DEVICES FOR FIELD DETERMINATION OF H_2O IN NATURAL GAS

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INTRODUCTION

Gas quality has always been an important issue, but within the last year it has become a critical issue for many pipeline companies. With the current energy crunch causing problems throughout the world, and gas prices at historical high levels, anyone who can sink a well and start pumping natural gas is doing so. Unfortunately, gas quality has taken a back seat to the urgency of fulfilling key quality issues. One of the key quality factors is moisture content. This paper will review the different sensor technologies in use today and also address key issues and proper procedures in assembling a sampling system to provide a clean, representative gas sample to the sensing device.

WHY MEASURE MOISTURE?

As removed from the ground, natural gas is typically described as being either rich or lean (wet or dry) as relates to the heavier hydrocarbon components in the stream. In addition to these hydrocarbons, natural gas will almost always contain water vapor as well as nitrogen, helium, carbon dioxide and, in some cases, hydrogen sulfide. Our focus here will be on one of the most undesirable components, water, both as free water and water vapor.

Natural gas, as removed from the ground, can be saturated with water vapor and must go through a dehydration process prior to transportation in the vast network of underground transmission pipelines. The dehydration process can be accomplished through various means. Typical dehydration technique is to pass the gas through a TEG (tri-ethylene glycol) contactor or passing the gas through a molecular sieve desiccant bed. Both of these processes will add up front cost to the gas, but are necessary for the following reasons:

1. The water vapor can combine with other trace contaminants in the gas stream, namely H_2S and CO_2, and form potentially corrosive acids in the pipeline. The presence of these acids in the pipeline will decrease the life expectancy of the pipeline and it's components. Long-term maintenance costs will increase as will the potential for catastrophic failure of the pipeline or any one of its components.

2. Rapid expansion of the compressed natural gas will cool the gas based on the Joule Thomson effect. The interaction of water vapor with heavier hydrocarbons in the gas stream at this point can result in the formation of hydrates in the pipeline. These hydrates can cause complete or partial blockage in valves, regulators or measurement devices in the pipeline resulting in partial or complete loss of flow in the pipeline.

3. Contractual obligations at custody transfer points require that the gas not exceed a specified maximum moisture level. Typical contracts call for this maximum to be 7 lbs/mmscf, although this number may change depending upon the geographic area and normal ambient conditions.

4. The BTU or heating value of the gas will be reduced as the amount of water vapor increases. If contractual obligations are not met, the producer can be shut in and will face a loss of revenue until the problems are corrected.

SENSOR TECHNOLOGIES

There are numerous manufacturers of moisture analyzers but, for the most part, we can break down the sensor technologies into four basic types typically used to determine the water vapor content of natural gas.

They are:

1. Electrolytic
2. Capacitance
3. Chilled Mirror
4. Vibrating Crystal

In addition to these types of sensors, length of stain tubes are widely used to determine an approximate water vapor content and new laser based devices are on the horizon as technology advances.

ABSOLUTE VS. RELATIVE

All sensor type will fall into one of two categories — Absolute or Relative. Absolute sensors are based on primary laws of physics and do not require periodic calibration against known moisture standards. Relative sensors are based on a comparative measurement and will require a known moisture source for calibration. Calibration frequency will vary depending on the individual sensor characteristics.

ELECTROLYTIC SENSORS

The typical electrolytic sensor consists of two precious metal electrodes wound around a support mandrel or imbedded in a hollow glass tube. These electrodes are coated with a thin layer of phosphorus pentoxide (P_2O_5). In operation, a controlled amount of gas is allowed to constantly flow through or across the sensor allowing sufficient time for the P_2O_5 coating to adsorb all of the moisture from the gas stream. A voltage potential is applied across the electrodes splitting (or electrolyzing) the water molecules that have been collected on the coating. Once equilibrium conditions are attained, the rate at which moisture molecules enter the cell will exactly match the rate at which the molecules are electrolyzed. Each electrolyzed molecule causes two electrons to be displaced from the anode to the cathode. The electrolysis current (Amps) gives the electrical charge (coulombs) discharged per second. Since the elementary charge of an electron is known by measuring the current we can determine the rate at which water molecules are entering the sensor. Combined with a known flow rate through the sensor, the moisture content of the gas can be determined. Since this is an absolute process, there is no need to calibrate against a known standard.

Electrolytic based moisture analyzers are available as portable and stationary devices with flow control mechanisms built into the unit. As with all analyzers, it is important that the proper sampling techniques and sample conditioning criteria be strictly adhered to. Failure to do so may cause premature failure of the sensor. Liquid intrusion or the presence of conductive particles can also cause premature sensor failure.

Electrolytic sensors are also available as relative devices that will require periodic calibration of the sensor against a known moisture source.

CHILLED MIRROR

Also known as the Bureau of Mines Tester, the chilled mirror hygrometer is a very simple and basic moisture measurement device that has been used for many years as a primary measurement tool. The sample gas stream flows across a temperature controlled polished surface or “mirror”. As the temperature of the mirror is slowly lowered, the water vapor will begin to condense or form dew on the mirror. The temperature at which the dew first appears is considered the dew point. Once the temperature dew point is attained, a simple conversion using existing charts or tables will give actual water vapor content of the gas. This type of analyzer can also be utilized to determine hydrocarbon dew points in the gas stream. Usually, an iridescent ring will form on the mirror surface. This is an indication of a hydrocarbon dew point and should not be confused with the water vapor dew point. Typically, the water vapor dew point will appear as a cloudy, opaque spot in the center of the mirror.

The critical components of the chilled mirror analyzer are the pressure chamber with valves to control the gas flow and pressure, a small mirror or polished surface, a thermometer to measure mirror temperature, a chilling device (propane tank, CO_2) and a view port to allow for observation of the mirror. In applications where the ambient temperature is below the dew point of the gas, it may be necessary to heat the sample line and analyzer to prevent condensation in the sampling system.

Since this is a direct measuring device, no calibration of the system against known moisture standard is required. Care should be taken to collect a representative sample of the gas using proper sampling and filtration techniques. Experienced operators can make highly accurate and reproducible measurements, but inexperienced operators may have some problems associated with interpreting the visual results. It is not uncommon to get different results from different operators on the same gas line.

CAPACITANCE SENSORS

Capacitance sensors fall into the category of relative devices. Periodic calibration of the sensor against a known moisture standard is a requirement. Of all the different sensor technologies, capacitance sensors are the choice of a majority of manufacturers. There are numerous types of capacitance sensors, including aluminum oxide, silicon oxide, polymer base and thin film, but they all share the same basic principle. Regardless of the sensor type, the core of the sensor consists of two electrodes and a dielectric material that absorbs the water vapor in the gas stream and achieves an equilibrium condition based on the partial pressure of water vapor in the specific gas stream.

In operation, moisture in the sample stream is absorbed into the dielectric material creating impedance within the sensor. An excitation voltage is applied to the electrodes and a return signal, proportional to the water vapor content, is transmitted back to the base electronics.

Capacitance based analyzers are available in both portable and stationary configurations. Although the sensor probe can be mounted directly in the process line, glycol and other contaminants in the gas stream can cause false readings and sensor failure. The sensor should be mounted in an independent sample conditioning system adjacent to the sample withdrawal point in order to protect against sensor contamination.

VIBRATING CRYSTAL SENSORS

Piezo-Electric sensors are commonly referred to as vibrating quartz crystal sensors. The crystal is coated with a hygroscopic material in order to allow absorption of the water vapor from the gas stream. The analyzer electronics monitor the vibration frequency change of the crystal as water vapor is absorbed onto the coating. During operation, the crystal is alternately exposed to

the sample gas stream and a dry reference stream. The reference stream is the actual sample gas, passed through an on board gas dryer.

In operation, the sample gas flows across the crystal for a fixed time period. During this time, moisture in the gas stream is absorbed onto the coating of the crystal causing a change in the vibration frequency. This frequency is read, stored and compared against a sealed crystal. The sample gas is then diverted through the on-board dryer and again is passed across the crystal. Once again, the frequency is read, stored and compared against the sealed crystal. Using the differential in the vibration frequency of the sample gas and the dried sample gas, one can determine the water vapor content of the sample gas.

These analyzers are strictly stationary devices and are not suitable for portable applications. They are also considered relative measurement devices that require periodic calibration against a known moisture source.

STAIN TUBES

For those of us who might only be interested in ballpark numbers on an infrequent basis, the length of stain tubes may be the best alternative. Encased in a glass tube, a chemically treated compound will change color when exposed to moisture in the sample gas. This is a quick and rough method to get a visual indication of the moisture content of the gas stream. Accuracy of these tubes is only ± 25% and is dependent upon the operator. Sampling is accomplished by breaking off both ends of the glass tube and inserting it into a hand pump. Care must be taken to avoid contaminating the reading with atmospheric moisture. A fixed number of pump strokes is required to achieve the final moisture value.

Although this technology is not suited for custody transfer measurements, it is a useful tool when looking for a quick, rough measurement. If you suspect high moisture content at your sample point, use the stain tube as the first pass before exposing the sensitive analyzer to potentially high water content gas. Moisture analyzers traditionally slow to respond are being saturated with water vapor.

LASER BASED ANALYZERS

Laser based analyzers are new to the moisture measurement field. The single greatest advantage of a laser-based system is the speed of analysis. Typical analysis times are measured in microseconds rather than minutes or even seconds. It can truly be called analysis at the speed of light.

A basic laser system consists of a cavity with highly reflective mirrors on each end, a laser source and a light detector. In operation, the laser source is tuned to the frequency of the specific molecule you are trying to detect then is diverted into the cavity to build signal strength and then taken off frequency. As the laser pulse travels back and forth between the two mirrors, the light energy is absorbed and the signal strength decays. By measuring the time it takes to absorb the light energy and return to the baseline signal, you can determine the actual water vapor content of the sample.

Laser based systems provide more flexibility than the other traditional sensing techniques. Laser diodes can be tuned to varying frequencies to detect other species in the gas stream, all within a single unit. The limitations at this time relate to the complex composition of the sample stream and the potential for interference in the selected frequency band.

SAMPLING SYSTEMS

All of these sensing technologies have their own advantages and shortcomings, but one issue is never in doubt. That is to say, we must use proper sampling techniques and sample conditioning to bring a representative gas sample to the sensing element.

The first, and most important component of the sampling system, is the selection of an appropriate sample point. The sample tap location should be in an area of the pipeline that is free from swirl flow. Meter runs, elbows and control valve locations may appear to be convenient points to take a sample, but there is a strong possibility that you will also collect liquid contaminants at these sample points. Always select a long, straight run of pipe for your sampling location. This will provide a firm foundation for collecting a representative gas sample.

Once an appropriate sample point has been selected, the design of the sample system can start to take shape. Consider that the liquids in the pipeline will travel along the walls of the pipe. Since we are most interested in determining the water vapor content of the gas stream, we need to extract a representative gas sample from the pipeline. The best way to do this is with an insertion probe, allowing for extraction of the gas sample from the center third of the flowing gas stream. The liquids in the gas stream will travel along the walls of the pipe and will be pulled into the analyzer if the sample tap is directly on the wall of the pipe. There are numerous options available today from a simple insertion probe to temperature compensated probe regulators or even probes with built in liquid separators.

Beyond the sample probe, additional filtration is normally required to condition the sample and remove any entrained liquids or vapors. A sample probe by itself is not enough protection for the analyzer. There is always the possibility of entrained liquids in the gas stream including glycol, methanol, hydrocarbon liquids and compressor oil. It is imperative that a filtration system be installed upstream of your analyzer, ideally directly at the sample tap. The idea is to keep the liquids out of your sample lines. Remember, if a sensor is contaminated, the entire system leading up to that sensor

will be contaminated and must be thoroughly cleaned. There are numerous filters available today including standard coalescing filters, membrane separators and glycol vapor removal filters. I suggest discussing the installation and application with the analyzer supplier to determine the best filtration system for the application. Also remember that filters require periodic maintenance. Don't install a system and forget about it, maintain it according to the supplier's guidelines.

Several other points to consider in the sampling system are:

1. Always use 300 series stainless steel sample lines and components to minimize corrosive effects and to maintain good sensor performance. Too many times, the inclination is to use any old rubber hose that happens to be lying around to deliver the sample to the analyzer and then blame the analyzer when the readings are not correct.

2. Select a sample point that is free from swirling gas flow. Try to select a sample point that is in the middle of straight, unimpeded run of pipe. Elbows, orifice plates and control valves can create swirl effects, which can sweep liquids from the wall of the pipe and right into the analyzer.

3. Design your sample system with minimal dead volume components to help the analyzer respond quickly to changes in moisture. Keep the components to an absolute minimum and place your analyzer as close as possible to the sample point. The more complex your sampling system is, the more time it will take to both purge it out and get a representative gas sample to your analyzer.

Following these basic guidelines, you can design a system that will give you protection from contamination while at the same time bringing a representative gas sample to your analyzer.

CONCLUSION

With the energy crunch that we are experiencing today, it is important that we not lose sight of the detrimental effects of water vapor in the vast natural gas distribution system and take appropriate steps to monitor the system from production through distribution. We must also never lose sight of the fact that the analyzer is only as good as the sample that is delivered to it. If we take the proper precautions to condition the sample and remove potential sensor contaminants, we can make an accurate measurement, which, in turn, allows us to keep the gas flowing at optimum conditions.

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