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Composite sampling of natural gas

3.4

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COMPOSITE SAMPLING OF NATURAL GAS

Thomas F. Welker
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The sampling of natural gas has been discussed and studied for many years. Serious testing on the proper sampling methods has been done in a number of locations in the recent past. From these tests, it has been determined that the sampling procedures must be carefully prepared and followed. For a person to collect a representative sample of natural gas, the procedures learned in spot sampling operations must be followed.

Continuous sampling is described as a method by which a representative portion of product is removed from a flowing stream and pumped into a sample container during a specific time or volume.

The object of the continuous sampler is to collect the sample in the sample container without changing the chemical composition, heating value, or physical characteristics of the products being sampled.

The continuous sampling system consists of a probe in the line, a sampling pump, a timing device, and a sample container. The continuous sampler is normally a mechanical device that is built to be a practical alternative to an on line analyzing mechanism, i.e., calorimeter, chromatograph, etc. The ease of installation, simple maintenance and reduced cost make the continuous sampler an attractive alternative to spot sampling and/or continuous recording devices.

The objective of any therm billing measurement program integrates accurate metering methods, including sampling, to accurately determine the heating value of the gas as delivered and sold to a customer. The heating value delivered is determined by multiplying the unit volume delivery by the heating value (BTU) of the sample extracted during the delivery period.

Since natural gas is commingled from various sources prior to the actual delivery to your customer, wide variations can occur in the components in the flowing gas stream. A repeatable, representative sample of the "as delivered" gas insures the accuracy of the billing.

An inaccurate method of sample heating value or the application of average figures can cost a gas company millions of dollars in lost revenue and/or contribute to the "lost and unaccounted for" volumes. Proper sampling philosophy can also lend accuracy to the sample analysis chemical composition in determining the correct supercompressibility factors in place of system averages.

The fact that the price of gas is high and the profit margin in your company is low dictates that present accepted measurement methods should be updated to present day metering technology. New equipment may be costly when viewed at its first cost, however, the new equipment may overcome inaccuracies that cost companies thousands of dollars per month per location. Corporate cash flow can be enhanced.

To collect a continuous or composite sample of gas, the following items must not be ignored:

1. Sample point
2. Sample probe
3. Hook-up and manifold of sampler and cylinder
4. Sampler
5. Purging of sampler and cylinder
6. Sample cylinder, cleaning, purging, valving
7. Cylinder transport
8. Leaks on sampler and cylinders and related piping
9. Preventative maintenance of the sampler

To ensure the continuous or composite sampler will give accurate and repeatable results, the above points will be covered briefly.

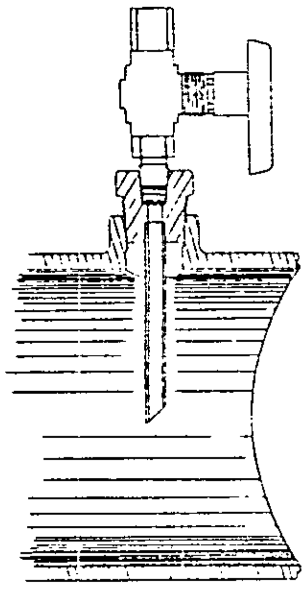
The Sample Point

A sampler is able to produce a sample no more accurate than the sample presented to it. The main consideration in the location of the sample probe is whether it sees the center one-third of the pipeline and whether it is in an area where there is good velocity with minimum turbulence. Turbulence is an aerosol generator and, therefore, liquids put into flight by the turbulence may affect the sample's result. This turbulence makes the liquids moving along the walls and bottom of the pipeline take flight and act as a gas. When aerosols are introduced into the sample container, condensation occurs. The sampler should be located in an area where the gas is moving. A sample should never be taken from a shut in or dead end line. Areas to be avoided are downstream of reduced port valves, control valves, check valves, obstructions and piping fittings. When installing the sampler downstream of an orifice plate, the probe should be as far away from the orifice as possible. Headers and blowdown stacks should be avoided as sample points. Samplers should never be connected to meter manifolds. Install the probe in a straight run of pipe as far away as possible from bends, tees, fittings or any type of obstruction in the line.

A sampler should not be installed without using a sample probe. A representative sample of any product cannot be taken without the use of a sample probe.

Sample Probes

The use of probes in the sampling operation is imperative. Without the use of a probe in the line, an accurate sample cannot be taken. A sample probe should be in the center one-third of the pipeline and equipped with a full open ball or gate valve. The placement of the sample probe is important in all sampling applications. Probes must be kept away from piping elbows, tees, manifolds, reduced port valves and orifice plates.



Design of the Probe

The probe may have a bevel or be cut flat across the end. The bevel on the probe may be faced upstream or downstream. Placement in the center one-third of the pipeline is the most important consideration.

If the probe is in the meter run, the placement should be away from the inlet elbow and as far downstream of the orifice plate as possible.

Headers and manifolds are poor locations for sample probes of any type. Turbulence generated by gas movement in headers and manifolds will not mix the gas uniformly. If gas comes into a header from multiple side taps, the gas moving through the header will not tend to mix readily with the gas moving in from the side.

Vertical headers are turbulence generators and liquid accumulators. Horizontal headers also have turbulence problems and should be avoided. Vertical headers having runs off of the side will encourage the heavies and liquids to move through the bottom run and the lighter, dryer gas will move through the upper meter run. In the weld cap of vertical headers, there is an impingement of the liquids. Therefore, the weld cap is not a proper location for probes for any use.

The actual location of a probe in the piping system is important. What is the objective? One rule is clear — the probe must be located directly in the flowing stream. Another more obscure consideration implies that the probe must be kept clear of free liquid and this includes aerosols which, in fact, are the real trouble makers. Since turbulence is the mechanism that generates aerosols, it is reasonable to make every attempt to stay away from the downstream end of turbulence producers such as reducers, elbows and measurement devices. How long a liquid remains in the aerosol state is a function of the gas velocity; however, in all likelihood, it will be a distance that exceeds 20 pipe diameters. This creates a problem when one considers that available straight and horizontal piping above ground rarely makes allowance for the ideal sampling location. For gas sampling, locate the probe in the top of a horizontal pipe.

Probe Construction

The probe should be constructed from a material that will not react with the product. 316 stainless steel is the most practical material for probe construction. Probes are normally constructed three different ways:

1. The stationary or permanent probe
2. The manually insertable probe
3. The automatic insertion probe

The stationary probe is installed as a permanent fixture in the piping system. A full open valve should be attached to the outlet of the probe.

The tube extending into the flow path should be made strong enough to resist bending.

The manual insertion probe is used in locations of medium pressure where a permanent fixture cannot be left in the pipe.

To insert the manual insertion probe, attach to a gate or ball valve and close the valve attached securely to the end of the probe. Open the pipeline valve and very carefully push the tube into the flow line. Tighten the fittings on the probe enough to hold the tubing in place and prevent leaks. Normally, the lower ferrule will be nylon (or PTFE) and the upper ferrule will be stainless steel. Once the stainless steel ferrule is "set," the insertion depth of the probe is fixed. This type of probe must be handled carefully with special attention given to locking the valve on the end of the probe and securing the probe into the insertion valve.

The Automatic Insertion Probe

The automatic insertion probe is used in locations that require frequent insertion and retraction of the probe from the pipeline.

The automatic insertion probe is built as a standard to screw into a 1-inch NPT ported valve. Other ends are available for attachment to the pipeline.

The use of the automatic insertion probe style allows easy access and removal of all types of probes into the line.

Probes in Wet Gas Systems

The wet gas pipeline system continuously exhibits the need for probes. In wet gas systems, liquid carryover in instrument supplies, valve operations, and chemical injectors is a continual problem.

Samplers, chromatographs, calorimeters and related on-line monitors should be hooked up to the line using a probe.

Sampler Hook-up and Manifold

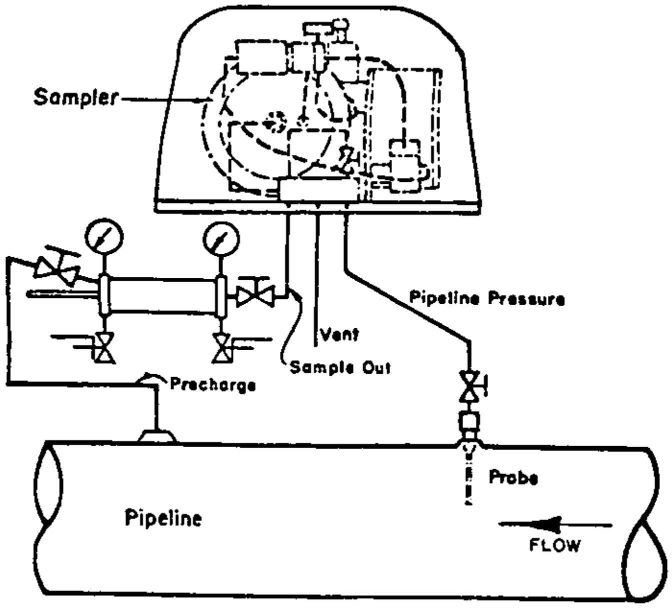
From the outlet of the probe, a ball valve or large ported valve should be installed. This valve should be opened completely. Downstream of the probe valve, a short length of small diameter line should be run upgrade to the inlet port of the manifold block on the sampler. The sampler should be mounted above the sample point on a pipe stand. The line to the sampler should always be sloped back toward the valve on the sample probe. This is to allow any free liquid to drain back into the pipeline. Free liquids should be discouraged from moving into the sample container. Two phase samplers in standard sample containers are difficult, if not impossible, to handle properly in the lab.

The installation of the sampler should be as close as practical to the sample point. Never sample a dead end line.

On the outlet of the sampler, the sample cylinder should be connected with a short length of small diameter tubing. This is to be pumped into the cylinder, not some excessive length of tubing. Mount the cylinder in some type of holder, not on the ground or deck.

The outlet tubing from the sampler to the cylinder must be carefully checked for leaks. Leaks allow the sample to dissipate nonuniformly. Gas will leak from a cylinder light ends first giving inaccurate results.

Care should be taken not to put filters, drips, or regulators between the probe and the sampler. This affects the gas and it is no longer representative of the pipeline product.



Sampler

The sampler is a mechanism that gives the operator an opportunity to have a composite sample in a cylinder. It is an alternative to a spot sample and/or an onstream monitoring device. The sampler should take its composite sample just as an operator would put a spot sample into his container. The sampler, however, does this continuously over a specific period of time.

The sampler may be a simple timed mechanism actuating the sampler periodically. It may be interfaced with measurement to cause the sample to be taken proportional to the flow electrically or pneumatically.

For stations or locations where the flow varies widely or the heating content swings up and down, the sampler should be actuated proportional to the flow.

For stations where the load is constant, a timer may be used without affecting the gas collected.

For stations or wells that have flow, no flow operations, the sampler should be turned off with a flow switch when the flow is off. Sampling should be stopped when there is no flow in every case. After a number of years and many test locations, it is recommended that in locations where gas has a heating value of 1025 BTU or above should be considered as prime locations for the use of a continuous sampler.

The sampler should be capable of pumping the sample into the sample container, regardless of ambient conditions.

The sampler should be able to purge itself prior to pumping a new "bite" into the sample container.

The sampler should sample the gas at pipeline conditions.

Purging the Sampler and the Cylinder

When the sampling device is put into service and a sample container is attached, the sampler and all its components including the cylinder should be properly purged.

The act of purging cleans the air from the sampler and associated components so they will not be present in the analysis. This purge also conditions the cylinder with the gas that is to be sampled. Note: If an evacuated cylinder is used, the associated tubing, fittings and valves still must be purged.

The Sample Cylinder

The sample cylinder is the carrier of the sample; therefore, it is an integral part of the system. It should be made of a material that will not react with the gas. It should be kept clean and well maintained. Valves and reliefs should be checked periodically for ease of operation and must be checked for leaks through the seat, bonnet and threads. No leaks may be tolerated. Soft seat valves should be used on sample cylinders.

The sample cylinder should be cleaned after each use with solvent and then air dried. Sample cylinders must be a proper working pressure to handle the source being sampled. Rising temperatures will increase the pressure in the cylinder so this should be considered when choosing a sample container.

Cylinder Transport

When the sample period is over, the sample container should be disconnected from the sampler and carefully checked for leaks. Plugs or caps should be installed on the valves. The sample information tag should be filled out fully. The cylinder should then be put into a proper case for transport. D.O.T. rules apply, even in your company trucks and autos. A cylinder should never be transported haphazardly.

Leaks

Leaks should not be tolerated in any portion of a sample system. Leaks will cause the sample to give incorrect results.

Maintenance on the Sampler

The continuous sampler is a mechanical device and should be checked each time the sample cylinder is changed. Simply remove the cover from the sampler. Check the supply, activate the sampler to check its stroke and supply regulator response. Open the vent valve on the filter (F-7) on the instrument supply to check if liquid is getting into your system. Close the outlet valve and activate the sampler to watch the pressure on the outlet gauge increase. Reopen the outlet valve.

Every three months, check the sample head for chemical attack or swelling.

Every year, change the o-rings and lubricate the shaft and three-way valve. Spare parts that should be kept on hand are:

1. Sampler head
2. -003 o-rings
3. O-ring kit
4. Batteries for timer (if required)

The Composite Sampler in Wet Gas Service

The composite sampler is effective in wet gas service. It is further recommended that a constant pressure sample cylinder be used in wet gas service. By using the composite sampler and the constant pressure cylinder in wet gas service, the sample can be maintained under pipeline pressure, thereby discouraging retrograde condensation in the cylinder. The sample in the constant pressure cylinder may be run in the lab under pipeline conditions, pressure and temperature to get a better result.

Measurement Effect of a One BTU Error (Expressed In Dollars Per Year)

Examples:

1. Daily Production Rate = 10,000 MCFD
   BTU from monthly spot sample = 1020 BTU
   BTU from composite-continuous sampling = 1019 BTU -- One BTU Variation
   Purchase Gas Cost = $3.50 per MMBTU (1000 BTU - Base)
   10,000 (1.020)($3.50) = $35,700 per day
   10,000 (1.019)($3.50) = $35,665 per day
   $ 35 per day
   $35 (25 days per month)(12 months) = $10,500

   One BTU Variation = $10,500 per year

2. Daily Purchase Rate = 200,000 MCFD
   BTU from spot sample = 1036 BTU
   BTU from continuous-composite sampling = 1035 BTU -- One BTU Variation
   Purchase Gas Cost = $3.50 per MMBTU (1000 BTU - Base)
   200,000 (1.036)($3.50) = $725,200 per day
   200,000 (1.035)($3.50) = $724,500 per day
   $ 700 per day
   $700 (30 days)(12 months) = $252,000

   One BTU Variation = $252,000 per year

DOLLARS PER YEAR DUE TO MEASUREMENT

VARIATION IN SPOT BTU SAMPLE VS. COMPOSITE SAMPLE

(Dollars based on $3.50 per MMBTU - 1000 BTU Base)

Sample BTU Variation	MMCFD - Daily Purchase or Sale Rate					
	5	10	20	25	30	50
1	$ 6,387	$ 12,775	$ 25,550	$ 31,937	$ 38,325	$ 63,875
2	$ 12,775	$ 25,550	$ 51,100	$ 63,875	$ 76,650	$ 127,750
3	$ 19,162	$ 39,420	$ 76,650	$ 95,812	$ 114,975	$ 191,625
4	$ 25,550	$ 51,100	$ 102,200	$ 127,750	$ 153,300	$ 255,500
5	$ 31,937	$ 63,875	$ 127,750	$ 159,687	$ 191,625	$ 319,375
6	$ 38,325	$ 76,650	$ 153,300	$ 191,625	$ 229,950	$ 383,250
7	$ 44,712	$ 89,425	$ 178,850	$ 223,562	$ 268,275	$ 447,125
8	$ 51,100	$ 102,200	$ 204,400	$ 255,500	$ 306,600	$ 511,000
9	$ 57,487	$ 114,975	$ 229,950	$ 287,437	$ 344,925	$ 574,875
10	$ 63,875	$ 127,750	$ 255,500	$ 319,375	$ 383,250	$ 638,750

Basis for above information:

Daily Purchase = 5 MMCFD

BTU Sample Content = 1001

Purchase Gas Cost = $3.50 per MMBTU (1000 BTU - Base)

5,000 (1.001)($3.50) = $ 17,517.50 per day
5,000 (1,000)($3.50) = $ 17,500.00 per day
$ 17.50 per day

$17.50 per day (365 days) = $ 6,387.50 per year

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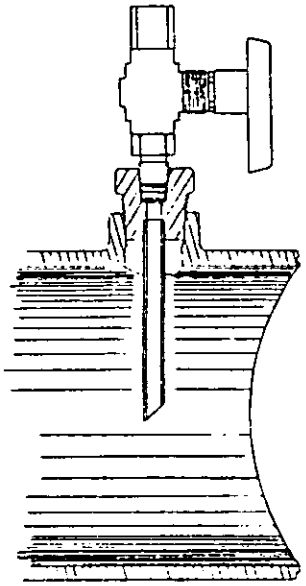

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To insert the manual insertion probe, attach to a gate or ball valve and close the valve attached securely to the end of the probe. Open the pipeline valve and very carefully push the tube into the flow line. Tighten the fittings on the probe enough to hold the tubing in place and prevent leaks. Normally, the lower ferrule will be nylon (or PTFE) and the upper ferrule will be stainless steel. Once the stainless steel ferrule is "set," the insertion depth of the probe is fixed. This type of probe must be handled carefully with special attention given to locking the valve on the end of the probe and securing the probe into the insertion valve.

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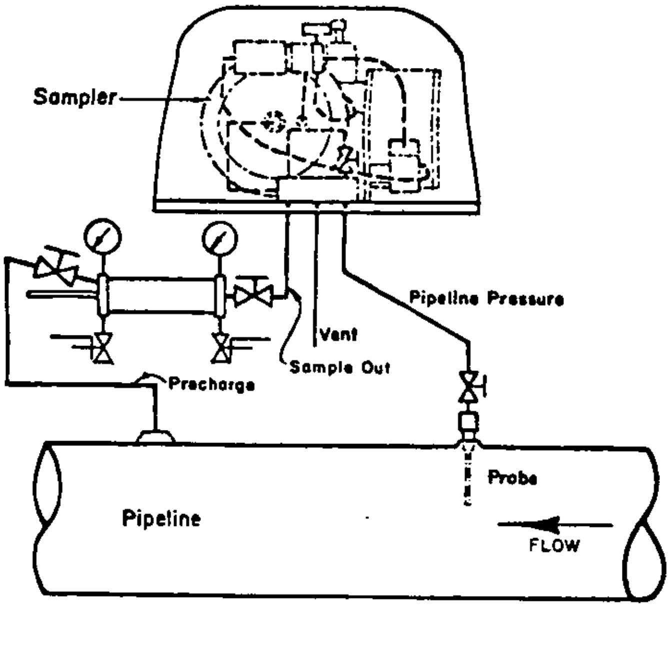

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When the sampling device is put into service and a sample container is attached, the sampler and all its components including the cylinder should be properly purged.

The act of purging cleans the air from the sampler and associated components so they will not be present in the analysis. This purge also conditions the cylinder with the gas that is to be sampled. Note: If an evacuated cylinder is used, the associated tubing, fittings and valves still must be purged.

The Sample Cylinder

The sample cylinder is the carrier of the sample; therefore, it is an integral part of the system. It should be made of a material that will not react with the gas. It should be kept clean and well maintained. Valves and reliefs should be checked periodically for ease of operation and must be checked for leaks through the seat, bonnet and threads. No leaks may be tolerated. Soft seat valves should be used on sample cylinders.

The sample cylinder should be cleaned after each use with solvent and then air dried. Sample cylinders must be a proper working pressure to handle the source being sampled. Rising temperatures will increase the pressure in the cylinder so this should be considered when choosing a sample container.

Cylinder Transport

When the sample period is over, the sample container should be disconnected from the sampler and carefully checked for leaks. Plugs or caps should be installed on the valves. The sample information tag should be filled out fully. The cylinder should then be put into a proper case for transport. D.O.T. rules apply, even in your company trucks and autos. A cylinder should never be transported haphazardly.

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Examples:

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   BTU from continuous-composite sampling = 1035 BTU -- One BTU Variation
   Purchase Gas Cost = $3.50 per MMBTU (1000 BTU - Base)
   200,000 (1.036)($3.50) = $725,200 per day
   200,000 (1.035)($3.50) = $724,500 per day
   $ 700 per day
   $700 (30 days)(12 months) = $252,000

   One BTU Variation = $252,000 per year

DOLLARS PER YEAR DUE TO MEASUREMENT

VARIATION IN SPOT BTU SAMPLE VS. COMPOSITE SAMPLE

(Dollars based on $3.50 per MMBTU - 1000 BTU Base)

Sample BTU Variation	MMCFD - Daily Purchase or Sale Rate					
	5	10	20	25	30	50
1	$ 6,387	$ 12,775	$ 25,550	$ 31,937	$ 38,325	$ 63,875
2	$ 12,775	$ 25,550	$ 51,100	$ 63,875	$ 76,650	$ 127,750
3	$ 19,162	$ 39,420	$ 76,650	$ 95,812	$ 114,975	$ 191,625
4	$ 25,550	$ 51,100	$ 102,200	$ 127,750	$ 153,300	$ 255,500
5	$ 31,937	$ 63,875	$ 127,750	$ 159,687	$ 191,625	$ 319,375
6	$ 38,325	$ 76,650	$ 153,300	$ 191,625	$ 229,950	$ 383,250
7	$ 44,712	$ 89,425	$ 178,850	$ 223,562	$ 268,275	$ 447,125
8	$ 51,100	$ 102,200	$ 204,400	$ 255,500	$ 306,600	$ 511,000
9	$ 57,487	$ 114,975	$ 229,950	$ 287,437	$ 344,925	$ 574,875
10	$ 63,875	$ 127,750	$ 255,500	$ 319,375	$ 383,250	$ 638,750

Basis for above information:

Daily Purchase = 5 MMCFD

BTU Sample Content = 1001

Purchase Gas Cost = $3.50 per MMBTU (1000 BTU - Base)

5,000 (1.001)($3.50) = $ 17,517.50 per day
5,000 (1,000)($3.50) = $ 17,500.00 per day
$ 17.50 per day

$17.50 per day (365 days) = $ 6,387.50 per year

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.