

Natural Gas Moisture Measurement

Overview

The moisture content in pipeline natural gas is one of many parameters that must be monitored as a part of controlling the quality of the gas. Some other parameters that are monitored include gas composition, heating value, and relative density (specific gravity).

The moisture content in natural gas will vary for a variety of reasons. There are various methods used to control the moisture in the gas and there are also different instrument types used to measure the moisture content. Measurement methods will be discussed as well as general guidelines for the use of typical moisture measurement instruments.

Moisture Control and Measurement

Moisture Control

Natural gas, as it comes out of the well, is usually quite warm, saturated with water, and laden with heavy hydrocarbons. The gas is then processed to dry it by removing the water that exists in both a liquid and vapor state as well as the heavy hydrocarbons.

A high level of moisture in natural gas pipeline operation can cause equipment maintenance problems, measurement inaccuracies, and can raise safety concerns. Moisture can cause corrosion in the presence of H_2S and CO_2 and problems at the compressor stations. Water and liquid hydrocarbons can also combine in the pipeline to form hydrates. This frozen mixture can cause restrictions in flow and capacity to a point of complete blockage of regulators, valves and compressors. It can also cause improper measurement at the flow meter and associated lines and fittings. Additionally, high levels of moisture can cause freezing where rapid expansion is occurring due to the Joule-Thompson effect. High levels of moisture can also lower the net heating value or BTU content of the gas. For these reasons contractual agreements between the buyer and seller of the gas always stipulate the allowable moisture content (typically 7.0 lbs/MMscf in the United States) and a minimum and maximum BTU content.

Two common methods for removing moisture from natural gas are to use either 1) a separator, or 2) desiccants consisting of a molecular sieve or a triethylene glycol (TEG) dehydration unit. Additional methods of control may involve injecting methanol or glycol into the pipeline upstream of the dehydration facility.

Moisture Measurement

There are two different types of moisture measurement: "Direct" and "Indirect." The Direct measurement technique is chilled-mirror hygrometry where the primary measurement is temperature. The Indirect technique uses electronic instruments such as in the electrolytic method, the aluminum oxide (Al_2O_3) capacitive method, the IR absorption method and the vibrating crystal method.

Chilled-Mirror Hygrometry

This method consists of accurately measuring the temperature at which condensate forms on a chilled surface that is in the presence of natural gas. Dew points exist at two temperatures for the gas: the water dew point and the hydrocarbon dew point (see Glossary). The formation of the condensates on the chilled mirror is identified visually or electronically depending on the instrument type. Once the condensate has formed at the dew point, the sample pressure and the temperature of the mirror are accurately measured. The moisture content is then determined from published tables.

Electrolytic (P_2O_5) Method

This method uses an electrolytic cell to produce an electrical current that is proportional to the amount of moisture in the natural gas. The cell consists of a pair of closely spaced metal electrodes that are coated with a phosphoric acid solution. A voltage is applied across the electrodes and low concentrations of moisture in the gas are broken into H_2 and O_2 as the gas passes through the cell. The resulting electrical current is proportional to the moisture content. Two different configurations of electrolytic cells exist: the relative measurement (RT) cell, and the total consumption (TC) cell. The RT cell senses relative changes in moisture content of the natural gas. Measurements made with this cell are not affected by minor changes in the sample flow rate through the cell. The TC cell relies on breaking down all of the water molecules that enter the cell. The accuracy of the measurements, using the TC cell, is affected by slight changes in sample flow rate.

Capacitive (Al_2O_3) Method

This method uses a capacitive cell in which the cell capacitance is proportional to the amount of moisture in the natural gas. The sensor is made from pure aluminum. An aluminum strip is anodized in sulfuric acid resulting in a layer of porous aluminum oxide on its surface. Then a layer



of a precious metal, typically gold, is thinly evaporated over the aluminum oxide so that it too is porous. This “sandwich” of three compounds is essentially a capacitor with the aluminum oxide layer being the dielectric. When the sensor is exposed to the gas stream water vapor is

absorbed onto the walls of the aluminum oxide layer. This absorption is functionally related to the partial pressure of the water vapor in the sample. As the content changes so does the capacitance.

Infrared Light Spectrometry

This method consists of transmitting and detecting a certain wavelength range of light through the natural gas sample. By measuring the exact amount of light that is absorbed by the gas sample at the specific wavelength, it is possible to directly determine the amount of water vapor by application of a simple absorption law called Beer’s Law. The relative change or absorption of certain wavelengths is measured and the absorption is proportional to the moisture content of the natural gas. This approach relies on sophisticated optoelectronics and computer-based analysis. There are no chemical conversions involved; this provides a direct and unambiguous measurement of the sample gas.

Vibrating Crystal Sensors

Piezo electric sensors are referred to as vibrating quartz crystal sensors. The crystal is coated with a hygroscopic material so that water vapor can be absorbed from the sample stream onto the crystal. The analyzer electronics monitor the changes in the vibration frequency as the water vapor is absorbed onto the coating on the crystal. During operation, the crystal or sensor is alternately exposed to the sample gas stream and to a dry reference stream. The sample gas flows across the sensor for a fixed period of time. During this time the water vapor is absorbed causing a change in the frequency of vibration. This frequency is read by the electronics, stored in memory and then compared against a sealed sensor. Then the sample gas is diverted through an on-board dryer and passed through the sensor. This frequency is also read, stored and compared to the sealed sensor. Using the differential of the frequencies of the sample gas and the reference gas, the water vapor content is determined. This method features the benefit of an on-board calibration/verification system.

Sampling Systems

The overall accuracy and reliability of all of the discussed methods for the measurement of moisture in natural gas depend on well-designed sampling systems. All moisture measurement instruments are susceptible to contaminants in the pipeline. These contaminants typically are particulates, liquid hydrocarbons, glycol, methanol, and other foreign materials/ chemicals. Proper attention must be given to designing and maintaining the sampling system, otherwise the instrument will be inaccurate and unreliable.

A well-designed sampling system must extract a representative gas sample from the pipeline, reduce the pressure, stabilize the sample temperature, remove the contaminants, and deliver the gas sample to the measurement instrument without altering its composition. There are several components involved and many choices to be made during the design of a sampling system. In general, the following guidelines apply:

Materials

The sampling system components should be made from stainless steel (300 series) for optimum corrosion resistance. Avoid using any type of plastics or rubber sample lines or components.

Sample Probe

The probe must extend into the center one-third of the pipeline. The probe must not be located near flow disruptions caused by elbows, orifice plate, flanges, etc. The probe should be installed in a horizontal straight run of pipe with 5-10 pipe diameters of straight, uninterrupted pipeline upstream and downstream from the probe.

Sample Valve

A suitable valve should exist downstream of the sample probe to allow the sample system to be isolated from the pipeline for routine maintenance. This valve may be part of the sample probe assembly. The valve should be constructed from stainless steel and should have as minimal volume as possible.

Dead Volume

The dead volume or the un-swept volume of the entire sampling system must be minimized. The smallest tubing diameter size (1/8", 1/4" or 4mm, 6 mm) should be used as a part of the sampling system. Use the shortest possible length of sample tubing between the sample probe and the inlet of the instrument. Large dead volumes will cause long instrument stabilization times and inaccuracies. Unless absolutely necessary, a Bourdon tube pressure gauge or other components that increase the dead volume should be avoided. An instrument bypass circuit, known as a speed loop, is typically used to reduce the stabilization time of the instrument readings if low sample flow rates are required.

Pressure Regulators

A low internal volume, stainless steel diaphragm regulator is optimum for reducing the pipeline pressure to the required inlet pressure of the moisture analyzer. Care must be used to avoid problems due to liquid condensation caused by rapid gas expansion through the regulator and the Joule-Thompson effect. Optimally, a combination probe/regulator should be used to greatly reduce the chances of the Joule-Thompson effects because the pressure reduction takes place inside the pipeline. If a probe/regulator is not available, a heated vaporizing regulator or multiple regulators may need to be used to avoid liquid condensation. Ideally, if an external regulator must be used it should be placed right at the sample probe on the pipeline. This will increase the volumetric flow rate, depress the sample dew point temperature, and reduce the sample lag time.

Filters

Basically three types of filters are used in the natural gas industry upstream of instrumentation. A *coalescing* filter is designed to remove particulates and liquid mists and aerosols. A *membrane* filter is designed to remove any and all liquids that may be present; membrane filters do not alter the composition of the sample. The third filter is an *absorbent* type of filter that is designed to absorb contaminants that exist in the vapor state such as glycol vapors. Some applications may require just one of these filters and others may require all three depending on the severity of the application and type of analyzer chosen. The most important things to remember when selecting a filter are to ensure the filter does not absorb any water vapor present and that it does not alter the composition of the sample.

Temperature Control

In cold climates, the entire system temperature must be maintained above the dew point temperatures of the gas sample. This includes all components of the sample system and the analyzer, until the gas exits the sample vent of the analyzer. To maintain this temperature you may need: heated, vaporizing external regulator(s), heat-traced tubing, insulation, and a heated insulated enclosure or environment for the analyzer. The most accurate moisture concentration measurements are made when the temperature of the entire system is stable and above both the water dew point temperature and the hydrocarbon dew point temperature.

Calibration

All moisture measurement instruments must be calibrated periodically. The calibration consists of creating known moisture content in an inert gas and using this standard to verify the accuracy and linearity of the instrument. There are two common methods used to create known moisture content in gas:

Saturation Method

This method consists of passing a dry, inert gas through a water saturator assembly that is maintained at a known temperature and at a known pressure. Changes in moisture content are achieved by changing the pressure and/or the temperature on the saturator assembly. Since the pressure and temperature of the gas are known, the moisture content is determined from published data that provides moisture content as a function of temperature and pressure.

Mixing/Partial Pressure Method

This method consists of mixing two known moisture-content sources together while each source is maintained at a known pressure. The pressure ratios are used to calculate the moisture content of the mixed stream. The moisture content is varied by changing the pressures of each stream.

Calibration Gas

A certified calibration gas can be purchased and used to calibrate moisture measurement instruments. Care must be used to periodically verify the accuracy of the standard since the moisture content will change as the bottle temperature and pressure changes over use and time.

Portable Calibrators

The recommended calibrator for portable applications uses the saturation method. The mixing method is equally accurate but it involves more equipment. The certified calibration gas method can be used a “spot check” of an instrument, but this method lacks flexibility. A few guidelines to use during the calibration of a moisture measurement instrument are:

1. Remove the instrument from the sampling system and purge with dry gas to remove all traces of moisture.
2. Connect the calibration source to the instrument and allow sufficient time for the reading to stabilize. Adjust and verify that the instrument displays the correct moisture value.
3. Attach the sampling system and repeat the calibration. The sampling system must have no effect on the instrument calibration. If the readings change, isolate and replace the sampling system component that is affecting the calibration.

Maintenance

Since the accuracy of all moisture measurement instruments is affected by normal usage, contaminants, or deficiencies in the sample conditioning system, an important feature is the ability to service the instrument on-site. Some instruments are designed to allow field calibration and maintenance and others must be returned to the manufacturer for routine service and calibration. Since maintenance, downtime, and related costs are major concerns to measurement supervisors, an instrument design that can be serviced, recalibrated, and returned to service quickly is clearly the best choice.

Conclusion

There are different methods used to measure the moisture in natural gas. Many of the instruments available for this purpose function well under ideal conditions. Some moisture analyzers are more susceptible to contaminants than others. Some instruments are intended for use in the laboratory. Others are specifically designed for use in pipeline environments as a stationary or a portable instruments. Not all moisture analyzers can be serviced or recalibrated on-site and some must be returned to the manufacturer for repair or recalibration. Removing normal pipeline contaminants that will affect the instrument or cause inaccuracy is the major problem that must be solved in most installations. If heavy contaminants are present and sample conditioning is not possible, using a chilled mirror hygrometer may be the only solution. Measuring the moisture in contaminated or corrosive natural gas is difficult but measuring the moisture in “clean” natural gas is relatively easy.

The accuracy and reliability of the measurements depend on the choice of equipment, the design of the sampling system, operator training, and the periodic maintenance and recalibration of the instrument. If these conditions are met, accurate moisture measurement is possible.



Glossary

BTU (British Thermal Unit)

A measure of energy. The amount of energy required to raise the temperature of one pound of water from 58.5°F to 59.5°F.

Coalescing Filter

A filter type that will cause liquids and solids to be removed from a gas stream. Moisture in the gaseous state will not be removed by this type of filter.

Dead Volume

The volume of any system flow passage where a dead-end or cavity could retain materials to contaminate subsequent samples. The quantity of the former sample that remains inside the component after flushing with some specified volume is defined as dead volume.

The dead volume or the unswept volume must be minimized. The smallest tubing size (1/8", 1/4", 4mm, or 6mm) should be used as a part of the sampling system. Large dead volumes will cause long instrument stabilization times and inaccuracies. Unless absolutely necessary, avoid a Bourdon tube pressure gauge or other components that increase the dead volume. An instrument bypass circuit, known as a speed loop, is typically used to reduce the stabilization time of the instrument readings if low sample flow rates are required.

Dew Point

The dew point represents the temperature and pressure at which water vapor or hydrocarbons condense from a gas. The dew point for water and hydrocarbons in natural gas exists at different temperatures and pressures. The relationship between dew point and moisture (water content) can be obtained from ASTM Method D1142.

Filters

A filter is used to remove particulates and liquids from the sample line. Filter elements that do not retain moisture must be chosen. A properly specified coalescing filter is recommended as part of the sampling system. Other filters downstream of the coalescing filter are usually designed to remove liquids, glycols, and other contaminants from the sample. The choice of filters must be made after considering the pressure drop across the filter(s) and the required sample flow rate of the instrument.

Gas Composition

The chemical content of the natural gas. A natural gas will contain varying amounts of methane, ethane, propane, nitrogen, carbon dioxide, and other components.

Heating Value

The energy content of the natural gas. This value is determined from the natural gas composition using a chromatograph, or from calorimetry. The units are BTU/Scf or kJ/m³ and reported as net, dry, or saturated values depending on the natural gas moisture content.

IR Light: Infrared Light

A specific range of wavelengths of light that are not in the visible range.

Joule-Thompson Effect

The cooling that occurs when a natural gas at high pressure is passed through an orifice to a lower pressure. This cooling can cause the condensation of liquids (water and liquid hydrocarbons).

Pressure Regulator(s)

A low internal volume, stainless steel diaphragm regulator is optimum for reducing the pipeline pressure to the inlet pressure rating of the instrument. Care must be used to avoid problems due to liquid condensation caused by rapid gas expansion through the regulator and the Joule-Thompson effect. In some cases, a heated sample regulator or multiple pressure reduction stages may be required to avoid the condensation.

Relative Density (Specific Gravity)

The ratio of the gas to the density of air standard temperature and pressure.

Sample Valve

A suitable valve should exist downstream of the sample probe to allow the sampling system to be disconnected. This valve may be part of the sample probe assembly.

Standard Temperature and Pressure (STP)

The standard (reference) temperature and pressure at which gas volumes are calculated. In the U.S., the base temperature is 60°F and the base pressure will vary (14.65, 14.696, 14.73 PSIA) depending on local standards. When comparing gas volumes, verify that the base conditions are the same.

Temperature Control

In cold climates, the sampling system temperature must be maintained above the dew point of the natural gas. In these climates, the use of a heated sample regulator and heated (or buried) sample tubing must be used to prevent condensation from forming in the sampling system. The most accurate moisture measurements are made if the temperature of the sampling system is stable.

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