TECHNIQUES OF COMPOSITE GAS SAMPLING

David J. Fish
Welker Engineering Company
13839 West Bellfort
Sugar Land, Texas 77498
U. S. A.

INTRODUCTION

The level of interest in effective and accurate gas sampling techniques is currently at a very high priority within the natural gas industry. With the fluctuating ranges in natural gas prices, exploration interests, profitability, deregulation and consolidation of the work force, recoverable revenue must be accounted for. At large volume delivery points, a 3-5 BTU error in energy determination can cost companies tens of thousands of dollars within a very short time period. Accurate sampling techniques must be implemented with equal interest as is given to accurate volume measurement. MMBTU is the total of volume and energy. Sampling is the energy determination delivery system for this equation.

Proper knowledge and correct implementation of the primary methods of sampling will provide a quality minded sampling program for the measurement personnel in natural gas companies.

The amount of hydrocarbon product that is transported between producer, processor, distributor and user is significant. To be able to verify the exact composition of the product is important from an economic and product treatment standpoint. A small percentage of savings made by correctly determining composition will quickly recoup the investment made in the purchase of a system designed to obtain an optimum sample. In addition, if the best sampling procedures are followed, the potential for disputes between supplier and customer will be greatly reduced. The importance of properly determining hydrocarbon gas composition, benefits all parties involved and will achieve greater significance as this precious commodity becomes less plentiful and more expensive.

Sampling is an art. It begins with the proper selection of the method and procedure for a given location. Then comes the correct selection of the equipment to be used for that installation. Proper installation and operation of the chosen apparatus will determine whether a representative sample is taken. The technician should be trained in the procedures that will be used and how to carry out the entire sampling operation. A solid understanding of the rules and regulations surrounding the transportation of the collected sample, will assure compliance with rules. The end result will be an accurate and repeatable sampling procedure to provide a representative sample to the laboratory and an analysis that can be trusted as correct.

GAS SAMPLING

The definition for sampling from the Gas Processors Association publication GPA 2166-86, is as follows, "The object of any sampling procedure is to obtain a representative sample of hydrocarbon from the system under investigation. Any subsequent analysis of the sample regardless of the test, is inaccurate unless a representative sample is obtained." And, from ISO-10715, a representative sample is, "A sample having the same composition as the material sampled, when the latter is considered as a homogeneous whole." API 14.1 offers a similar statement in the latest revision, "a representative sample is compositionally identical or as near to identical as possible, to the sample source stream." These standards are the most common referenced on Gas Sampling procedures, along with the AGA Gas Measurement Manual, Part No. 11, Section 11.3 and ASTM 5287-97.

Proper sampling is fundamental to the correct determination of the product composition. In a majority of cases, the sample is also the source for the determination of the specific gravity of the gas. This figure is a critical component of the flow formula, from which we derive the product quantity. An error in sampling effects both quality and quantity, and ultimately, profitability.

Natural Gas sampling has been performed for years with techniques handed down from generation to generation. Many of the older methods are not sufficient to meet today's requirements of accuracy and repeatability; however, standards have been developed to reach toward these demands. The most widely known standards are GPA-2166-86 and ISO-10715. API has produced a revised API 14.1, which was published in June, 2001. This new standard has already generated significant interest in proper sampling techniques, due to a large volume of data produced during the revision work.

Proper maintenance of all sampling equipment is vital to the operations of all sampling methods. A review of relative sampling standards and the manufacturer's operation, installation and maintenance manuals, is an important step the total accurate sampling process. Dirty or poorly maintained sampling apparatus will adversely affect the final results and profitability of the gas company's operation.

SAMPLING COMPONENTS

Sampling can be accomplished by primarily three techniques; spot, continuous composite or continuous on-line sampling systems. Our concern in this paper is with the composite sampler system. The various components of a composite sampling system deserve individual consideration before the sampling system is installed and initiated.

Regulators - Composite Samplers use instrument regulators for instrument supply only. A composite sampler main body should be designed to operate under full line pressure so that the process is not regulated in pressure prior to the sample being taken. The regulator should be capable of handling the full line pressure and, the gas composition and contaminants

Relief valves - Regulators should have a relief valve installed downstream, if the equipment downstream is not able to withstand full upstream pressure. Most sampler actuators need a regulated and protected instrument supply. Regulators will not always give a guaranteed shut-off and their lock-up pressure will climb to a dangerous level should there be failure to attain a good shut-off as a result of seal damage, diaphragm damage or impurity build-up on working parts and sensing lines.

.

Valves - If shut-off/isolation valves present a restriction that causes a pressure drop, it is possible that condensation could occur. When used with a collection cylinder it is important that there are no leaks from the gland. Light ends will be the first to leak off, thereby causing the sample to be over-represented with heavy ends. It is wise to use valves with soft seals to give a positive shut-off. Large orifice valves should be used, as restrictive valve paths can cause fractionization of the sampled gas.

Filters - Filters should be carefully chosen, if used at all. It is not wise to filter the pipeline gas prior to taking the sample, as alteration of the gas is a possibility. A filter on the instrument supply, downstream of the sample grab point, is acceptable.

Pipework - Should be as short and as small in diameter as possible. It will help maintain the sample integrity. Probe and lead lines to continuous samplers should slope back towards the pipeline. All connections must be leak tight!

Heating Elements – There is sufficient evidence to show that heating all components of a sampling system is frequently a prudent step in having a reliable and accurate sampling system. The hydrocarbon dew point of a natural gas stream is a critical issue in obtaining a representative gas sample.

Probes - The use of a probe is imperative in proper sampling. Without the use of a probe, an accurate sample is not likely to be taken. The probe may have a bevel or be cut flat across the end. The probe itself is typically 3/8 inch tubing, but can be larger in some cases. The probe should be equipped with a full open ball valve or gate valve, or large ported valve. Do not use a metering valve or small orifice valve. The probe design must be checked for wake frequency and bending moment calculations, to insure that it is structurally sound in design. The correct placement is at the top of the pipe, into the center one third or at least 200 mm (8 inches) for larger diameter pipes; in an area of minimum turbulence, that is to say, away from headers, bends, blow-down stacks, elbows, traps, valves, etc. Turbulence will stir up the contaminates that usually reside at the bottom of the pipeline and are therefore not normally part of the gas stream. By having the probe at a point of turbulence these contaminates will be taken into the sample, thereby providing a sample that is not representative. Probe placement should be in a flowing and non-turbulent spot in the pipeline.

Sample Pump - These pumps are, of course, needed to extract the sample from the line and transfer the sample to the analyzer or collection cylinder. They should have the capability to be able to extract the sample under flowing conditions, maintain a consistent discrete size of sample, take a fresh purged sample every time and have the ability to be controlled by a timer or proportional-to-flow controller. This forms the heart of the continuous gas sampling system. If the pump or sampler is unable to perform all these functions, a representative sample will not be taken and the sampling exercise will be flawed.

Pumps can be either pneumatic or electric. The safety requirements of the electrical components such as motors and solenoid valves and the environmental protection rating, dictate careful selection and compliance with applicable codes. The selection options may well be limited if electrical components have requirements which are incompatible with the use of standard components elsewhere in the system.

Sample Cylinders - Used for the collection of gases and light liquid hydrocarbons, sometimes called "sample bombs". The cylinders come in two forms; one is a plain single cavity cylinder with a valve at each end, and the other is known as a Constant Pressure Sample Cylinder, which takes the form of a closed end cylinder with an internal piston. Using the Constant Pressure Cylinder the sample can be collected at a pressure above the vapor pressure of the light ends. By having the piston at the end of the cylinder, the need for excessive purging is eliminated. Pulling a vacuum in the sample cylinder (which is often destroyed by technicians) or using the water outage method is not necessary. The hook-up is simple and straightforward making the operation easier for technicians and minimizing the possibility of an incorrect sample being taken.

The need for maintaining the gas at full line pressure from beginning to end has been recognized as a positive feature for several years. Any reduction in pressure and change in temperature from the line condition at the time of sample, was deemed to alter the gas analysis in almost every case. Only low BTU gas (1000 BTU and below) seemed to possibly escape alteration.

Then, once the cylinder is in the laboratory, a gas supply can be connected to the pre-charge side equal to the pipeline pressure. As the sampled gas is injected into the chromatograph, the piston is being pushed by the pre-charge gas. While the cylinder is being emptied, full pressure is being maintained and the gas composition is not being altered as a result of pressure reduction. The cylinder can be stored, or sent to another laboratory for confirmation, and when the remaining gas is analyzed, it will give repeatable results, because the condition of the gas is maintained by the constant pressure cylinder.

The cylinder is equipped with valves, safety reliefs and gauges on both ends, and thus the pressure can be controlled and monitored at all times on both ends. The temperature is maintained just as with Standard Cylinders i.e. heating blankets, ovens, or water baths.

The Constant Pressure Cylinder also brings with it, additional safety in handling the sample. No longer do you have to purge the cylinder and vent large amounts of gas to the atmosphere. A brief purge of the sample line up to the cylinder is all that is required. The piston is at the sample end of the cylinder when you commence to fill, so there is no "dead volume" to purge.

Also, because of the design of the cylinder, with seals on the end of caps, it cannot be over pressured to the point of exploding. If the cylinder is over pressured, the safety reliefs will allow the pressure to escape. In the rare event that they fail to work the cylinder will swell and the seals will stop sealing, allowing the product to escape safely.

Constant Pressure Cylinders provide for accurate sampling procedures, better sampling systems, repeatability, safer handling, accurate analysis and storage of samples as well as storage of gas and liquid standards for the laboratory.

All updated ISO, GPA, ASTM and API standards and committee reports, address the proper usage of Standard and Constant Pressure Cylinders for the gas and liquids industry.

Sample cylinders should be constructed with a material that is compatible with the gas. For instance, H_2S can be absorbed into the structure of 316 stainless steel. This will necessitate coating the inside of the cylinder, otherwise the resultant sample will not be truly representative.

Sample cylinders are normally protected with bursting discs. They are less expensive and are lighter weight than relief valves, though their proper selection and replacement should have more importance than is sometimes given them.

With all of the notes on the various components should go the comment which is one of the basic rules of sampling. ***The materials of construction of the sampling equipment that come into contact with the sample are to be compatible with the product being sampled.*** It is normally reasonably safe to use 316 stainless steel and Viton elastomeric components. One should look for these materials in selecting equipment, and ask questions of suppliers about material selections.

HYDROCARBON DEW POINT KNOWLEDGE

An additional major factor in correct sampling procedures is an awareness of the hydrocarbon dew point of the gas stream being sampled. The importance of knowing the HCDP is related to 1). The ambient temperature; 2). The temperature of the equipment being used to collect the sample; and 3). The temperature of the flowing stream. The creation of liquids due to equipment design and equipment temperature must be avoided. Determination of the HCDP of the gas stream can be done by the chilled mirror method or by the use of a number of equation of state models for hydrocarbon dew point determination. There are several programs available such as Peng-Robinson or SRK. The variations of the calculated results between different equations of state are so wide, that it is strongly recommended to add 20° to 50°F (11° to 28°C) to the answers. This is to assure the operator that he is designing his sampling system temperature requirements above the actual hydrocarbon dew point.

COMPOSITE SAMPLING

Composite sampling is the proven middle ground between spot sampling and the continuous on-line analytical gas chromatographs.

A composite gas sampler or gas sampling system consists of a probe, a sample collection pump, an instrumentation supply system, a timing system (timed or proportional-to-flow) and a collection cylinder for sample transportation. Its sole objective is to collect and store over a period of time or volume of flow, a representative composite sample at line conditions, allowing it to be transported to the laboratory for repeatable analysis, without changing the chemical composition, heating value, or physical characteristics of the products being sampled.

This package will mount on a pipeline and collect samples over a desired sample period unattended. For the sake of illustration, a description of a common system is provided here.

A probe should be installed which extends into the middle 1/3 of the flowing stream. This location should be chosen to provide a representative sample of the gas stream, thus devoid of stagnant gas, i.e. blowdown stacks, and devoid of free liquids and aerosols, i.e. downstream of piping elbows or orifice fittings which cause turbulent flow. The probe should have a large ported outlet valve to prevent fractionation, resulting in compositional changes in the gas.

A self-purging sample collection pump designed to operate under pipeline conditions should be located above and as close to the probe as is practical and possible. Filters, drip pots, screens, regulators and such conditioning equipment shall not be placed between the probe and the sampler, as this will affect the representative nature of the sample which is taken. Inlet check valves can also cause the gas to fractionate, due to the restriction it causes in the line.

The sampler instrumentation source can be from the pipeline itself (the most common installation) or from an auxiliary instrument supply.

The timing system can be a simple function timer and solenoid, a proportional-to-flow signal conditioner and solenoid, or simply, a solenoid ready to be connected to field RTU's or other electronic devices capable of providing the desired signal.

The sample collection cylinder can be either a conventional single cavity sample cylinder or the more contemporary piston style, constant pressure sample cylinder. As these cylinders will be transported, they should meet design criteria such as ASME Section 8 or carry approvals from recognized agencies such as D.O.T., DNV, Lloyds, etc. A typical system would include a 500ml cylinder which would be used on a monthly basis to contain 2200+ bites of .2 cc size during the sample period.

Using the grab sampler, it is possible to obtain a representative sample over a pre-determined period. It is the only practical method for collecting a continuous sample. The grab sampler will introduce a set volume, taken in equal amounts to the collection cylinder over a set period and is the preferred method when a representative sample has to be taken over time.

It has the advantage of being able to measure precisely a predictable amount over a given period when using a timer, and can also take samples proportional-to-flow when taking a modified signal from a flow meter.

In addition, the sample is taken from the flowing stream at the system pressure and can be fed into the sampler or sample cylinder at the flowing pressure; thus any change in composition is avoided.

Another feature required of any sampler is that it should not have areas or pockets where residue of previous samples can accumulate and, must take a fresh grab or bite of gas each time it samples.

This then describes a typical continuous composite sampling system, which has been proven to provide a representative sample for analysis. Such systems have been tested against continuous on-line gas calorimeters and gas chromatographs with $\pm$ 1 BTU accuracy for the total sample period, at considerably less cost and maintenance than on-line GC's.

TRANSPORTATION

The transportation of natural gas samples is a very important issue for both the companies that are involved and the individual personnel who are transporting the samples. The United States Department of Transportation (DOT), covers the transportation of samples in CFR-49. Everyone involved in transporting sample cylinders and other sampling apparatus, both to and from sample collection locations, should be familiar with the rules and regulations set forth in CFR-49.

As well as the safety issues, markings and forms that are to be filled out for DOT purposes, other considerations should be addressed as well. Among these are:

- Proper tagging of the cylinder for time, date, location of the sample
- Pressure and temperature of the pipeline source
- Technician who took the sample
- Method used to obtain the sample
- Plugging of the valves and checking for leaks prior to transport
- Protection of the cylinder and sample apparatus during transport, both to and from the sample location
- Temperature concerns during transport, both to and from the sample location – if necessary or required
- Other company procedures that will assist in the success of a quality sample being delivered to the laboratory for an accurate analysis.

CONCLUSION

The methods, techniques, and designs of today's sampling systems should be considered by every producer, shipper, buyer and end-user. Regardless of the application or installation, there is a system which meets your needs, and will effect your company in the profit and loss column. Sampling and metering are the cash register of your company. Sampling is an art! Examine your methods, procedures and needs closely.

REFERENCES

"Proper Sampling of Light Hydrocarbons", O. Broussard, Oil and Gas Journal, September 1977

"Standard Cylinder vs. Constant Pressure Cylinders", D. J. Fish, Gas Industries, January 1994

"Analyzing Heating Value", T. F. Welker, Pipe Line Industry, October 1990

"DOT Requirements for the Transportation of Sample Cylinders", D. J. Fish, Presented at American School of Gas Measurement Technology, September 2001

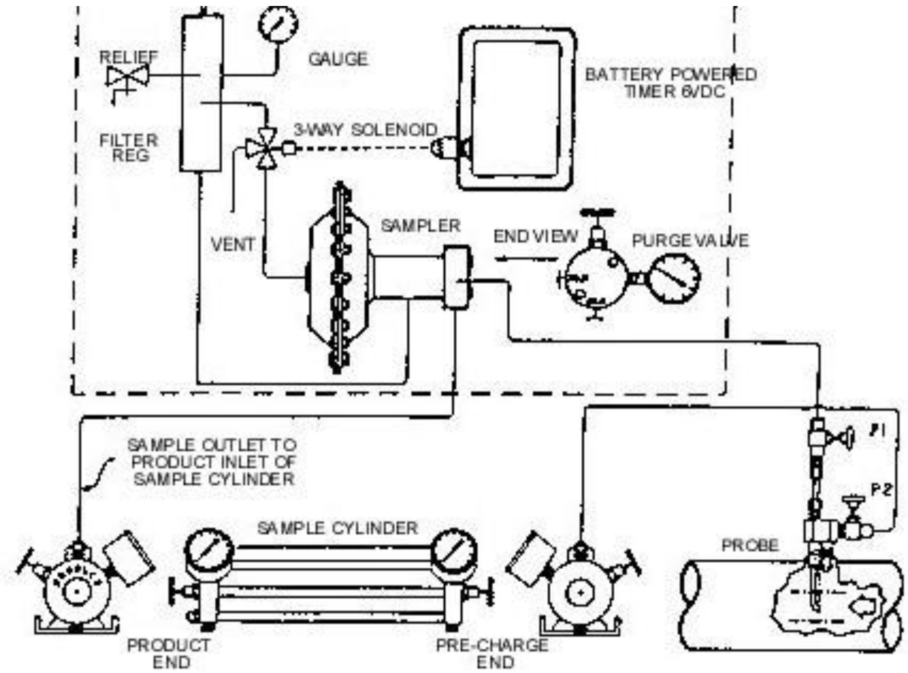
"Natural Gas Sampling", T. F. Welker, Presented at AGA Annual Meeting, Anaheim, California, 1981

"Methods, Equipment & Installation of Composite Hydrocarbon Sampling Systems", D. J. Fish, Presented at Belgian Institute for Regulation and Automation, Brussels, Belgium, 1993

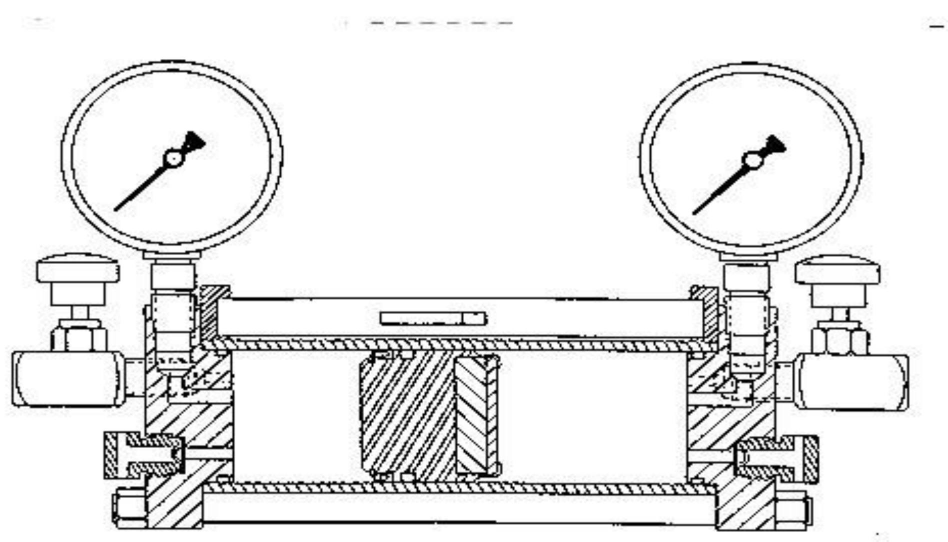
"Practical Considerations of Gas Sampling and Gas Sampling Systems", D. J. Fish, Pipeline and Gas Journal, July 1997

"Selection and Installation of Hydrocarbon Sampling Systems", D. A. Dobbs & D. J. Fish, Presented at Australian International Oil & Gas Conference, Melbourne, Australia, 1991

Various Standards of AGA, GPA, API, ASTM and ISO



TYPICAL GAS SAMPLING SYSTEM



TYPICAL CONSTANT PRESSURE
SAMPLE CYLINDER