

Ken Soleyn, GE Sensing and Inspection Technologies, USA, reiterates the importance of monitoring the water level of natural gas, and introduces a new instrument in this field.

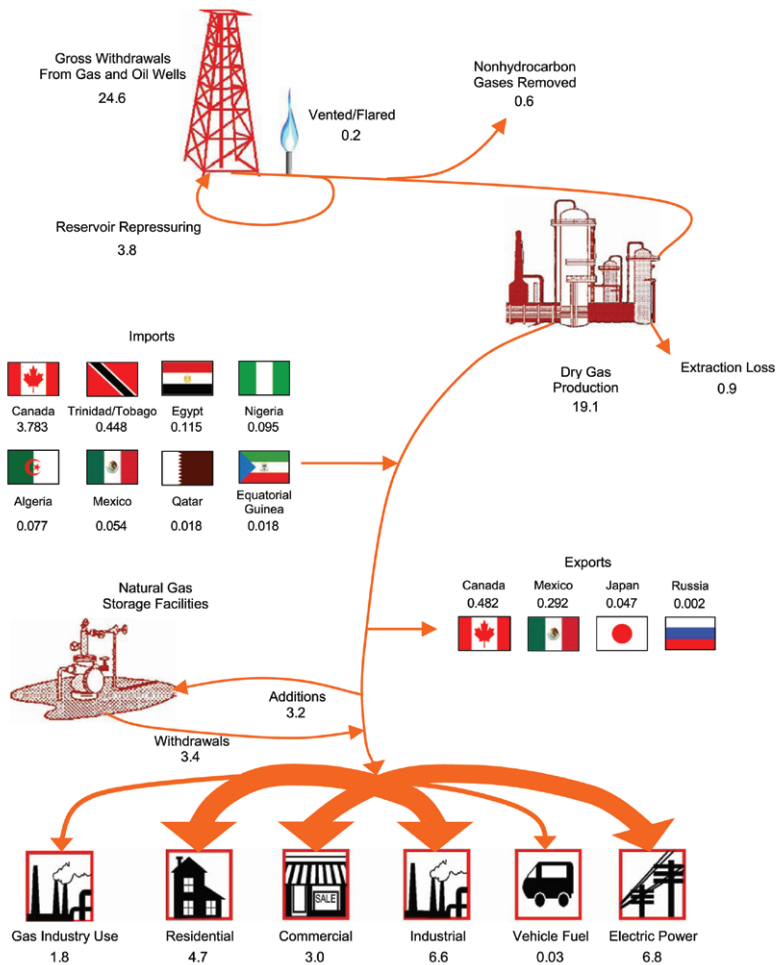
THE WAR AGAINST WATER

Water, even in small concentrations, poses large problems for the distribution of natural gas. Natural gas is dehydrated and treated prior to transportation and use, at considerable cost to the supplier and consumer. However, attempts to reduce dehydration result in a reduction in 'gas quality' and an increase in maintenance costs and transportation, as well as potential safety issues. Consequently, to strike the right balance, it is important that the water component of natural gas is measured precisely and reliably. A new instrument that utilises a tunable diode laser is now available to continuously monitor the water concentration in natural gas and offers considerable advantage over traditional instrument technology.

Natural gas

Natural gas is a major industrial and domestic fuel, used to power electricity generating turbines, where it produces approximately 45% less carbon dioxide than burning coal. Its global consumption is expected to increase at a rate of 2.5% per year, and according to the US Energy Information Administration (EIA), an estimated 2.97 trillion m³ was consumed globally in 2005 and consumption is expected to increase to 4.7 trillion m³ in 2030.

Generally, the water in natural gas is present in the form of water vapour. However, if the gas temperature falls below the dew point, or contacts any surface that is below the dew point temperature, the vapour will condense as a liquid. Bearing in mind that natural gas is primarily



Sources: Energy Information Administration (EIA), Form EIA-176, "Annual Report of Natural and Supplemental Gas Supply and Disposition"; Form EIA-895A, "Annual Quantity and Value of Natural Gas Production Report"; Form EIA-914, "Monthly Natural Gas Production Report"; Form EIA-857, "Monthly Report of Natural Gas Purchases and Deliveries to Consumers"; Form EIA-816, "Monthly Natural Gas Liquids Report"; Form EIA-64A, "Annual Report of the Origin of Natural Gas Liquids Production"; Form EIA-191M, "Monthly Underground Gas Storage Report"; Office of Fossil Energy, U.S. Department of Energy, "Natural Gas Imports and Exports"; the U.S. Minerals Management Service; Form EIA-923, "Power Plant Operations Report"; Form EIA-886, "Annual Survey of Alternative Fueled Vehicle Suppliers and Users"; and EIA estimates.

Energy Information Administration / Natural Gas Annual 2007

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Figure 1. Map or schematic of natural gas distribution. Source: US Department of Energy/Energy Information Administration, from their Natural Annual Report 2007.

transported across vast geographical areas through a network of carbon steel pipelines, it can be appreciated that excess levels of water in natural gas can cause significant problems, some of which are summarised below:

- Ice formation in pipelines can lead to reduced flow or even blockages. Under high pressure, water also forms a lattice structure around methane to form methane hydrates (a solid ice like substance).
- Water leads to corrosion of pipelines and pipeline components. Water combines with gases in natural gas such as carbon dioxide and hydrogen sulfide to create acids that accelerate corrosion.
- Water increases the cost of transportation by adding mass.
- Water lowers the calorific value of natural gas.

Dehydration

Numerous natural gas dehydration processes are available, including: triethylene glycol (TEG) contactors, desiccant dryers, membrane dryers and refrigeration/removal of condensate; each method requires the consumption of considerable amounts of energy. Figure 2 shows a typical

wellhead TEG absorption plant. The process allows a stream of natural gas containing water to come into contact with triethylene glycol in a 'contactor' vessel. The glycol has a chemical affinity for water and will absorb water from the wet stream. Once absorbed, the glycol aerosol becomes heavier and sinks to the bottom of the containing vessel. The liquid glycol is pumped to a heat exchanger where water is boiled off to allow the glycol to be regenerated and pumped back to the contactor.

Why monitor the water content?

Industrial users of natural gas have specifications pertaining to natural gas quality inclusive of the water concentration. For example, combined cycle gas turbines preheat the natural fuel feed to a minimum of 28 °C above the dew point temperature, to ensure that liquids will not form. For gas turbines, high pressure natural gas goes through a series of pressure reduction stations before entering the combustion zone. At each pressure reduction, the gas experiences cooling due to the 'Joule-Thompson' effect. The temperature of the gas will drop approximately 5.6 °C per 1000 KPa of pressure reduction. By measuring the dew point temperature of the gas stream, sufficient heat can be applied to the fuel to prevent the formation liquids or ice. The gas is typically preheated by water or steam heat exchanger. An online moisture monitor is used to ensure that water will not condense; the monitor also provides 'early warning' of water leakage

from the heat exchanger, which may be due to corrosion.

In the transportation and distribution of natural gas, contractual specifications establish the maximum amount of allowable moisture and this is normally expressed in absolute humidity (the mass of water/volume of natural gas usually expressed in mg/m³) or volume ratio (volume of water/volume of natural gas usually expressed in parts per million, ppm). The dew point temperature is also important because it predicts the temperature at which water will condense from the gas phase. Since the dew point temperature is dependent on partial pressure of water and the partial pressure is proportional to changes in the total pressure, the dew point temperature is referenced to either the process pressure or standard conditions.

In the European Union, for example, the maximum dew point temperature for 'cross border points' is -8 °C at 70 bar(a). In the US, the standard for the maximum absolute humidity in interstate pipeline natural gas is 7 lb/million ft³ or 112 mg/m³. Suppliers who exceed this standard or 'tariff,' run the risk of being shut out of the pipeline transportation and distribution network. Consequently, an extremely accurate and reliable method of measuring water content in natural gas is of vital

importance and a new tunable diode laser absorption spectroscopy instrument has been developed to meet this need.

Measuring water content

A number of technologies have been used for moisture content measurement. The most commonly used technologies include: aluminum oxide sensors, thin film polymer capacitance sensors, electrolytic instruments (which measure the current required to dissociate water into H₂ and O₂), quartz oscillators and chilled mirrors. Every moisture measurement technology, no matter how reliable, needs methods to calibrate and verify the integrity of the measurement. All conventional moisture measuring instruments, by the very nature of their design, will drift to some degree. The magnitude of drift is dependent on the technology used, the sampling system, temperature, pressure and the exposure to condensed water. In addition, the composition of the relevant gases or liquid matrix can degrade the sensor over time. One of the main advantages

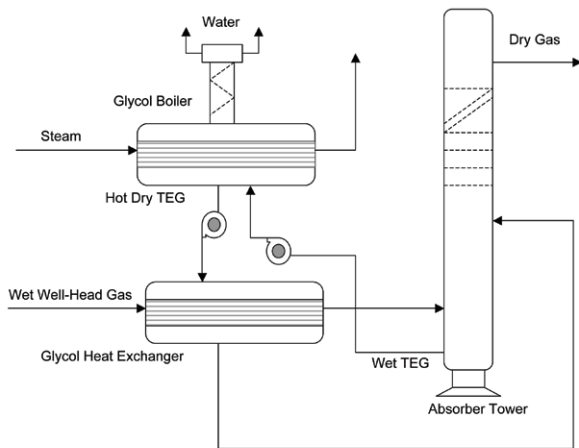


Figure 2. Schematic of TEG dehydration.

$$T = \frac{I}{I_0} = e^{-\sigma LN}$$

T = Transmission of light through the media
I = Intensity of light leaving the media
*I*₀ = Intensity of light entering the media
e = Base of the Natural Log
σ = Absorption coefficient
L = Distance the light travels through the media
N = Concentration of the analyte

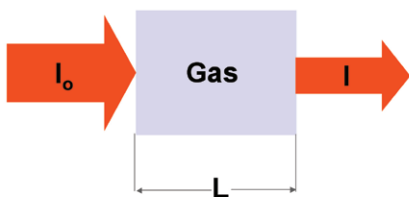


Figure 3. Beer-Law for gases.

of tunable laser diode absorption spectroscopy (TDLAS), in addition to its high accuracy, is its negligible drift over the long term.

Tunable laser diode absorption spectroscopy

TDLAS has been applied with some success in the measurement of the water content of natural gas. The Aurora, from GE Sensing and Inspection Technologies, combines all the advantages of TDLAS in a turnkey system, which can be located in hazardous areas and areas subjected to extremes of weather.

Tunable diode laser (TDL) hygrometers measure water based on the Beer-Lambert principle. This states that when light energy at certain wavelengths travels through gas, a certain amount of the energy is absorbed by the water within the path. The amount of light energy lost is related to the concentration of water.

A diode laser is very similar to an LED in that when a current is injected into a p-n junction, holes and electrons recombine and release photons. A diode laser stimulates the release of these photons and incorporates an optical cavity to create laser oscillation and the release of a beam of coherent light at a single wavelength or frequency. The first person to demonstrate coherent light emission from a semiconductor diode (the first laser diode), widely acknowledged to have been Robert N. Hall and his team at the General Electric research centre in 1962.

It is possible to change the frequency of the emitted light by changing the temperature or the 'injection current.' The monochromatic frequency can also be modulated. Consequently, by passing light at the water absorption frequency through a sample chamber containing natural gas of a certain moisture content, it is possible to establish the water content precisely by measuring the amount of loss in the absorption spectrum.

In practice, a TDL system measures the water concentration in natural gas by sweeping a narrow band laser diode and changing its wavelength by ramping the injection current while holding the temperature constant by use of a thermoelectric (Peltier) heat pump array. The laser is also modulated at high frequency. At the centre frequency, the second harmonic (known as 2F) peak height is measured. The 2F peak height is directly proportional to the partial pressure of water in



Figure 4. Aurora analyser installed on a pipeline.

the absorption cell. By simultaneously measuring the cell total pressure, the concentration is determined. The simultaneous measurement of the gas temperature and process pressure enable other humidity parameters such as absolute humidity, dew point and process dew point to be determined with a high degree of precision.

A practical TDLAS instrument

For use in natural gas, the wetted components are constructed of stainless steel with the exception of the optical window that consists of proprietary glass and the mirror that consists of proprietary polished metal alloy. Those components are selected for their resistance to corrosion and 'optical purity.' The path length is related to lower detection limit, and has been optimised for a volume ratio of approximately 5 - 5000 ppm_v. The photodiode and reference photodiode are housed in a hermetically sealed and dry enclosure. A platinum resistance temperature detector (PRTD) measures the gas temperature and a silicon micro machined strain gauge pressure sensor measures the sample pressure. The temperature sensor is encased in a 316 stainless steel sheath and the pressure sensor is also constructed of 316 stainless steel with a hastelloy wetted diaphragm. Only light and inert materials come into contact with the process gas. Unlike conventional sensors, there is no sensing surface that may corrode or degrade over time. As a result, the instrument has negligible long term drift and no field calibration is needed.

When installed in the field, an insertion membrane filter and pressure regulator separates liquids (hydrocarbons, liquid water and glycol carry over from the dehydration process) and drops them back into the pipeline, and also reduces the pressure. A coalescing filter removes any additional liquids, aerosols and particulate not interdicted by the membrane filter. A second pressure regulator decreases the pressure close to atmospheric. The flow rate through the absorption cell is controlled with a needle valve and a rotameter monitors the flow rate. The sampling system and absorption cell are installed in a stainless steel

enclosure that is heated by a thermostatically controlled electrical resistance heater. The application of heat also assists in keeping the sample in the gas phase.

The optical bench, flow cell and housing for the microprocessor and driving circuitry are designed to meet NEC Class 1, Division 1, Groups C and D, ATEX Zone 1 and the CSA equivalent. The hygrometer is equipped with three programmable digital displays, three programmable analog (4 - 20 mA signals) and a RS-232/485 digital serial interface with MODBUS protocol. The keypad of the analyser utilises magnetic induction, therefore the user may program the unit in the hazardous area without the need for a 'hot permit.'

Conclusion

TDLAS instruments show several marked advantages over conventional moisture measuring instruments. They respond faster by several orders of magnitude. Faster response results in faster recovery of the natural gas supply after process upsets, resulting in revenue for natural gas that fulfils contractual and tariff specifications. They have negligible drift and hence no need for field calibration, and they are accurate to $\pm 2\%$ of a reading. They suffer no effects from glycol carry over from the dehydration process and can be used on sour gases with a high H₂S concentration.

Digital data can also be streamed to SCADA or similar data acquisition systems. Users can program their own SCADA systems to record data, provide alarms and carry out diagnostics etc.

All these benefits have been enhanced with the introduction of the Aurora, which is supplied with its own dedicated software as a stand alone utility, and data may be exported as ASC11 text for use in Excel and other programs.

Water will always be a constituent of natural gas. There will always be a need for dehydration and there will always be a need to monitor the level of moisture content for quality and operational reasons. TDLAS instruments make that monitoring more reliable, more productive and safer, while reducing maintenance costs. 