TECHNIQUES OF COMPOSITE SAMPLING

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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 one must ensure they are receiving maximum 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

In 1821, the first well with the specific intent of bringing natural gas to the service was drilled by William Hart in Fredonia, New York. Since that time we have been continuously working to improve the processes and quality. With that in mind, there are many reasons why natural gas sampling is and should be undertaken. Wells may be owned by different companies, but 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 producers, processors, and transporters is to ensure that all involved will be compensated correctly based on the volume and quality of the gas produced or processed.

Gas allocation is made up of two components; the volume of natural gas and the composition 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. As a fossil fuel, 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. In summary, the total heating value determination of a natural gas stream is dependent on the accurate compositional analysis of samples taken.

Industry Standards

There are several well known industry standards related to natural gas sampling that address proper sampling technique and equipment, as well as the common causes of sample distortion and the best practices used to avoid them. The findings and recommendations of these standards are based on years of hands on experience and exhaustive field testing. The two most referenced industry standards for gas sampling 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. The sixth edition was published in 2006 and the seventh edition is expected to be released in 2015.

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

This standard is commonly known as GPA 2166

The API and the GPA standards have been developed by industry stakeholders and experts with a common goal of developing sampling techniques and best practices to obtain the most representative sample possible for any given condition. Personnel who will be sampling, collecting, or transporting samples should be continually trained on proper techniques as well as installation and handling of any equipment associated with sampling as these standards and best practices change. Poor technique,

poorly maintained equipment, and deviation from these standards can negatively impact the quality and accuracy of any samples taken.

Issues in Obtaining a Representative Sample

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

Hydrocarbon Dew Point

Failure to consider the hydrocarbon dew point is the most common cause of sample distortion in all methods of gas sampling. The avoidance of hydrocarbon dew point issues is a heavily discussed topic and is considered to be the most important factor in any sampling process. Hydrocarbon dew point is defined as the temperature at any given pressure at which condensation begins to form. Prior to any sample being collected the hydrocarbon dew point of the process gas should be known. If needed, the necessary steps can then be taken to prevent condensation from forming in the sample system. API 14.1 states that the sample system and all of its components shall be maintained at least 30° F (17° C) above the hydrocarbon dew point of the flowing gas stream.

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".

We understand that statement to say, that 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. Although a seemingly simple task, single phase flow can be difficult to maintain and even more so in colder climates. The potential for cold ambient conditions coupled with the fact that many separator designs expose the gas leg or meter run 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 migrate along the pipe wall in the direction of the gas flow. In this scenario, two phase flow now exists as does the risk for sample distortion. Steps must be taken at this location to maintain the sample system and all of its components above the hydrocarbon dew point of the sample stream.

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 or the formation of condensation. Many believe incorrectly that once collected, the sample can always be returned to its original state by being heated or re-vaporized prior to analysis. This statement only holds true if the condensation occurs after the sample has been captured and stored. 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 or during the sampling cycle. When retrograde condensation occurs prior to sample collection, 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 form in the sample system they can accumulate in cavities or 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 causes of retrograde condensation are as already discussed hydrocarbon dew point and condensation created by a Joule – Thomson Effect, which is 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.

To avoid all potential causes and associated effects of retrograde condensation the sampling technician should consider the following points when designing and installing 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.
- The smallest orifice in the sample system should be at the end of the pigtail during the fill and empty process.

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 (spun) 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.
- Not performing a proper fill and empty procedure prior to sampling.

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 manufacturers can be of assistance in recommending the best choice of valve for sampling systems and cylinders and there are typically many connection sizes and styles available. The manufacturer may also provide the 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

Potential Revenue Loss Due to Improper Technique

Sampling Basics

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 a given time frame. In operations such as gathering systems, production facilities, or any facility where gas streams from multiple producers, or wells with varying gas quality and composition all flow 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. Even though most spot sampling today is done as a supplement to or in conjunction with continuous composite sampling. There are often times during a continuous sampling cycle that a sample is needed for immediate analysis. As a result spot sampling is still widely utilized in that capacity.

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 and the sample period. 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 sample 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. As discussed, 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 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 while the tip can be beveled or straight cut, the blunt or straight cut is preferred.

Dual Flow Sample Probes - The dual flow probe is most often used when the sampler is remotely mounted but can be used on direct mount systems as well. It eliminates the need for a downstream pressure drop and works by using the differential pressure between the probe tip and the sample return in the thread-o-let area. This slight pressure differential creates a slipstream loop which provides a constantly flowing stream of sample gas from the pipeline to the sample system. Although a sample loop is established when the dual flow probe is utilized, the tubing to and from the sample pump should be kept as short as possible in remote mount installations.

Sample Cylinders

The two types of cylinders primarily used for natural gas sampling are the spun end cylinder and the constant pressure cylinder. When selecting a cylinder and its components such as valves and burst discs, consideration should also be given to the materials used. As defined by API 14.1, the sample container should not alter the gas composition in any way nor affect the proper collection of the gas sample.

Spun End Cylinder - Spun end cylinders are the most commonly used and are used almost exclusively in dry gas applications. These are also known as constant volume cylinders. The cylinder body is of seamless construction and will typically be 316SS. A valve will be applied to each end and per DOT: CFR 49 at least one of the cylinder valves must contain a pressure relief for safety during transportation. Most spun cylinders are DOT 3E rated and will contain a burst port with an 1800 PSI burst disc in compliance with the DOT rating. When filling, care should be taken to leave room for gas expansion. The industry standard is filling to 80% capacity.

Constant Pressure Cylinder - Constant pressure cylinders, also known as floating piston cylinders are most often used in wet gas or liquid sampling applications. While they can be used for dry gas and are known to provide a more representative sample, they are not as common in that application as the spun cylinder. The design of the constant pressure cylinder is such that the cylinder piston separates the cylinder body into two parts. The cylinder will have a pre-charge side and a product side. The pre-charge side will be pressurized or 'pre-charged' with the pipeline gas or more typically an inert gas such as nitrogen, helium, or instrument air to a pressure that is slightly above the line pressure of the gas being sampled. Pre-charging will push the piston to the 0   % fill mark at the product end of the cylinder. When sample collection begins the sample gas will push against the piston and the pre-charge gas will be exhausted though an adjustable relief on the pre-charge side. Unlike a spun cylinder this allows the sample gas or liquid being collected to maintain its line pressure throughout the sampling process.

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 involved to ensure that they get the maximum value for the natural gas products they produce, process, and transport. The responsibility of this task starts with the location of the sample point best suited for representative average sampling. It encompasses everyone involved from sample system set up and installation to collection, 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, and transport of this valuable resource.

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