TECHNIQUES FOR SPOT SAMPLING GAS

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Introduction

While inaccuracies in measurement can be costly and common, they are also avoidable in most cases. Technicians willing to study the experiences and best practices of industry leaders can make a world of difference by applying what they've learned and sharing the knowledge shared in this paper with others. This paper aims to describe spot sampling as defined by industry standards, and discuss important factors that may impact accuracy when taking a spot sample.

A Starting Point

The first step towards proper spot sampling is to develop a solid grasp of what 'representative' means in a measurement context. Simply put, a representative sample is nothing more than a volume of natural gas whose makeup is consistent with the pipeline flow from which it was taken. If there is a single area of measurement that is most responsible for inaccuracy, it must be the process by which products are moved from inside the pipe to inside the cylinder. If no care is given to preserving the sample's representative nature, there should be no expectation of accuracy.

The standards that speak to this are API 14.1 and GPA 2166.

For a sample to remain 'representative' according to these widely accepted standards it must:

1. be compositionally identical, or as near to identical as possible to the sample source stream
2. remain above the hydrocarbon dew point once in the sample system
3. represent only the composition of the vapor phase portion of the system being analyzed

According to API 14.1, "The main consideration in the design of a natural gas sampling system is to deliver a representative sample of the gas from the sample source to an analytical device," and the reason these samples are so important is their close relation to the bottom line.

Once the importance of maintaining the representative nature of a sample is understood, the next step is to understand the monetary value of natural gas is determined not only by volume, but also by its heating value. Natural Gas is made up of numerous constituents, each with different qualities. Consider gold, copper and silver coins: Should one consider a pound of gold coins to be worth the same as a pound of copper ones? If a box of mixed coins was offered, wouldn't it be wise for the buyer to understand the mix? This is the nature of the energy industry. No two wells are exactly alike. They produce products with different mixes that must be measured and accounted for on the basis of volume and value. The methods for collecting this information each have their own place.

Spot Sampling and The Other Techniques

There are three primary techniques of capturing a representative sample.

Spot Sampling only provides a representative sample for a specific point in time. It is commonly used for applications with very low flow rates, or to discover estimated energy values in applications like well testing. It's like a photograph of a sporting event: It doesn't provide the story of the whole game, just a moment. Unfortunately spot samples cannot fully represent a gas stream of varying composition according to API 14.1, so they are not the first choice in situations where swings in value occur.

When a snapshot simply is not good enough, composite sampling is the next step up. It is commonly used to balance plant volumes, measure natural gas collected at different points in a gathering system, allocate production to producers in transmission applications, as well as measure value at custody transfer points. A composite sampler collects small grabs of a flowing gas, based on intervals of time or flow, to represent what was flowing in the pipeline for a given sample period. Imagine a recording of the game. It's better than a single picture. The more frames you have, the more information you have, but it's not live information.

There's nothing like being at the game though. When real-time, live-action analysis is needed, Online Chromatography is a must. It puts the Gas Chromatograph in the field, skipping the proverbial middle man, but having a GC at every location would be costly. The instrument itself is only part of the cost. The representative nature of the sample must still be maintained. GC's often require a tremendous amount of expertise to maintain, and require a certain environment to perform correctly which can be too costly for a lower flow location.
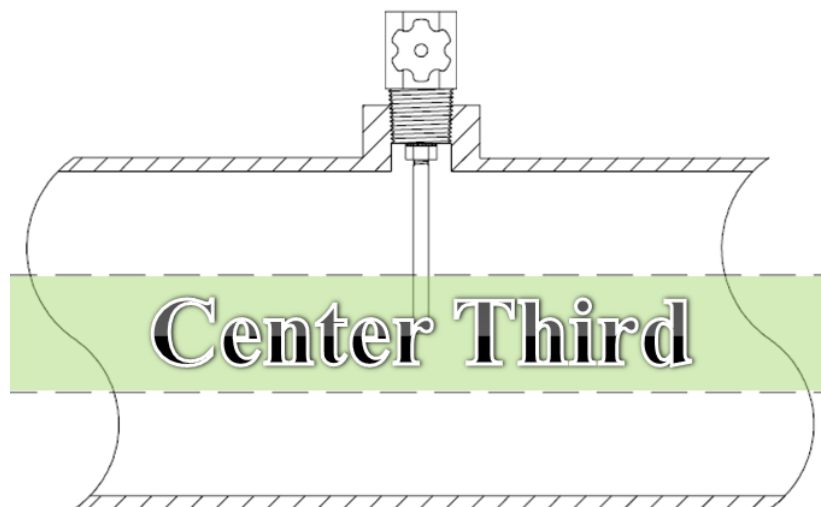
<u>Probe Location</u>

Pipelines are sprawling webs of gathering, transmission and distribution. These vast networks are stabbed and dotted with temperature probes, orifice plates, 90° bends, dead-ends, or worse. These obstacles can make it challenging to find a viable sample point. In short, look for the longest, straightest portion of the line. , but here are some more guidelines (see Figure 1):

1. Avoid dead-ends where gas is not flowing.
2. Sample at least 5 obstruction diameters downstream of any obstruction (orifice plates, pipe bends, fittings, valves, etc.), because turbulence can stir liquids into aerosols that result in liquids finding their way into your sample. Inclusion of liquids makes for a non-representative sample.
3. Make sure your probe is in a vertical position to allow gravity to assist in shedding liquids (API 14.1 7.4.2).
4. The tip of the probe should extend to the center third of the pipeline (or up to 10" in large pipelines) to avoid contaminants along the wall, and take advantage of positive velocity and less turbulence. This is a common industry practice, but 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. At very least, make sure you are 2 inches off the pipe wall.
5. It is also best to be as close to any pipeline separator as possible, so heavier constituents don't condense before they make it to the sample point.
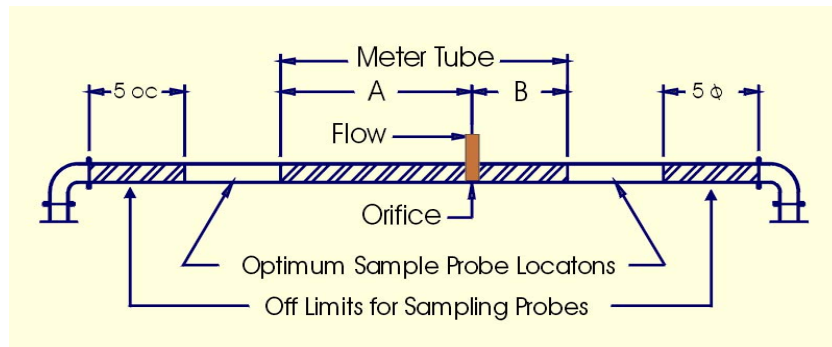

Figure 1. **Optimum Sample Probe Locations**

Figure 2. Sample Probe Insertion Depth

Probe Type

Once the proper location and depth are found, the next step is to select the proper probe type.

First and foremost, use a membrane tipped probe whenever possible. The presence of liquids can be unpredictable. GPA 2166-05 Appendix B.1.8 states, "To effectively separate the unwanted liquids and to collect a representative sample of the vapor phase of the product stream, it is imperative that any liquid separation device operates at flowing temperature and pressure conditions." Further, GPA 2166-05 B.2.1 correctly notes that, "The insertion membrane filter probe meets the requirements set forth in B.1.8 in that the membrane filter is directly mounted in the product stream," (see Figure 3).

Probes can be permanently installed, can include housings that are permanently installed but allow for removal of the probe for maintenance without blowing the line down, can be fully retractable, and can be portable. Selecting the right probe can not only improve accuracy, but also make life much easier operationally.
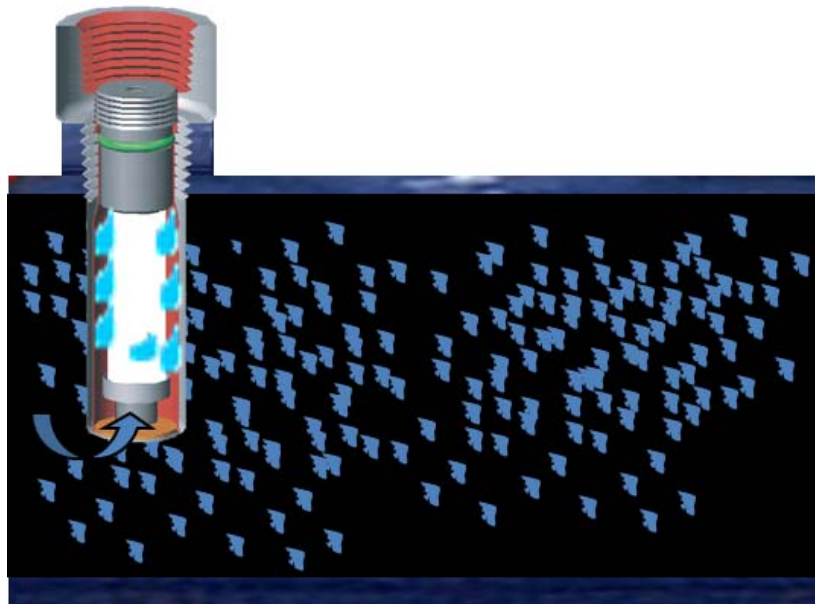
Figure 3. Rejection of Liquids at Pipeline Pressure and Temperature

Resonant vibration, triggered by vortex shedding at high gas velocities, can cause probe breakage. A table and calculation provide a means for determining the maximum probe insertion depth for a given probe design (see Figure 4). More information on this subject can be found in section 7.5.2 of GPA 2166, or section 7.4.1 of API 14.1. These standards also recommend using probes less than ten inches in length between the point of attachment and the probe tip.

Probe Outer Diameter (inches)	Recommended Max Probe Length (Inches)
0.25	2.00
0.375	3.25
0.50	4.25
0.75	6.50

Table 1. Probe Diameter for Varying Lengths

Square cut probes are preferred over angled, because an improperly installed angle probe (short side facing upstream), could force liquids into the system, rendering the sample non-representative.

The Spot Sampling Task

When a "snapshot" in time is suitable, or on sources whose flow rate is too low to economically justify a composite sampler or on-line analyzer, spot sampling is commonly used. Spot samples can also be used to confirm the compositional analysis from an on-line analyzer.

Several methods are detailed in GPA 2166-05, for collecting spot samples. The common methods used today are the Fill and Empty method (Section 6.1), and Helium Pop method (Section 6.5), but it's wise to understand each:

1. Fill and Empty: Cylinders that contain atmosphere that must be forced out by filling and emptying a specified number of times without allowing atmosphere to seep back in.
2. Controlled Rate: Cylinders that contain atmosphere that must be forced out by allowing product to flow through the cylinder for a specified amount of time, depending on line pressure.
3. Evacuated Container: The Cylinder is provided with the ratio of 760 to 1 standard atmosphere or 1 mm Hg, a technical way of saying that it is virtually empty. The system must still be purged up to the cylinder before opening it to the sample system.
4. Reduced Pressure: This method is primarily used when your sample system cannot withstand the force of pipeline pressures. It also uses an evacuated cylinder, but pressure is reduced before the sample bottle.
5. Helium Pop: An evacuated cylinder is filled with 5 psi of helium, which is inert and doesn't impact BTU value determination.
6. Glycol or Water Displacement: Bottle is filled with one of the two mentioned, which must be forced out completely by the pipeline gas.
7. Floating Piston Cylinder: A piston forces out the contents of the sample chamber which is carefully vented as the precharge chamber on the other side of the piston is filled. When the sample chamber is connected to line pressure, the precharge chamber is slowly vented, filling the sample chamber with a representative spot sample. New techniques use a collapsed bag rather than a piston.

Among the techniques listed above, Fill and Empty and Helium Pop are also used to ready a cylinder for use with a composite sampler. Each of these methods has advantages and disadvantages (see Figure 5).

Method	Advantage	Disadvantage
Fill and Empty	Little Preparation- Cleaning only Inexpensive equipment	Residual Contamination Possible condensation problems Inconsistent execution of method
Controlled Rate	Little Preparation- Cleaning only Inexpensive equipment	Residual Contamination Possible condensation problems Inconsistent execution of method
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
Glycol or Water Displacement	No air in cylinder to purge, constant pressure	Rarely used- susceptible to contamination
Floating Piston Cylinder	No air in cylinder to purge, constant pressure	Cylinder is difficult to clean and lube

Table 2. Advantages and Disadvantages of Sample Collection Methods

When purging is required, purge with a pigtail (see GPA 2166-05 9.1). Pigtails Provides thermal isolation so that Joule-Thompson effect does not cool the sample cylinder during purging. Typically, at least 3 feet of ¼" tubing and a throttling device (valve and/or orifice-1/16" or 1/8" diameter) downstream of sample cylinder is sufficient. If the pigtail is coiled, make sure there are gaps between coils to prevent thermal coupling. Unfortunately, using a pigtail does not keep sample from cooling and condensing in cylinder when ambient temp is below the sample's hydrocarbon dew point.

Sample Conditioning with Heat

The Hydrocarbon Dew Point is that point (at given pressure and lowest temperature) at which liquids begin to condense. API 14.1 suggests a 30ºF buffer zone due to the uncertainty in measuring or calculating the hydrocarbon dew point.

API 14.1 section 6.6.6 says that the entire sample should be maintained above the Hydrocarbon Dew Point, even the sample cylinder, to ensure the composite sample is representative. To quote the standard, "Tests conducted under actual field operating conditions have shown that composite sampling systems do not consistently provide representative samples when exposed to ambient temperatures below the sample gas hydrocarbon dew point."

GPA 2166-05 section B.1.7 also acknowledges that natural gas products at their Hydrocarbon Dew Point that experience even slight changes in temperature or pressure can see liquids vaporize or vapors condense. It's necessary to reiterate that in either noted case, the sample is no longer representative. The BTU value is either biased high if heavier constituents vaporize, and biased low if they drop out.

But if a representative sample passes through a functioning membrane probe, preventing liquids in the pipeline from entering the sample system entirely, the issue of vaporizing liquids becomes irrelevant. All that is necessary at that point is to prevent new liquids from condensing by establishing a temperature 30ºF above the expected hydrocarbon dew point throughout the system.

API 14.1 section 13.1.4 also mentions that the sample line between the sampler and cylinder should be a short as possible, heated and insulated to avoid condensation.

Installation and Materials

Once the sample point, probe type, mounting location and hydrocarbon dew point requirements have been determined, there are still some minor details to attend to in order to preserve an accurate system.

Stainless Steel, or other materials that don't interact with constituents, should be used to finish the connections. According to API 14.1 section 10.2, heavier components and contaminants such as CO_2 , N_2 , and H_2S stick to carbon steel and other porous materials. This reaction with these contaminants found in the pipeline can also cause errors in the analysis. Furthermore, sample valves, cylinders and other parts made from carbon steel and other materials have proven to have dangerously high corrosion rates.

It's also important to shorten lines to avoid dead volume and condensation and avoid low spots where liquids can pool. Also avoid bends over 45° which can cause flow resistance (API 14.1 section 13.1.4).

The maintenance of sample bottles is also important. See GPA 2166-05 Appendix A for more details, but here are some points of note:

1. Good Valves (GPA 2166-05 section A.1.1, A.1.5)
2. Clean with Wet Steam and Evacuation (GPA 2166-05 section A.3.1-5)
3. Helium pop if possible

Challenges

There are many challenges faced when relying on spot sampling.

Spot sampling technology is not always as advanced as analytical and flow measurement technology, and spot sampling systems have not traditionally been a "product" provided by a single supplier, but rather an amalgamation of components assembled by the user. In many cases, this results in an error prone system.

Sampling from a 2-Phase natural gas source is also challenging. As noted, to comply with the standards, the liquid portion of the stream should be rejected at flowing conditions, allowing only the gas (vapor) phase of the source to be collected. The gas will be saturated near its hydrocarbon dew point, so any cooling will result in condensation of the heavier components. When sampling a gas having a high hydrocarbon dew point, even minimal cooling can drop a sample below its dew point, erroneously enriching the sample. As noted, heating the sample cylinder and tubing can help keep the sample above the dew point. Sampling in cold climates is also challenging and requires heating of the system. Contact with cold sampling

equipment can cause the sample gas to cool below its dew point and condense in the cylinder, erroneously enriching the sample.

Still, the purging of the sample cylinder is the most problematic area of spot and composite sampling. It can't be emphasized enough, when using the methods that require purging, care must be taken to keep the sampling equipment 30F above the source gas temperature to prevent the heavy components from condensing. If the right number of purge cycles aren't performed, or if the purge isn't long enough, residual gas from previous samples or air could also alter the composition of the current sample. And don't forget, there are 2 separate volumes that need to be purged; the sample path and the sample cylinder. Typically, the volume of the sample path is only a fraction of the volume of the sample cylinder, so purging the sample path happens very quickly. This is why most of the purging error is a result of purging the sample cylinder. The purging methods are very susceptible to interpretation differences and possibly inconstant procedures followed by individual technicians. Too much or too little purging of the sample volume can be problematic. Too much purging means more emissions and a greater likelihood that variations in pressure, temperature and heat transfer will cause sample distortion. Too little purging assures that the sample will remain contaminated. Technicians are left with the nearly impossible challenge of purging exactly the right amount of gas for the appropriate amount of time for every circumstance. Even the most detailed cylinder purging procedure can be executed differently and produce different results.

Shale gas also provides a challenge. Each shale formation, and sometimes different locations within the same formation, can have unique processing and sampling requirements because of the wide variance in composition. There can be a wider range of hydrocarbon components, wider span of BTU value, and higher levels of water vapor and other contaminants than pipeline tariffs or purchase contracts typically allow. Hydrocarbon dew points can vary just as widely and are difficult to measure and predict with equations of state, making it difficult to select the appropriate sampling components and determine proper heating requirements. Shale gas streams containing high levels of contaminants are also being treated. Various chemicals (methanol, scavengers, corrosion inhibitors, etc.) are being directly injected into the gathering lines and processing plants to handle the contaminants contained in these streams. This poses yet another challenge for traditional sampling equipment.

Industry Standards

An understanding of the standards and how to apply them is the bedrock of good measurement.

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
Manual 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.

Summary

To paraphrase the late/great Don Mayeaux, gas chromatographs are not clairvoyant. They will provide garbage out if garbage is provided in. Thorough training, proper maintenance and adherence to the standards are a step in the right direction in the pursuit of good measurement.

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