Techniques of Gas Spot Sampling
Class # 5290

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Abstract

This paper will provide an overall view of the spot sampling task, identify the most significant factors which impact spot sampling, and offer recommendations. It will also acquaint the reader with the components used in the spot sampling process and introduce the GPA 2166 and API 14.1 standards. The main objective of the paper is to encourage the reader to approach the spot sampling task from a scientific standpoint rather than the blind "cookie cutter" approach.

Introduction

Obtaining a spot sample for compositional analysis from a natural gas pipeline is not as straight forward and simple as it may appear. Major sources of disparity between measured and actual compositional analysis stem from not only the type of sample collection method, but also the type of components utilized to carry out the task. Spot sampling is a challenging task that should be executed properly considering the amount of money that is at stake.

The need to accurately determine the compositional analysis of the natural gas being sampled is crucial to the natural gas and petrochemical industries from both an economic and product treatment standpoint.

From an economic standpoint: Natural gas is purchased or sold based on its energy content, expressed in dekatherm units, which is the product of volume and heating value. Physical properties of the gas used in flow rate (volume) calculations and heating value (in BTU's) are both computed from the compositional analysis. If the compositional analysis is inaccurate, then the volumetric calculations and/or BTU value will also be inaccurate which directly correlates to an incorrect assessment of the gas value. This is the reason why the gas sampling system is often referred to as the "cash register".

From a product treatment standpoint: Natural gas is used as a feedstock for various petrochemical streams. The final product derived from the feedstock is greatly dependent upon the feedstock's composition and BTU value. If the compositional analysis and BTU value of the natural gas feedstock are inaccurate, then the presumed quality of the petrochemical product being produced from the feedstock may be impacted.

Whether you are in the business of buying/selling gas or producing a petrochemical product, it becomes evident that the initial upfront investment of time and effort spent towards selecting the appropriate sample collection technique and components capable of delivering a "representative" sample will quickly be recouped.

The Spot Sampling Task

There are three primary methods for obtaining natural gas samples: Spot, Composite, and Continuous (On-line). The objective of all three methods is to obtain a "representative" sample of the source gas. When spot sampling is performed a sample is extracted through a probe extending into the pipeline, collected into a sample cylinder, and then transported to a laboratory for analysis. The entire volume of gas flow between sample periods is evaluated for quality with that one sample or "snapshot" in time. Spot sampling is typically performed on sources whose flow rate is too low to economically justify a composite sampler or on-line analyzer. Spot samples can also be used to confirm the compositional analysis from an on-line analyzer.

There are several methods, detailed in GPA 2166-05, for collecting spot samples. Some of the common methods used today are Purging- Fill and Empty method (Section 6.1), Heluim "Pop" method (Section 6.5), and Floating Piston Cylinder Method (Section 6.7). Each of the methods has advantages and disadvantages (See Figure 1).

Method	Advantage	Disadvantage
Evacuated Container	The cylinder is evacuated (vacuum) so no other fluids are present	Susceptible to air leaking into the sample cylinder
Reduced Pressure	Problems associated with high pressure are reduced	Smaller sample quantity
Helium Pop	No air in cylinder to purge	Dilutes sample- more difficult to perform
Floating Piston Cylinder	No air in cylinder to purge, constant pressure	Cylinder is difficult to clean and lube
Water Displacement	No air in cylinder to purge, constant pressure	Rarely used- susceptible to contamination
Glycol Displacement	No air in cylinder to purge, constant pressure	Rarely used- susceptible to contamination
Purging- Fill and Empty	Little Preparation- Cleaning only Inexpensive equipment	Residual Contamination Possible condensation problems Inconsistent execution of method
Purging-Controlled Rate	Little Preparation- Cleaning only Inexpensive equipment	Residual Contamination Possible condensation problems Inconsistent execution of method

Figure 1- Advantages and Disadvantages of Sample Collection Methods

Industry Standards

Industry standards are essential to the advancement of natural gas sampling technology. There is a large amount of information that the standards provide guidelines on, but there is still a lot in the area of natural gas sampling that they do not address. The best way to determine what the current industry standards do and do not address is to examine their scope.

GPA Standard 2166-05

Obtaining Natural Gas Samples for Analysis by Gas Chromatography
Adopted as a Tentative Standard, 1966; Revised and Adopted as a Standard, 1968; Revised 1986, 2005

1. Scope

1.1 The purpose of this publication is to recommend procedures for obtaining samples from flowing natural gas streams that represent the composition of the vapor phase portion of the system being analyzed. These representative samples are subsequently transported to a laboratory and analyzed for composition and/or trace contaminants or analyzed onsite by portable or on-line chromatographs.

1.2 The methods outlined in this publication are designed for sampling natural gas from systems that are at or above the Hydrocarbon Dew Point temperature. As the temperature of the flowing stream decreases or the pressure increases to impinge upon the Hydrocarbon Dew Point, it becomes increasingly difficult to obtain a representative sample of the flowing stream. This standard does not address accounting for the liquid hydrocarbon portion of two-phase systems.

1.3 The scope of this standard does not include composite gas sampling (samples taken in increments over relatively long time periods) systems. For information on composite sampling, the reader is referred to API 14.1 and ASTM D5287.

API American Petroleum Institute

Manuel of Petroleum Measurement Standards
Chapter 14-Natural Gas Fluids Measurement: Section 1-Collecting and Handling of Natural Gas Samples for Custody Transfer
Measurement Coordination Department; Sixth Edition, February 2006

2 - Purpose and Scope

The purpose of this standard is to provide a comprehensive guideline for properly collecting, conditioning, and handling representative samples of natural gas that are at or above their hydrocarbon dew point.

The standard considers spot, composite, continuous, and mobile sampling systems. This standard does not include sampling of liquid streams.

This standard includes comments identifying special areas of concern or importance for each sampling method included. It is intended for custody transfer measurement systems and may be applicable to allocation measurement systems.

The accuracy of moisture determinations from samples collected using the recommendations in this standard has not been determined.

This standard does not include sampling multi-phase flow (free liquid and gas) or supercritical fluids.

After reading the scopes of the standards, one can see that their intention is to provide guidelines and recommend procedures related to sampling natural gas at or above its hydrocarbon dew point. The standards do not include liquid sampling, supercritical fluid sampling, or multi-phase (free liquid and gas) sampling.

It is important to note that the scope of both standards state, in one form or another, that procedures for sampling gas containing entrained liquid are excluded from the standard. The reason this type of sampling is excluded is because there is no current, readily available technology that will allow one to obtain a sample from a multi-phase (gas and liquid) natural gas stream containing a representative amount of both phases.

Even though the scope of either standard excludes procedures for sampling multi-phase streams, they do offer some good advice when sampling from these types of sources. Both standards warn that if liquid is present in the source gas then it needs to be separated and removed under the source conditions of pressure and temperature. Allowing either condition to change in any direction will alter the gas phase composition.

By now it should be clear that a “representative” sample of natural gas, as defined by the standards, is one representing ONLY the gas phase as it exists at pipeline conditions of pressure and temperature. What constitutes a “representative” sample has been the subject of much debate but credit should be given to the industry standard organizations for taking a position in the matter.

API 14.1 Hydrocarbon Dew Point Requirement

In order to prevent the sample from cooling below its hydrocarbon dew point during the sampling process, the API 14.1 standard recommends maintaining the sample 30°F above the expected hydrocarbon dew point throughout the sampling system due to the uncertainty in measuring or calculating the hydrocarbon dew point. If any part of the sampling process allows the sample to cool below its hydrocarbon dew point, then sample distortion is likely to occur. This heating requirement by API 14.1 means that there may be a need to heat different components within the spot sampling system.

Spot Sampling Challenges

The following is a list of spot sampling challenges, which are further explained in more detail below:

- The process of collecting a spot sample seems to be simple, but it isn’t.
- Many technicians involved in spot sampling are not properly trained in the task or well versed in the industry standards.
- Spot sampling technology is not as advanced as flow measurement technology.
- Sampling multi-phase and high hydrocarbon dew point streams is difficult.
- Sampling in cold climates is difficult.
- Purging the sample cylinder without affecting the sample gas composition is difficult.
- Ensuring the sample cylinder is clean is difficult with certain types of cylinders.

The process of collecting a spot sample appears simple, but it isn't. In order to properly execute the sample collection process, one must have a keen understanding of the physics and chemistry involved and a good working knowledge of current industry standards. Spot sampling is performed on different types of gas, under varying operating and ambient conditions making the appropriate hardware and sampling technique very much situation dependant.

Many of the technicians performing the spot sampling task are not properly trained or well versed in the industry standards. Both of the standards contain a large amount of valuable information which is often ignored. Training on basic science and knowledge of current industry standards should be included in the minimum requirements for measurement technicians or related personnel. They should be completely knowledgeable of the proper spot sampling methods, company procedures, and techniques involved and should receive periodic training and educational updates on new standards. They should also be trained on the proper way to operate the sampling equipment. The technicians should understand that properly performing their individual roles will have a direct financial impact on the profits of their company.

Spot sampling technology is not as advanced as flow measurement technology because the spot sample system has not traditionally been a product provided by a single supplier but rather an accumulation of components assembled by the user. This, in many cases, results in a less than adequate system.

Sampling from a natural gas source which is multi-phase (gas & liquid) is challenging. In order to comply with the standards, the liquid portion of the stream should be rejected at flowing conditions of pressure and temperature allowing only the gas (vapor) phase of the source to be collected. This gas will be saturated and at its hydrocarbon dew point, so any cooling of this sample will result in condensation of the heavier components. When using the fill and empty or purge through methods for sample collection, care should be taken to keep the external sampling equipment 30°F above the hydrocarbon dew point temperature to prevent the heavy components from condensing and erroneously distorting the BTU value of the gas. This is a difficult task to accomplish, so a sampling method or cylinder that does not require purging of the sample cylinder is better suited for sampling multi-phase or high hydrocarbon dew point streams.

When sampling a gas having a high hydrocarbon dew point, minimal cooling due to a pressure reduction during the purging process can cause the sample gas to cool below its dew point erroneously enriching the sample. Precautions such as heating the sample cylinder & tubing should be taken to keep the sample above the hydrocarbon dew point. Sampling in cold climates is challenging because it may also require heating of the sample conditioning system. Contact with the cold sampling equipment during the purging process can cause the sample gas to cool below its dew point and condense in the cylinder, erroneously enriching the sample. Sampling high hydrocarbon dew point gas may mean maintaining the equipment at high temperatures to prevent condensation during purging, or using sampling method or cylinder that does not require purging of the sample cylinder.

Purging of the sample cylinder is the most problematic area of spot sampling. The highest probability of error and/or sample distortion comes from purging the residual gas from the sample cylinder, especially if the sample has a high hydrocarbon dew point and/or in low ambient temperature conditions. As previously discussed, when using the fill and empty or purge through methods for sample collection care should be take to keep the external sampling equipment 30°F above the hydrocarbon dew point to prevent the heavy components from condensing and erroneously increasing the BTU value of the gas. Using sample collection methods and cylinders that do not require purging will help to eliminate this source of error.

Another large area of sample distortion stems from unclean or improperly cleaned sample cylinders. Residual gas from previous samples will alter the composition of the current sample. The standards require the cylinders to be purged and cleaned AFTER EACH USE, prior to the next sample collection. Clean wet steam, free of corrosion inhibitors or boiler water treating chemicals, is the most effective cleaning agent. The cylinders should be dried and purged after any wet cleaning procedure to eliminate any residual liquids.

Spot Sampling Components

All sampling components should be properly installed, operated, and maintained. Dirty or poorly maintained equipment that is not operating properly will have an impact on the analysis. Components should be constructed with a material that is compatible with the gas that is being sampled.

Sample Probe

A sample probe should always be used to help extract a representative sample. Sampling from a valve on the wall of the pipeline is a bad technique because contaminants residing on the wall can be pushed through the valve and into the sampling system. If the source contains entrained liquid, a phase separation membrane probe should be used to eliminate the liquid portion inside of the pipeline in accordance with the standards.

The probe mounting location recommended by the API 14.1 & GPA 2166 standards is vertical mounting at the top of a horizontal pipe run, in an area that will best represent what is in the pipeline. The probe should not be located in any "dead-end" section of the pipe. It is also recommended that the probe be at least five diameters downstream of a disturbing element (if the disturbing element is some type of projection in the gas flow, such as a thermo-well).If the disturbing element is a section of the pipeline, such as an elbow or orifice plate, then the diameter referenced is that of the pipeline.

The probe insertion depth suggested by the API 14.1 & GPA 2166 standards is in the center one-third of the pipe. Although this is a common industry practice, it is not required. The standards warn of possible probe breakage resulting from resonant vibration triggered by vortex shedding at high gas velocities. A table and calculation provide a means for determining the maximum probe insertion depth for a given probe design. For more information on this subject refer to GPA 2166-Section 7.5.2 or API 14.1- Section 7.4.1.

Both standards recommend using probes less than ten inches in length. The length referenced is not the distance between the inner pipe wall and probe tip, but rather the length between the point of attachment and the probe tip (See Figure 2).

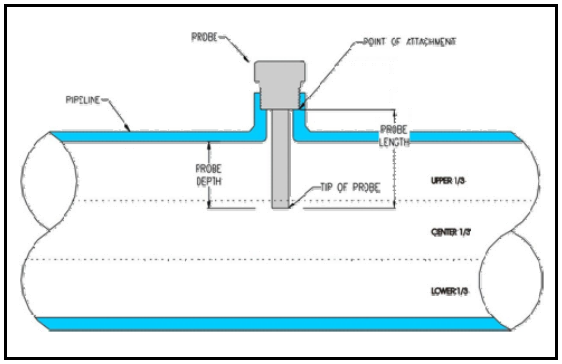

Figure 2- Probe length consideration

Square cut probes are preferred over angled. If an angle probe is oriented with the short side of the angle upstream, liquids could be ingested in the sample probe, rendering the sample non-representative.

Sample Separators & Filters- GPA Separator

The GPA separator (see Figure 3) is intended to separate entrained liquid from a multi-phase sample stream and MUST BE operated at the EXACT temperature and pressure of the flowing natural gas source, which is not easy to achieve. GPA requires a thermometer be installed in the separator to constantly monitor the line temperature and that the separator be insulated.

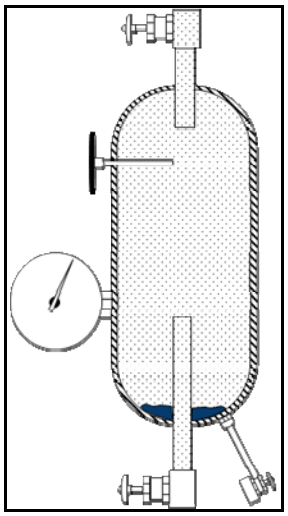

Figure 3- GPA Separator

Although the GPA separator has been around for many years, it is challenging to collect a representative sample with this piece of equipment because it is a large volume to purge, and condensation often occurs during the purging process of the separator. It depends solely on gravity to perform the liquid/vapor separation and does not eliminate liquid aerosols from the sample gas. This introduces large errors when liquid aerosols are present.

A pigtail on the end of the separator is not required if the drain valve is opened only slightly to allow a slow weep for monitoring for the presence of liquids. If the drain valve is to be left open during sampling, then a pigtail is required.

Sample Separators & Filters- Membrane Filter

In accordance with GPA 2166, a membrane filter inserted directly into the flowing gas stream (See Figure 4) can be used to remove unwanted contaminants. Since the separation is being made at flowing gas temperature and pressure by virtue of its location, changes to the gas sample are avoided. The membrane eliminates vaporization of heavy components due to changes in temperature/pressure.

The flow rate through the membrane should be considered, and there should be a means to restrict the flow through the membrane to prevent a large pressure drop across the membrane that will result in forcing liquids through the membrane.

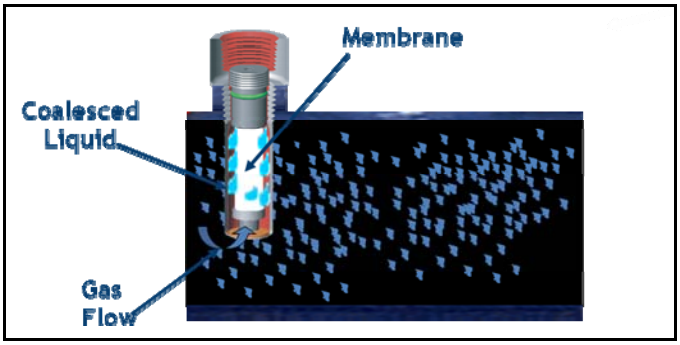

Figure 4- Membrane tip probe

Valves & Tubing

Condensation can occur in both process isolation & cylinder valving if there is a restriction in the valve creating a pressure drop. Use valves, including cylinder valves with large Cv values. The Cv of the cylinder valves should be balanced against the Cv of the last valve/restriction at the end of the pig tail.

Cylinder valves should be free of leaks. If a leak occurs, some of the sample will escape from the cylinder. Typically, the lighter hydrocarbons will escape first and the remaining sample will be overrepresented with the heavier components (C3, C4, etc.).

API 14.1 recommends the minimum diameter of the tubing to be ¼" to eliminate any JT cooling. The tubing should be kept as short in length as possible to reduce the heat transfer to the ambient surroundings. The goal is to attach the cylinder as close to the sample point as possible and avoid the use of unnecessary tubing lengths and fluid handling components such as the GPA separator or coalescing type filters.

Extension Tube ("Pig Tail")

The pig tail (See Figure 5) consists of a throttling device (valve and/or orifice) and length of tubing (usually ¼") placed downstream of sample cylinder to thermally isolate the outlet valve of the sample cylinders so that the Joule Thompson effect does not cool the sample cylinder during the purging process. It is important to keep in mind that the pig tail does not prevent the sample from cooling and condensing inside of the sample cylinder during the purging process when ambient temp. is below the HCDP.

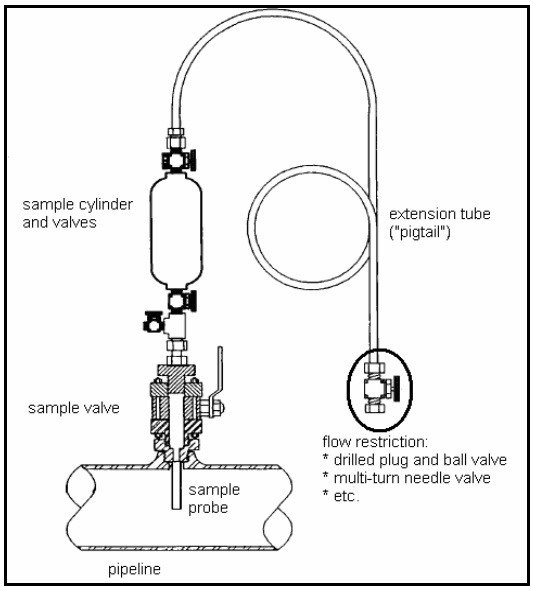

Figure 5- Sample Cylinder with Pigtail

The smallest diameter of the sample system will be the point of maximum pressure drop where JT cooling will have the greatest effect, resulting in the greatest reduction of temperature. For this reason, the standards recommend that the smallest diameter of the sample conditioning system should be the internal diameter of the flow regulating plug/valve on the end of the pig tail.

Although the standards address thermal isolation of the sample cylinder, they do not address all issues concerning thermal isolation such as that of the process isolation valve. The GPA 2166 methods require "blowing down the process valve" which creates a significant amount of cooling on the valve that the sample has to flow through before reaching the cylinder. This is an area that needs improvement to incorporate a better scientific approach.

Sample Cylinders – Spun End

The most widely used type of sample cylinder and most economic from an initial purchase stand point is the single cavity "spun end" cylinder with valves at each end (See Figure 6). The set up and operation of this type of cylinder is simple and straight forward, although proper cleaning and visual internal inspection can be difficult.

It is also challenging to sample gas that is very near its dew point or in cold environments with this type of cylinder because it is possible to condense heavies during the purging process, erroneously enriching the sample. Using a sample method or cylinder technology that does not require purging will help to prevent these types of sampling errors from occurring when sampling gas that is very near its dew point or in cold environments.

Figure 6- Single Cavity, Spun End Cylinder

Sample Cylinders- Constant Pressure ("Floating Piston")

A constant pressure cylinder can be described as a closed ended cylinder with an internal piston (See Figure 7). The cylinder is prepared before use by pressurizing one side of the cylinder, forcing the piston to move towards the inlet end of the sample cylinder and expelling the air inside of the cylinder thus eliminating cylinder purging.

This is a good cylinder to use when sampling in cold climates or gas that is very near its dew point because there is no need to purge the cylinder so the chance of error that occurs during the cylinder purging process is eliminated. Some challenges with this type of cylinder are that it is difficult to disassemble and properly clean, and the lubricant that is used around the piston seals could contaminate the sample.

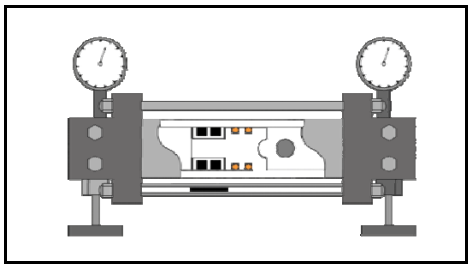

Figure 7- Constant Pressure Cylinder

Sample Cylinder- New Technology- Q2

The Q2 sample cylinder is of head and bowl design, and features an inert one time use bag liner (See Figure 8). The bag is collapsed internally by applying a minor back pressure of Helium or other inert gas (or the sample gas itself) eliminating the need to purge the cylinder. This makes it suitable for sampling in cold climates or gases that are very near their dew point.

The valves are built into the ends of the cylinder, eliminating the need for ancillary hardware. The bowl can be unscrewed from the head to allow for visual inspection, and the disposable bag liner eliminates the need to clean the cylinder.

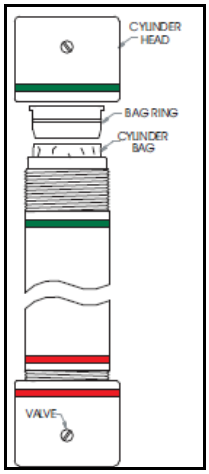

Figure 8- Q2 Sample Cylinder

The set up and operation of the cylinder is simple and straight forward. It uses a low volume manifold to closely couple the cylinder to the sample source. The preferred sample collection technique is the Line Purge and Cylinder Fill, which is summarized below. (Figure 9 shows the start condition in the field).

- After collapsing the bag, connect the cylinder manifold between the process valve and the cylinder inlet. Confirm the cylinder valves are closed.
- Open the line purge valve to allow sample gas to sweep through the sample connection right up to the cylinder's closed integral valve seat. (~2-5 sec). Close the purge valve.
- Open the valve on the red end of the cylinder, then open the valve on the green end of the cylinder to fill the cylinder (~ 5-10 sec). Once the cylinder has been filled, close all valves.
- Depressurize manifold by opening purge valve. Disconnect cylinder.

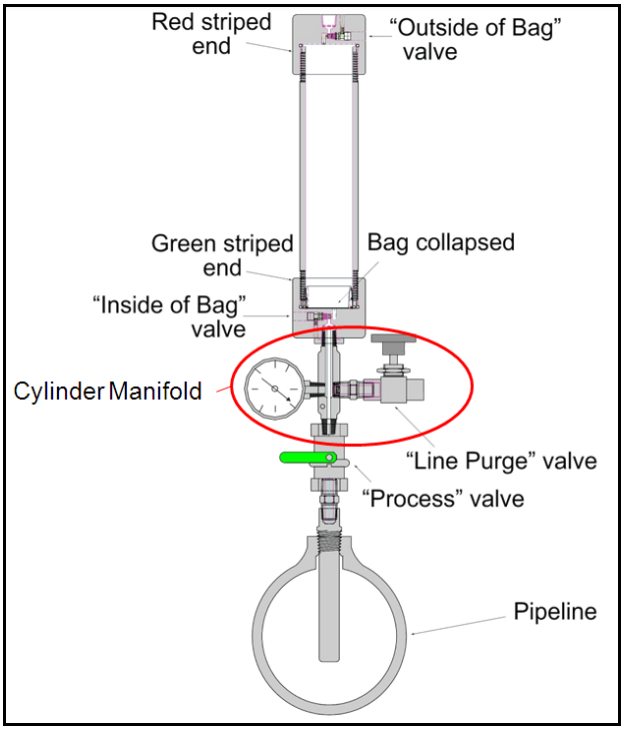

Figure 9- View of Line Purge and Fill Set Up- Start Condition

Although the Q2 sample cylinder and Line Purge and Cylinder Fill sample method are new technology, they have been tested by and conformed to the API 14.1 sampling protocol. In October 2008 the Pipeline Research Council International (PRCI) sponsored research in Casper, Wyoming, which tested the accuracy and reliability of the Q^2 along with other types of sampling equipment. This research was managed and reported by Dr. Darin George of South West Research Institute (SWRI). The protocol for this research was drawn from the industry standard API Chapter 14.1, Appendix F (the API Sampling Protocol), which means that sampling equipment and their methods which successfully comply with this protocol would necessarily comply with API Chapter 14.1.

The conditions of the test were such that both the ambient temperature and the sampling equipment's temperature were below the hydrocarbon dew point (HDP). The tests concluded that the new equipment and its method satisfied API's repeatability and reproducibility criteria. As such, the Q^2 Sample Cylinder can officially be declared as conforming to API 14.1 standards.

Key Recommendations for Spot Sampling

Following is a list of general recommendations for properly accomplishing the spot sampling task.

- Have a good understanding of the basic physics and chemistry involved in the spot sampling process.
- Use a probe to extract the gas sample. If liquid is likely to be present, use a phase separation membrane tip probe.
- Attach the sample cylinder as close to the sample source as possible by avoiding the unnecessary use of tubing and fluid handling components such as the GPA separator, coalescing filters, etc.

- Since the major source of error in spot sampling occurs during purging of the sample cylinder, utilize a sample collection method (Helium Pop or Line Purge and Cylinder Fill) or cylinder technology (Constant Pressure or Q2) that does not require purging.
- Purge the sample line for the minimum time required to fill it with a representative sample.
- Stay abreast of current industry standards and new spot sampling technology

Summary

The process of obtaining a representative spot sample is critical to the correct assessment of its monetary value. Many problems were identified which have a significant impact on determining the correct composition of a natural gas source when certain spot sampling methods or cylinder types are employed. When sampling from multi-phase natural gas sources, in cold climates, or gas having a high hydrocarbon dew point, special attention should be given to selecting the appropriate sampling method and cylinder technology. More attention needs to be paid to industry standards, and technicians need more and better training. Manufacturers should be encouraged to produce more and better products.

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