TECHNIQUES FOR NATURAL GAS SAMPLING

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Introduction

Since a gas sampling system can be referred to as a "cash register" it is very important that the correct sampling method be selected and the appropriate industry standard be followed. Methods reviewed by this paper will include spot sampling, composite sampling, and on-line chromatography. In addition, Gas Processors Association (GPA) 2166-86 and American Petroleum Institute (API) 14.1 will be described.

Natural gas is sampled to determine quality for custody transfer applications, balance a plant process, or gathering system.   In the late 1970's most natural gas custody transfer contracts used gas volume (MCF) for the units of measure. In 1978 Congress passed the Natural Gas Policy Act in an attempt to deregulate the natural gas industry. This act dictated that natural gas should be purchased or sold based on energy content.   Today natural gas is purchased based on the amount of energy delivered. The quantity of energy delivered is calculated by multiplying the gas volume per unit time by the energy value (BTU) per unit volume. A gas chromatograph is typically used to identify individual components of the sample and their quantity, thus determining quality of the sample taken. Correctly obtaining, transporting and analyzing the sample is crucial to the accuracy required for custody transfer of this product.

Natural gas sampling can be accomplished using several different methods.   The most common method, spot sampling (depicted in GPA 2166-86), involves manually filling a sample cylinder connected to the center of the pipeline by a probe and separator. The entire volume of gas that has flowed between sample periods is evaluated for its quality with that one sample or "snapshot in time". It is obvious why this method is used only in gas streams that are extremely constant in volumetric rate and composition.

In locations where high volumes of gas are transferred, it is common for on-line chromatographs to be utilized in determining the composition of the flowing gas stream in a real-time manner. Special temperature compensating regulators are utilized to supply a constant representative sample from the center of the pipeline to the chromatograph.

However, many other applications have volumetric flow rates, which cannot justify the cost of an on-line analyzer, but require the same accuracy for custody transfer. These applications require the use of an automatic composite sampling system. These systems take periodic samples, based on time or volumetric flow rate, to create a composite sample which best represents the true composition of the gas stream during the sample period. The sample is stored in a sample cylinder and transported to a laboratory where its composition and quality are determined by gas chromatography. The advantages of these systems are their accuracy, low cost, simplicity in design and minimum amount of maintenance required to keep them operating.

Our task is to determine "What technique of sampling best fits the application, and what is the proper installation and operation of said equipment for an accurate sampling program?" Improperly applied or installed equipment and poor sampling methods can cause BTU variances worth thousands of dollars.

Spot Sampling

In 1986 the Gas Processors Association (GPA) issued a revision of the standard 2166-86 "Obtaining Natural Gas Samples for Analysis by Gas Chromatography" A total of 1050 samples were collected and analyzed resulting in nearly 70,000 data points. Eight sampling methods were evaluated for their impact on the components of common natural gas.

 The standard determined that "good samples" could be obtained using any of the eight methods, provided extreme care is taken while the samples are being obtained. A brief description of each method…

Fill & Empty: requires sample line separator, sample cylinder, extension tube, appropriate valves and gauges. This method involves purging the sampling apparatus, then repeatedly filling and emptying the apparatus. The number of cycles is line pressure dependent.

Controlled Rate Method: requires the same apparatus as Fill & Empty method with the addition of a flow tube

plug (orifice) in the extension tube. This method allows for a controlled flow of sample through the apparatus for a specific length of time. The amount of time varies depending on line pressure at the sample source.

Evacuated Container Method: requires an evacuated sample container with a pressure of 1 mm Hg or less. Instead of an extension tube this method requires a vent tube installed between the sample source and the sample cylinder. After a careful purge procedure the cylinder is filled with natural gas.

Reduced Pressure Method: similar to Evacuated Cylinder method. This method is not recommended when line pressure is below 100 psi.

Helium "Pop" Method: Begin with an evacuated cylinder (1 mm Hg). Carefully fill sample cylinder with Helium (approximately 5 psi). Use the same sampling configuration as the Evacuated Cylinder method. After purging the sampling apparatus, the cylinder is filled to line pressure. This method requires a separate determination for helium to calculate the correct BTU content.

Glycol or Water Displacement Method: A sample cylinder filled with clean glycol or water and a vessel to measure the displaced liquid are required for this method. Carefully purge the sampling apparatus. Open sample source, slowly open outlet valve allowing displacement of fluid. Close outlet valve as soon as gas can be seen or heard. The source gas must displace all fluid during sampling.

Floating Piston Cylinder Method: This sample cylinder has a piston that creates a precharge chamber, and sample chamber. Fill the precharge chamber with an inert gas (slightly above line pressure). Carefully purge the sampling apparatus. Slowly open the outlet valve allowing the sample to displace the piston and fill the cylinder. The amount sampled should not exceed 80% of the cylinders capacity.

On-Line Chromatography

An on-line gas chromatograph (GC) can provide almost real time measurement of the natural gas. Unlike calorimeters, which only give us energy value, a GC also gives us the compositional makeup of the gas. This additional information is fed into a flow computer and used in the AGA 8 supercompressibility equation, which is then used in the volumetric calculation.

Because the GC is on-line it is able to run an analysis of the flowing gas every few minutes and supply the flow computer with up to date data. Most on-line analyzers can also provide other important information, such as archived data (hourly, daily, or monthly averages for BTU or gas compositions etc.), and limit alarms for component concentrations that may go out of a specified range. On-

Line Gas Chromatographs (GC's) have been widely used when rigid custody transfer standards are needed for natural gas trading, and when gas specifications need to be monitored closely.

Gas chromatography is a scientific method in which a gas sample is separated into its component parts for measurement. The gas chromatograph consists of subsystems that inject the sample, separate the sample, detect the components, integrate the peaks, and report the results. The injection, separation, and detection all occur in the heart of the GC known as the GC oven. The integration and calculation of results are done in the controller, which can be considered the brains of the system.

Composite Sampling Systems

These are the major considerations of a composite sampling system installation and its operations:

- Locating the right sample point / sample probe.
- Choosing the proper sample system configuration.
- Components of the sampling system.
- Controlling the sampling system.
- Sample cylinder selection.
- Operational training.

Each of the components must receive proper attention or the results of the sample may be compromised.

Locating the right sample point

In all sampling applications, no matter what the product, it is important that the sample probe be in a location that best represents the product to be sampled. In natural gas sampling, we are only interested in the composition of the flowing stream that is in a gas phase. If the sample probe is in an improper location, the sample entering the system may not be representative and the end analysis in the lab may be inaccurate. The sample point should be top center mounted in a straight and horizontal pipe section. It should be five pipe diameters away from orifice plates, pipe bends, fittings, valves or other restricting devices that create turbulence.

When liquids are present in the piping, turbulence can create aerosols that are a mixture of liquids and gases flowing together. As mentioned before our only interest is to sample the flowing stream in a gas phase. The liquids that create the aerosol can be present along the bottom or upper circumference of the pipe wall. Areas of turbulence cast these liquids into flight where they mix with the flowing gas to create a mist or aerosol. If our

sample point is located in or close to this region, the aerosol will be sampled and stored in the sample cylinder. If these mists are included with the sample, the analysis may be inaccurate.

Choosing the right sample probe

Once the best sample point has been selected, the next consideration is the type of probe to be used. Two types of probes are commonly used, the single flow and dual flow probes. The inlet of any probe must be located in the center 1/3 of the pipe. This will ensure that the sample taken will be from a region of representative flow, and avoid sampling any liquids that may be present along the bottom or upper circumference of the pipe wall.

The single flow probe consists of a 316 stainless steel probe, cut at a 45 or 90 angle on the end, and welded or machined integrally with a male threaded nut. In composite sampling, a means must be provided for purging the volume of gas residing in the single flow probe before the sampling cycle begins. To achieve this, some sampling systems either bleed gas continually to the atmosphere, or to a low pressure source, ensuring the probe is purged before the sampling cycle begins.

Proper Sample System Configuration

Composite sampling systems are normally configured in one of two ways. They may be mounted on a leveling saddle, or if areas of vibration are a concern, mounted on a freestanding pole next to the pipeline. This configuration utilizes a dual flow probe. Or the sampling systems can "probe mounted."

"Probe Mounted" sampling systems are close coupled with the single flow probe, and are designed to use the entire volume of gas in the probe as an actuation source to power the sampling system. When the actuation gas is exhausted, the next sample is removed from the purged probe to reside in the pump, awaiting the next actuation. This process is called "self purging"; meaning the entire volume of gas in the probe is used and replaced before each sample is taken.

The dual flow probe is designed to create a slipstream loop for a continuous supply of representative sample gas from the middle 1/3 of the pipeline. It requires only one threaded coupling on the pipeline for the inlet and return of the probe. The dual flow probe consists of a stainless steel probe that extends to the center 1/3 of the pipeline, and a return port located at the bottom of the probe body. The dual flow probe works by using the differential pressure created between the sample point located in the center 1/3 of the pipeline, and the return port at the bottom of the probe body inside of the treaded coupling. This pressure imbalance creates a slipstream, which provides a constantly moving supply of fresh representative sample gas, from the middle 1/3 of the

pipeline to the sampling systems manifold. Tests have shown that the probe penetrating the center 1/3 of the pipeline, if bent 90 degrees and facing the flowing gas, may increase the velocity of the slipstream and ensure its direction of flow.

"Probe mounted" composite sampling systems are configured to mount directly on the pipeline. This eliminates the need for a dual flow probe because the system comes complete with a single flow sample probe and isolation valve as integral components. Because the sample pump and pipeline are closely coupled, only a small volume of gas occupies the integral probe that needs to be purged. Additionally, no external tubing exists for the sample gas to flow through to the sampling system. There is concern that the exposed tubing, used to interconnect a dual flow probe with the sampling system, may provide a means for heavy components in the slipstream to condense due to chilling of the tubing under specific ambient temperature conditions. Loss of these components could have an effect on the integrity of the sample.

It is important to mount the sampling system vertically above the sample point to prevent the flow of liquids into the system. Also, if the sampling system is to be mounted on a leveling saddle or pole, it should be mounted as close to the sampling point as possible with no traps or right angles in the slipstream tubing.

Composite Sampling System Components

Most composite sampling systems contain these components:

- Manifold / Probe Body
- Sample Pump
- Filter / Regulator
- System Controller

The sample pump is the component that pumps the sample in specific volumes into the sample cylinder. The sample volume can be changed to accommodate different size sample cylinders and sampling periods. In a probe mounted automatic sampler, the sample pump is powered by natural gas supplied through a low powered solenoid valve that is normally closed. When energized, natural gas flows from the probe body, through the regulator and solenoid valve, to actuate the pump.

A filter/regulator is integral with the system to regulate the pump actuation gas. The regulator has a filter and pot to remove any particulate and moisture from the pump actuation gas. It is important for the regulator to be located downstream of the pump sample inlet on the manifold, so the pressure drop will not affect the integrity of the sample.

The manifold and probe body each provide points of entry to the sample pump, and for sample discharge to the sample cylinder. A purge valve is integral with the manifold and probe body that provides communication between the sample cylinder and the inlet of the sample probe. The purge valve provides a means for purging the ambient air and stagnant gas in the sample probe and related tubing, manifold, and sample cylinder before the start of a sample period.

The enclosure that houses the sampling system must fit the extremes of the environment it will be placed in. Offshore and marine applications should have an enclosure that is resilient to corrosion. This is also true of the sampling system components. Not only should they be compatible with the gas they are sampling, but also with the environment they are operating in.

Controlling the Sampling System

A composite sampling system controller determines when a sample should be taken, and activates the system based on pre-set parameters. The type of control utilized is dependent on the flow conditions of the stream to be sampled. In all flowing condition, the sampling system must be "proportional-to-flow". Four typical flow conditions are:

1. Continuous flow / constant volumetric rate.
2. Intermittent flow / constant volumetric rate.
3. Fluctuating volumetric rate w/ electronic measurement.
4. Fluctuating volumetric rate w/out electronic measurement.

In applications where the volumetric rate does not change, and the flow is constant, a sampling system with a simple re-cycling timer is sufficient to be proportional-to-flow. In this mode, the controller will activate the sample pump at predetermined time intervals over the entire sampling period. Based on the pump displacement and sample cylinder volume, a "time between strokes" can be selected and programmed into the controller which will bring the sample cylinder to line pressure at the end of the sampling period.

In applications where the volumetric rate is constant, but the flow starts and stops, a sampling system with a simple re-cycling timer and an "on-off" switch, is sufficient to be proportional-to-flow. The "on-off" switch senses differential pressure at the orifice plate in the meter. When differential pressure is not present, the controller is interrupted. When differential pressure exists, the controller is allowed to operate the sampling system. Operating in this manner is considered to be proportional-to-flow, and not sampling a stagnant non-moving stream.

Some applications have a volumetric flow rate that fluctuates the entire range of the meter setting, while the flow starts and stops. In this scenario, the sampling system will need to change the rate at which it samples, and stop when flow ceases in order to be proportional-to-flow. This type of sampling system has a controller that will accept a proportional-to-flow signal input from a flow computer. A simple calculation can be used to determine the sample rate needed to bring a sample cylinder to line pressure during the sample period.

If there is no flow computer to provide the flow signal, or the sampling system cannot be interfaced with the flow computer, some sampling systems can provide their own differential pressure transmitter as a part of the sampling system. The differential pressure is measured and converted into an analog flow signal to drive the sampling system proportional-to flow. The advantage to these systems is that they stand alone, and require no interface with a flow computer or external power.

Sample Cylinder Selection

One of the most critical aspects involved in composite sampling is the proper use and selection of the sample cylinder. There are two types of sample cylinders commonly used. The constant volume and the floating piston sample cylinders. The constant volume cylinder is typically used with "dry gas", and the floating piston cylinder is used with gas having a high BTU content or "wet gas". The floating piston sample cylinder keeps the sampled gas at line pressure until it is analyzed. This will ensure that all constituents present in the sample, in a gas phase, will remain in the sample and not condense due to retrograde condensation.

The floating piston sample cylinder is equipped with rupture discs and purge valves. The interconnecting tubing between the sampling system and any sample cylinder should be as short as possible to eliminate dead space. The Gas Processors Association (GPA), standard 2166-86 contains procedures for purging and cleaning the cylinders. Department of Transportation (DOT) regulations govern the design, manufacture, and transportation of these cylinders. Every effort should be made to comply with these regulations.

API 14.1

This standard details requirements and procedures required to correctly collect and handle natural gas samples for custody transfer. A particular emphasis is placed on the impact of hydrocarbon dew point to the overall accuracy and success of your sampling program.

Accurate sampling from gas streams with temperature at the hydrocarbon dew point temperature is more difficult than sampling from streams with temperatures above the hydrocarbon dew point temperature.

If any part of the sampling process causes the sample to fall below the hydrocarbon dew point, scattered and

biased analytical results and non-representative samples are likely to result. In order to avoid this problem, the sample gas temperature must remain above the gas hydrocarbon dew point during sampling. This can be accomplished by heating sample probes and by heat tracing lines, regulators and sample cylinders or by employing some other means of delivering heat to the fluid in the sampling system.

Due to the uncertainty in measuring or calculating the hydrocarbon dew point, it is recommended that the gas being sampled be maintained at 20-50°F (11-28°C) above the expected hydrocarbon dew point throughout the sampling system. If ambient temperatures are above the hydrocarbon dew point, heating may not be required. When the sampling process involves a pressure reduction, provide sufficient heat at or prior to, the point of pressure reduction to offset the Joule-Thomson effect (approximately 7°F (3.9^{o}C) per 100 psi of pressure reduction.

Operational Training

The scope of any sampling program should be well defined. Technicians responsible for installing the sampling system, gathering the samples and conducting the analysis should be well versed in their tasks. A lapse in any step of the process could skew the results. If any doubt exists regarding the proper use of composite sampling systems and their ancillary equipment, most manufacturers offer operational training and technical assistance.

Conclusion

Obtaining a sample is easy. However, obtaining an accurate sample that is representative of the flowing stream is a challenge. The process requires use of the proper method, selecting the correct equipment, and attention to detail.

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