TECHNIQUES OF GAS COMPOSITE SAMPLING

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Introduction

While inaccuracies in measurement can be costly and common, they are also avoidable in many 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 this knowledge with others.

Composite sampling is a straightforward method. When managed correctly, samplers are able to take small bites of a flowing gas or liquid in such a way that the complete sample accurately represents what was in the pipeline for a given sample period.

Composite sampling continues to be a widely used method for economically and accurately collecting a representative sample for a prolonged sample period, so it is important for technicians in the field to develop an understanding of the best practices.

A Starting Point

The first step towards an understanding of composite sampling is developing a solid grasp of what 'representative sample' actually means. 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 composite and spot sampling are API 14.1 and GPA 2166. For a sample to remain 'representative' according to these widely accepted standards it must meet these criteria. It must be:

1. 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." The reason these samples are so important is their relation to bottom line.

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.

Sampling Techniques

As mentioned before, Spot Sampling requires individuals to manually capture a sample, and only provides a 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.

Because a cylinder is still used to collect samples in composite sampling, some techniques used in spot sampling carry over. Techniques of Spot Sampling should be attended for more detail, but here are some notes that also relate to use in composite sampling.

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, Helium Pop, and Floating Piston Cylinder are all commonly used to ready a cylinder for use with a composite sampler.

Online Chromatography is used in applications where associated costs are justified by large enough volumes. They are also used in applications where real-time analysis is needed. Remember that the samples collected in composite sampling also end up feeding a gas chromatograph somewhere.

Composite sampling 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.

Misapplication

First is the choice of sampling technique. Spot sampling, Composite Sampling and Online Chromatography each have their respective places in the energy industry. A basic understanding of their related and independent roles is vital to properly identifying which is right for any given application

1. For example, 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.

2. Gas Chromatography on the other hand is excellent at measuring these changes in real time and should be considered for applications where flow rates justify the additional cost, but they often require a tremendous amount of expertise to maintain. They also require a certain environment to perform correctly which can be costly to maintain for a lower flow location.

3. Composite Sampling can be misapplied as well. API 14.1 says "Time proportional samplers, particularly if they continue to sample even when flow has stopped, are not capable of accurately characterizing natural gas streams that have variable compositions." API 14.1

The Fundamentals

Once the proper method of sampling has been identified, learning how to take a representative sample is imperative. If a composite sampler is improperly setup, it can easily become a glorified spot sampler. Likewise, a spot sample can be worse than no sample at all. The most impactful step would be to develop an understanding of the industry standards (API 14.1 and GPA 2166).

Attend hands-on classes and read the equipment manuals to glean important details about proper installation steps and gain an understanding of the components. Manufacturers represented at ISHM participate in these schools as students and teachers. Great efforts have been made to make sure the knowledge gained and shared here is 'built in' to the recommended process and installation notes documented in the various manuals.

At a surface level, it's important to recognize that most Composite Samplers include four simple components:

1. Manifold/Probe Body- These allow the sample to make its way to the pump and filter/regulator

2. Sample Pump- Responsible for compressing specific volumes into the cylinder.

3. Filter/Regulator- Separate from the sample stream but using gas from the probe, the Filter/Regulator regulates and removes any particulate and moisture from the actuation gas. Properly conditioned actuation gas allows for proper pump function.

4. System Controller- When connected to a solenoid, the system controller can react to time or flow to harness the actuation gas supplied by the filter regulator and cycle the pump.

A technician that understands these fundamentals is more likely to achieve accurate sampling

Sample Pacing

In composite sampling, understanding the flow condition to ensure the sampler is configured properly for 'proportion to flow' sampling is paramount. Samplers can be configured to take bites on a timer or react to a pulse based on flow conditions. Samplers can be set in proportion to time only when flow rates are continuous and consistent, essentially circling back to being 'proportion to flow.'

Typical applications are these:

1. Continuous flow with Constant Volumetric Rate: Time based sampling is sufficient, because the method is still proportion to flow thanks to consistency and predictability. In this case the sampler will stroke on a time interval calculated based on a known flow rate, pump displacement, and cylinder volume.

2. Intermittent flow with Constant Volumetric Rate: Time based sampling is sufficient as long as the sampler can be interrupted when there is no flow. A simple on/off switch is needed.

3. Fluctuating Volumetric Rate with electronic measurement: When a flow meter is available, the controller can react to pulses that determine the time between strokes. This allows the sampler to adapt to different flow rates and maintain flow-proportional sampling.

4. Fluctuating Volumetric Rate without electronic measurement: Some sampling systems are equipped with their own transmitters to detect differential pressure and react to changes in flow rate.

Consider this from API 14.1 section 14.2 on the proper Setup using flow rather than time where necessary or possible: "In choosing the method to be used in pacing the sampler, the sample source stream is the primary concern. Flow proportional composite sampling systems are most likely to produce a representative sample. If the stream has a constant composition or flow rate, a time pacing mechanism may be used. Provisions in time based systems must be made to stop sampling when there is no flow."

Area classification should also be considered when connecting measurement equipment. Intrinsically safe barriers may be required.

Probe location

Pipelines are sprawling webs of gathering, transmission and distribution. These vast networks are stabbed with temperature probes, orifice plates, 90° bends, dead-ends or worse. All of these things make it challenging to find a sample point. The point to sample is in the longest, straightest portion of the line. Here are some guidelines:

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.

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.

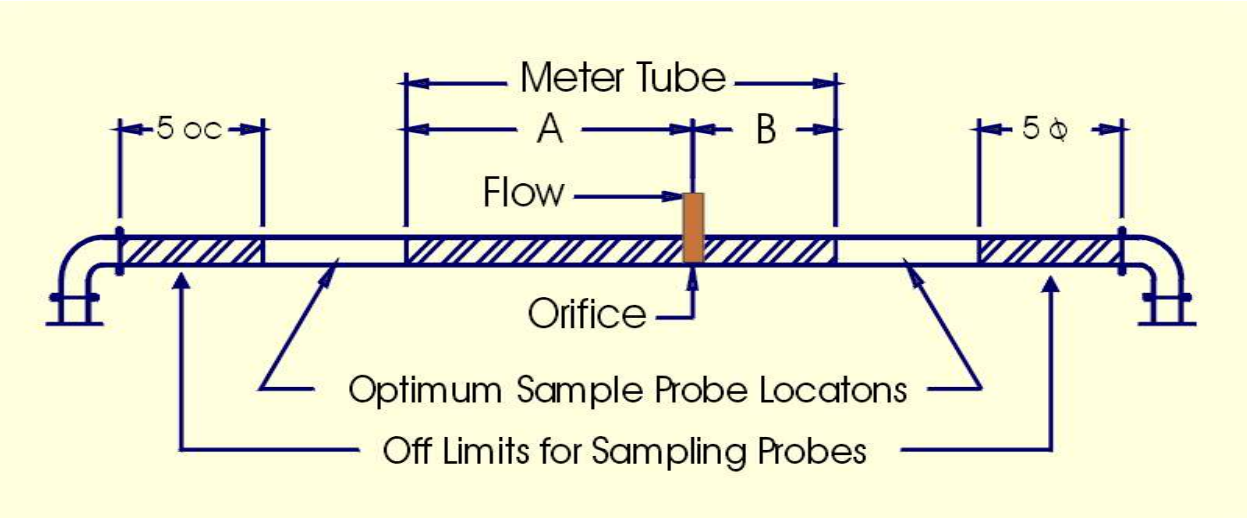

Figure 1; Optimum Sample Probe Locations

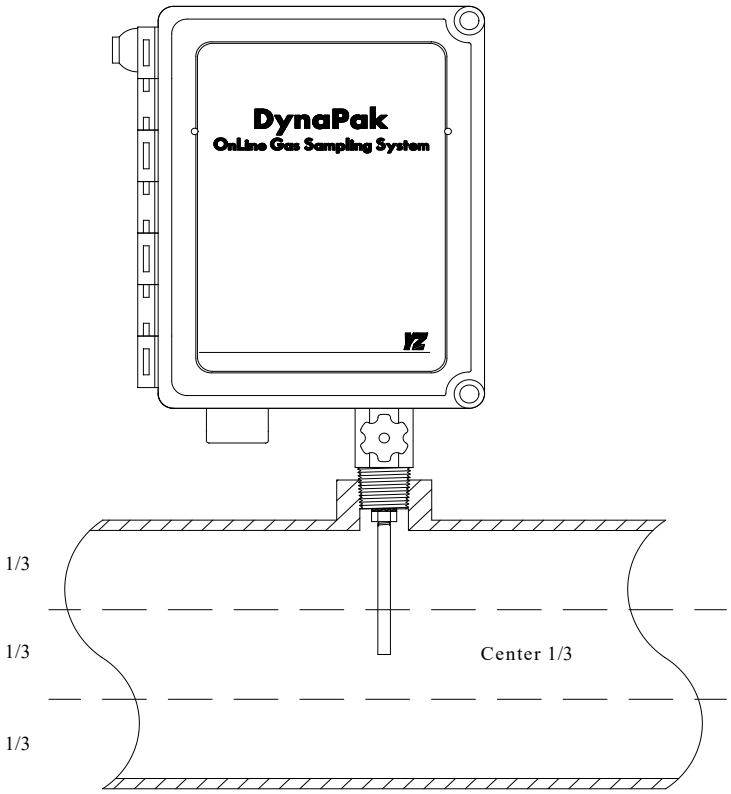

Figure 2; Sample Probe Insertion Depth

Probe and mounting configuration

The Proper location for the sampler is a close to the probe as possible.
Direct Mount provides the shortest distance from the sample point to the bottle, resulting in the freshest sample. Remote Mount is only recommended when Direct Mount is simply not possible, because dead volume between the sample point and the sampler can bias the sample and even result in a very expensive spot sample in some cases. Long tubing runs also expose the sample to the environment which can result in retrograde condensation. Again, any time liquids are condensing, the sample is no longer representative.
Heavy wall probes can prevent damage from velocities that can shear the probe off or harmonics that can vibrate it off.

Single Flow Probes have a single passage in the probe, but can also be used with a slip stream system that can create a positive sample flow by reducing pressure at another point no more than 36" downstream, allowing the natural gas to return to the pipeline.
Dual flow Probes accomplish a slipstream as well but have two passage ways through a single probe, allowing that positive sample flow to occur at one threadolet.
Use a membrane tipped probe whenever possible. 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."

Figure 3; Direct Mounted Sampling System with EFM

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.

Figure 4; Heated Sampling System

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 2 S 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

Lastly, purge with a pigtail if necessary to avoid Joule-Thomson Effect (see GPA 2166-05 9.1)

Summary

There are resources abound for learning the proper way to obtain a representative sample. These resources indicate that where online, real-time analysis is not economical, composite sampling is an affordable and accurate solution. Take advantage of the knowledge shared at this School to deploy your composite sampling system with confidence.

References

Advances in Natural Gas Sampling Technology ASGMT, Donald P. Mayeaux

Techniques of Gas Spot Sampling ISHM, David Fish

Techniques for Natural Gas Sampling ASGMT, Kris Kimmel

Manual of Petroleum Measurement Standards. Chapter 14- Natural gas Fluids Measurement, Section 1-Collecting and Handling of Natural Gas Samples for Custody Transfer, American Petroleum Institute, Washington, D.C., February 2006

Lessons Learned from the API 14.1 Gas Sampling Research Project, ASGMT, Darin L. George and Eric Kelner

Testing of Natural Gas Sampling Methods at Hydrocarbon Dew Point Conditions (Contract PR-015-08603), Pipeline Research Council International, Inc., Darin L. George

Obtaining Natural Gas Samples for Analysis by Chromatography, Gas Processor's Association Standard 2166-05

Techniques of Gas Spot Sampling Presentation, A+ Corporation, Charlie Ramsey

Techniques of Gas Spot Sampling ISHM, Shannon Bromley