry Standards

There are several well known industry standards related to natural gas sampling that detail the potential causes of sample distortion and recommend proper sampling equipment and sampling techniques to avoid these issues. The findings and recommendations of these standards are based on years of hands on experience and exhaustive field testing. The two most referenced for gas sampling standards are:

*American Petroleum Institute (API)
Manual of Petroleum Measurement Standards
Chapter 14 – Natural Gas Fluids Measurement
Section 1- Collecting and Handling of Natural
Gas Samples for Custody Transfer*

This standard is commonly known as API 14.1

*Gas Processors Association (GPA)
Obtaining Natural Gas Samples for Analysis by Gas Chromatography*

This standard is commonly known as GPA 2166

Both the API and the GPA are industry standards that have been developed by industry stakeholders and recommend how sampling should be done to obtain the best representative sample from the flowing stream. Many of the points and recommendations in this paper are discussed in greater detail in these standards. Before any company sets up a sampling program or installs a composite sampling system they should consult these sources directly in order to completely understand the problems and solutions that exist when trying to obtain a true representative sample of the flowing gas stream.

Issues in Obtaining a Representative Sample

There are many reasons for the inaccuracies that can and do occur during natural gas sampling. Among those are poor sampling techniques that fail to account for phase change issues, poor choice of sample location, and poor analytical processes. This section will discuss some of the more common issues.

Phase Change Issues – Single Phase Flow Streams

API and GPA both define single phase flow as “natural gas flowing at a temperature above the hydrocarbon dew point and free of compressor oil, water, or other liquid or solid contaminants in the flow stream”.

That being said, accurate gas sampling can only be accomplished if the flowing stream is in a gas only phase. Therefore it is critical that the sample be taken at a point in the system where single phase flow is present. This may sound like a simple requirement, but there are a number of factors that conspire to make a single phase flow difficult to maintain, especially in cold temperature climates.

The potential for cold ambient conditions coupled with the fact that many separator designs expose the gas leg to the ambient environment contribute to the potential of two phase flow.

As an example, in a gas separator phase equilibrium exists at the line pressure and temperature. The gas leg exists at the hydrocarbon dew point directly downstream of the separator outlet. Should the temperature drop below the hydrocarbon dew point, droplets of liquid hydrocarbons will condense from the flowing stream. These droplets may be entrained in the flow stream or, more commonly, they attach themselves to the pipe wall and are carried along the pipe wall in the direction of the gas flow. Two phase flow now exists and sample distortion will occur if a sample is taken at this location unless steps are taken to maintain the leg above the hydrocarbon dew point

Phase Change Issues – Retrograde Condensation in the Sample System.

There is a widespread misconception that once a sample has entered the sample system, it is no longer necessary to be concerned about phase behavior. The belief exists that the sample can be returned to original state by heating the sample in the lab. This statement only holds true if the condensation occurs after the sample has been captured and stored in the sample cylinder. Retrograde condensation (caused by a decrease in pressure or an increase in temperature) in the sampling system will result in sample distortion *if* it occurs prior to the sample being captured in the sample cylinder. When retrograde condensation occurs prior to the cylinder, droplets of hydrocarbon liquid will form in the sample system. If condensation occurs in the probe these heavier droplets will often run back through the probe and return to the flowing stream. If they are in the sample chamber they can accumulate in cavities within the chamber or they may collect in low spots throughout the sample system tubing. When components of the sample are lost in this manner, they cannot be recovered by heating the sample cylinder (re-vaporization) prior to analysis and permanent sample distortion has occurred.

The most common cause of retrograde condensation is condensation created by a Joule – Thomson Effect, a reduction in pressure and the resulting reduction in temperature. Any of the following practices can create a JTE: Using a small orifice sample probe or sampling through a small orifice manifold valve, any tubing, fittings, or valves that would create a significant pressure drop, performing a fill and empty process without a pigtail (extension tube) attached to the sample cylinder.

In summary to avoid all potential causes and associated effects of retrograde condensation the sampling technician should consider the following points when designing the sample system:

- Insulation or heating must be used to eliminate any cold spots between the sample point and the sample cylinder.
- Sample lines should be as short as possible and designed to avoid any low spots where liquids could collect.
- Minimize the use of small orifice valves on the probe and sample lines.
- Be aware of all tubing fittings and other components within the sample system that have the potential to create a pressure drop.
- Avoid using orifice meter impulse lines and manifold valves for the purpose of taking samples.
- Include a properly designed pigtail (extension tube) for fill and empty of the sample cylinder.

Contamination of the Sample Due to Cleanliness and Handling Issues

Lack of cleanliness as it relates to the sample system set up and equipment is a common cause of sample distortion.

Prior to a sample cylinder being used, it should be completely clean and free of any contaminants that may distort the compositional analysis of the flowing stream. Sample cylinders, particularly constant volume cylinders, must be cleaned and entirely purged after each use and that state must be maintained prior to the cylinders next use. A very effective and one of the most commonly used methods for cylinder cleaning is wet steam. After steam cleaning the cylinders are dried and purged and prepared for the next collection period. Additional detail on cylinder cleaning methods and best practices can be found in both the API and GPA industry standards.

Cleanliness during maintenance should also be considered. When performing maintenance or re-building a composite sample pump cleaning solvents must be non-residual and o- ring lubricants must be of a synthetic non-petroleum based composition to avoid sample distortion.

A common handling issue is allowing air contamination of the collection system and consequently the sample. This is typically the result of either not purging the sample line properly after changing the cylinder or as a result of improper handling of the sample cylinder.

Common handling mistakes to avoid are:

- Opening the valve on the sample cylinder to check that the cylinder is still under vacuum.
- Opening the valve on the cylinder to check that the cylinder has a blanket gas fill.
- Opening the valve on the cylinder to confirm that there is not another sample in the cylinder.

Air contamination can also be the result of cylinder valve leakage as sometimes little thought is given to the type or quality of valves used and many valves are not suitable or designed to contain a vacuum.

Valve manufactures can be of assistance in recommending the best choice of valve for sampling systems and cylinders. They can also provide recommended maintenance procedures to ensure longer leak free performance of the valve.

To further stress the importance of cleanliness, handling, and setup and the impact poor practices can have consider the following revenue analysis. This chart represents the amount of revenue a company could potentially lose with errors in sample accuracy.

No. of Wells	Cost/MMBTU	Calculated BTU/SCF	Flow Rate (MCF/day)	Value of Gas Produced Per Day	% BTU Error	Cost of Error		
						Per Day	Per Month	Per Year
1	\$7	1,000	200	\$ 1,400	1%	\$ 14	\$ 420	\$ 5,040
					3%	\$ 42	\$ 1,260	\$ 15,120
					5%	\$ 70	\$ 2,100	\$ 25,200
2	\$14	2,000	400	\$ 2,800	1%	\$ 28	\$ 840	\$ 10,080
					3%	\$ 84	\$ 2,520	\$ 30,240
					5%	\$ 140	\$ 4,200	\$ 50,400

Sampling Basics

Determining how often to sample

For many years a basic standard for sampling has been the “grab sample” or “spot sample”. When done in accordance with GPA and API standards it will provide a representative sample of the flowing stream. By definition, however, a spot sample is exactly that. A spot sample represents what exists in the flowing stream at that instant in time. Should the composition of the flowing stream change after a spot sample is taken, the change may never be discovered or will not be discovered until the next sample is analyzed. With that in mind, the frequency of spot samples must take into consideration all compositional variations that occur. These variations can be daily, weekly, monthly, or seasonal and the frequency of spot samples taken should be in anticipation of the expected variations and be done as often as necessary to capture these variations within any given time frame.

In operations such as gathering systems, production facilities or any facility where gas streams from multiple producers or wells and gas of varying quality and composition are all flowing into a common stream, sampling must be done much more frequently than is realistic for the spot sampling technique. In these instances an automated composite sampler or continuous online gas chromatograph should be considered.

Getting to know the Composite Sampler

Automated composite gas sampling systems are designed to take small bite size samples from the flowing stream at regular intervals and store them in a sample container or cylinder. The samples taken can be either time based or proportional to flow. When the cylinder is filled, the typical sample period is thirty or thirty-one days, it is taken to the lab for analysis. Field testing and research have proven that these systems can provide results comparable to that of an online gas chromatograph when the system is designed and used in accordance with API and GPA standards. They also provide an economical solution when increased sampling frequency is a necessity.

Composite sampling systems are typically composed of a sample pump, sample vessel, and sample probe. Dependent upon the type of probe used and the mounting orientation of the pump, a product loop a.k.a. hot loop may also be utilized. Most sample systems available also have the option of a programmable electronic user interface to control the pump and sampling parameters.

Time Based Sampling

Time-based sample control is designed to inject a selected amount of sample (bite) over a predetermined time to fill a sample cylinder to line pressure. Calculation tables are available to determine the time verses the amount of sample to be injected into a specified volume sample cylinder. The variables in the calculation would be the sample bite size and the size of the sample cylinder. The sample period may also be a variable but is typically thirty or thirty-one days. Samplers programmed as time based should have the capability to stop sampling when a no-flow condition is detected. Time based sampling can be successfully used to obtain a representative average sample when the gas stream is known to have a constant composition or steady flow rate.

Flow Based Sampling

The flow based or flow proportional sampler is electronically set to take a sample proportional to flow. This means that the sample rate is not fixed as in time based sampling and will increase or decrease dependent upon the process flow rate. Typically the signal to sample will come from a nearby flow computer, and there are a number of methods used to calculate when that signal should be sent. As with time based calculations the main variables are bite size, and sample cylinder size. Using these and the average daily flow rate the flow signal to sampler frequency can be determined.

Installation

The location of the sampler is critical in that improper placement can affect the ability to obtain a representative average sample. The sample point should be on a horizontal level run of pipe and consideration should be given to nearby turbulence factors. The ideal mounting location would be at least five pipe diameters downstream from elbows, tees, fittings, valves, orifice plates, or any other restricting devices. These devices can create swirls (re-circulation eddies) which may have a composition markedly different than the flowing stream. These disturbances can also pull liquids off the pipe walls and create aerosols that will adversely affect the sampling process.

Direct Mounted Sampler

The most common mounting method for composite samplers is the direct mount method. The pump is close coupled with the sample probe and mounted directly to the thread-o-let on the process pipe. The direct mount system also referred to as probe mounted is generally preferred for several reasons. The primary one being that the sampler mounted directly on the probe provides the shortest distance to the sample point, and ultimately, the freshest sample. Most samplers will include a port for a hot loop, which keeps the gas flowing through the sample chamber. Single flow sample probes are typically used with the direct mount sampler and dependent upon the type of sample probe used the hot loop may or may not be needed.

Remote Mounted Sampler

Remote mounting is typically done when physical constraints such as obstructions or access issues prevent the pump from being direct mounted. The pump will typically be mounted on a two inch pipe stand or other peripheral structure as close as possible to the sample point. Keeping the tubing between the pump and the probe as short as possible and using a dual flow probe are key to the success of a remote mount system. Dual flow probes are preferred on remote mounted samplers to enable positive flow through the sample chamber. If a dual flow probe is not used the hot loop should return to a lower pressure point downstream.

Heated Sample System

Heated enclosures for the composite sampler are used where climate conditions, process conditions and/or customer requirements related to API 14.1 mandate heated sampling. A typical heated system will consist of the composite sampler installed in an insulated cabinet with a catalytic or electric heating system. The cabinet will accommodate the sampler, the sample cylinder, the exposed portion of the sample probe, and all the related tubing. The heated sample system ensures that the sample gas temperature is maintained above the hydrocarbon dew point (HCDP) of the flowing gas stream. The API recommendation is that the temperatures be maintained at least 30°F (17° C) above the known hydrocarbon dew point. If the sample gas is near or below the hydrocarbon dew point of the flowing stream condensation can occur and may cause gas sample distortion. In areas where the ambient temperatures are known to always be above the hydrocarbon dew point of the gas stream heated sampling is typical not mandated.

Sample Probes

A well designed sample system is dependent upon the use of a properly installed sample probe. Probes may be direct mounted single flow, dual flow, or insertable/retractable. The two most commonly used are single flow and dual flow.

Location

The API recommendation and industry standard is that the probe tip be located in the center one-third of the process pipe. This configuration avoids the pipe walls which are prone to hold migrating hydrocarbon liquids and places the sample point in what is the most likely location for single phase flow. When determining probe length, consideration should also be given to potential effects of resonant vibration. Resonant vibration occurs when the vortex shedding frequency around the probe is equal to or greater than the probes natural resonant frequency. Refer to API 14.1 section 7.4.1 for further recommendations regarding probe length.

Single Flow Sample Probes

The single flow straight tube sample probe is the simplest of sample probes. It is generally constructed from a piece of tubing and welded or integrally machined into a ½", ¾", or 1" bushing or valve. The probe material is most often 316SS and the tip can be beveled or straight cut. A straight cut probe tip is most often preferred. Most single flow probes include a hot loop connection to allow for positive flow between the sampler and a downstream pressure drop.

Dual Flow Sample Probes

The dual flow probe is most often used when the sampler is remote mounted but is used on direct mount systems as well. It eliminates the need for a downstream pressure drop and works by using the differential pressure created between the probe tip and the return port at the bottom of the probe connection. This pressure differential creates a slipstream loop which provides a constantly flowing stream of sample gas from the pipeline to the sample system. When mounted remotely from the pump, an effort should still be made to keep the distance between the sample pump and the probe connection as short as possible.

Sample Cylinders

There are two common types of sample cylinders and the goal of both is to provide a protected and secure state for the samples being taken. There are a variety of options and features, materials, valves, seals, etc... available with these cylinders and all must be selected with the main goal of sample preservation in mind.

Spun End Cylinder

The spun end cylinder also known as a constant volume or single cavity cylinder is most commonly used with composite sampling systems in dry gas applications. It is of seamless construction and is hot spun out of 316 stainless steel tubing. These cylinders can be of the single or double valve variety and the valves must meet all DOT safety requirements and have a relief valve of either the spring or rupture disc type.

Constant Pressure Cylinder

The constant pressure or floating piston cylinder uses an inert gas or pipeline gas to keep the pressure inside the cylinder constant with the intent of preserving the sample in exactly the same state as it is in the pipeline excluding temperature. Constant pressure cylinders are believed to provide a more representative sample in wet gas applications which is where they are most often used. The cylinder has two sides separated internally by a floating piston. The pre-charge side is pressurized to slightly above line pressure and the pre-charge gas keeps a constant pressure on the product being sampled into the product side. As volume on the product side builds the pressure on the pre-charge side bleeds down but continues to maintain a constant pressure until the cylinder has reached capacity. The same DOT requirements for isolation valves and relief valves applicable to spun end cylinders also apply to constant pressure cylinders.

Conclusion

There are many people and processes involved in gas sample collection and the composite sampling system can be crucial to accurate, reliable, and repeatable gas analysis. Proper sampling techniques are also an important element in determining the quality and value of the gas being sampled. Obtaining a good representative sample of the flowing gas stream can be a challenge, but is essential for all stakeholders to ensure that they get full value for the natural gas products that they produce, process and transport. The responsibility of this task starts with location of the sample point best suited for representative average sampling. It encompasses everyone involved from sample system set up and configuration to collection, conditioning, handling, transportation, and analysis. Understanding the importance of proper installation, cleanliness, handling, and analysis are necessities for any sampling program to work effectively. Additionally awareness of the hydrocarbon dew point and its importance in obtaining a representative sample is a key factor. Understanding and following the published industry standards and regulations insures your company will get what it deserves from the production, processing or transport of this valuable resource.

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