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Improving process control with TDL technology

Ultra-fast and highly accurate TDL-based analysers are replacing conventional sensors at refineries and gas processors, saving on maintenance while providing enhanced control over process integrity

Sam Miller

SpectraSensors Inc

Confronted with increasing costs and product integrity issues, the hydrocarbon processing industry has become increasingly dependent on sensors for detection and the measurement of impurities in gas streams. For some sensing technologies, this can be a hit and miss situation that can compromise process control and result in costly actions, including high maintenance costs, unplanned shutdowns and unanticipated shut-ins.

Protecting expensive process equipment

Gas processing plants require fast and accurate measurements of moisture (H_2O), hydrogen sulphide (H_2S) and carbon dioxide (CO_2), because these contaminants damage expensive equipment such as turbo-machinery and pipelines; shorten desiccant, contactor or molecular sieve lifetimes; and threaten the operator's ability to maintain tight process control and product quality. In some cases, the gas processor's downstream customer can shut in their supplier, which costs hundreds of thousands of dollars.

For refineries and chemical plants, the emergence of tunable diode laser (TDL)-based technologies has been a major development and created opportunities to maximise productivity while avoiding high maintenance costs. TDL-based gas analysers are being used to monitor high-grade feedstock, recycle streams in reforming, fuel gas monitoring, isomerisation units, alkylation units, catalytic cracking processes, sulphur recovery and more. Refineries strive to reduce maintenance issues, because engineering and instrument technicians are usually overloaded.

By instantly and accurately pinpointing the presence of moisture, HCl , H_2S and other impurities in feedstock and fuel gas streams, the TDL-based gas analyser is able to provide significant benefits. Among those are prevention of foreshortened

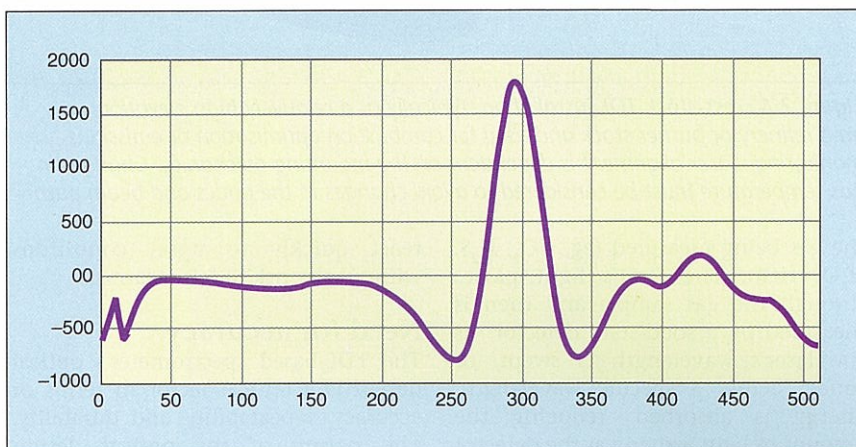


Figure 1 Typical moisture peak in a background of natural gas. Tall peak is formed by the moisture, and surrounding features are formed by the presence of methane

lifespans for costly catalysts, enhanced assurance of product quality, reduced turnaround recovery times and avoidance of unscheduled shutdowns.

TDL-based analysers are increasingly being used in "pain-point" analytical applications to measure contaminants reliably while reducing maintenance and operating costs. TDL absorption spectroscopy employs a laser mounted behind a window that protects it from the adverse effects of caustic gas contents, while enabling the analyser to accurately and quickly read varying gas concentrations. The laser does not come into contact with the gas and calibration does not change or drift over time.

TDL technology

Categorically, the TDL analyser is a photometer. While other types of photometers (eg, infrared and ultraviolet) are used to detect contaminants in gas streams, they are generally less precise in measuring absorption bandwidth than TDL-based technology. This type of analyser technology offers high spectral purity (high resolution or narrow spectral line width), enabling the detection of certain gases at the parts per billion (ppb) level with very short signal integration times.

Current gas measurement capabilities using near-infrared, room-temperature laser devices include water vapour, methane, acetylene, hydrogen fluoride, hydrogen sulphide, ammonia, carbon dioxide, carbon monoxide, ethylene oxide and oxygen.

While the chemical industry has for many years used non-dispersive infrared devices for performing optical measurements, the recent availability of cost-effective semiconductor lasers has provided that and other industries with a superior analytical tool. A TDL is a type of semiconductor-based laser that can be tuned to optically select a very specific wavelength (or colour) of light. Prior to the application of TDLs in the refining, gas processing and petrochemical industry, NASA's Jet Propulsion Laboratory (JPL) developed long wavelength, near-infrared tunable lasers and processor controls that enable users to precisely target specific molecules and detect trace elements in gas. This spectroscopy technology was vital to research and operations in the Space Station and Mars Polar Lander programmes, as well as studies on global warming, emissions, weather and climates throughout the world.

TDLs emit near-infrared light at wavelengths that can be absorbed by

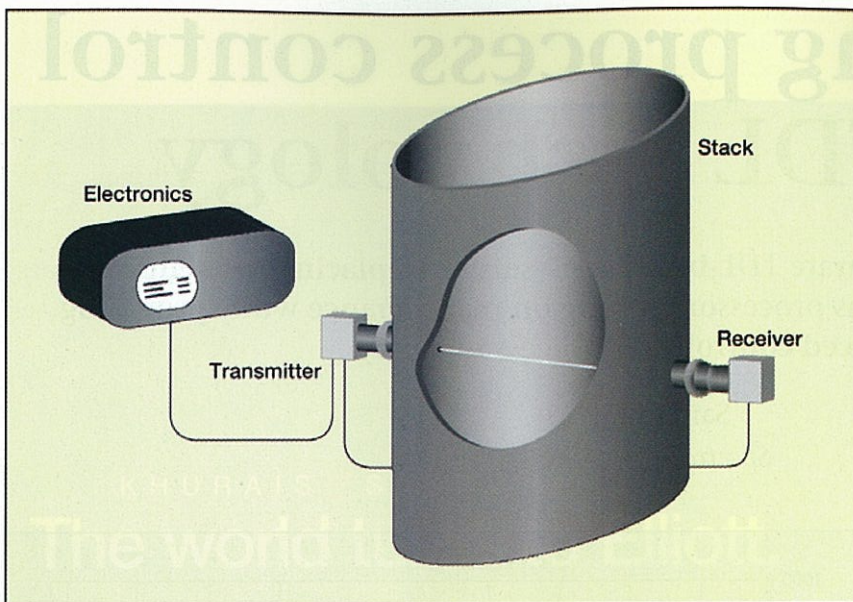


Figure 2 A cross-stack TDL installation, typically at a relatively high elevation on a refinery or burner stack and used for combustion optimisation or emissions monitoring. Laser alignment is dependent on the mounting mechanics. Changes in gas temperature must be considered to avoid changes in the optics and beam path

the gas being measured (eg, CO_2 , H_2S , H_2O , HCl). The laser's light passes through the gas sample and then is measured by a solid-state detector. As the laser's wavelength is swept, or tuned, across a specific wavelength, energy is absorbed, reducing the amount of light arriving at the detector (at that specific wavelength only). The result is a sharp peak-shaped curve (Figure 1). The fraction of light absorbed (the peak height) is directly proportional to the concentration of the associated target gas.

Since the laser is tuned across the line multiple times per second, it can be used for fast, accurate measurements and the control of process parameters. TDL gas analysers have the ability to

react quickly to upset conditions without the risk of false alarms.

Need for accuracy

The TDL-based spectrometer's optical design is a critical factor in terms of accuracy, repeatability and durability. The nature of the optical design developed by SpectraSensors is such that the sample flows through a chamber and the sensor is isolated behind a window, rather than in the stream of gas. By doing so, the accuracy of the analyser is not affected by the gas or impurities, which are harsh enough to debilitate the accuracy and service life of conventional probe-type electro-mechanical analysers.

Open path

Essentially, there are two popular TDL analyser system designs in use: the open path type and the extractive type. Both use similar principles, but they vary significantly in application. The open path system (Figure 2) is applied in situ (in the stream) and is generally used to measure gases in cross-stack or offgas (atmospheric vent) applications. Cross-stack use is commonly applied to flue gas stacks to measure contaminants contained in gases emitted from a furnace or boiler. Offgas applications include the measurement of gases in ventilation passages, through which various fumes are emitted. These types of emission are commonly referred to continuous emissions monitoring systems (CEMS). CEMS analysers monitor hazardous and prohibitive contaminants such as sulphur.

Depending somewhat on the design, open path TDL analysers are capable of measuring a number of near-infrared absorbing gases in difficult environments. Many are quite robust, and capable of detecting and measuring gases under relatively rough conditions, including streams of high temperatures, high pressures and those containing corrosives or substantial particulate matter. Additionally, measurements are usually fast and interference free, offering a high degree of relative accuracy.

In its product lines, open path TDL manufacturers note their in-situ gas analyser's measurements are performed in real-time, enabling proactive control of dynamic processes and allowing fast, cost-saving corrections, plus built-in auto-calibration. Applications cited include process control, NO_x optimisation, combustion control (typical measurements are CO and O_2) and emission monitoring plus filter optimisation.

Extractive TDL

The other major branch of TDL absorption spectroscopy is the extractive technology, or online/at-line approach. This technology samples gases extracted from the stream into a compact tubular chamber with mirrors (Figure 3). The mirrors reflect an incoming laser beam between 1–100 times before it exits the cell again. Typical cell diameters vary from 25–75 mm, and length from 100–500 mm.

Due to its condensed design, the extractive TDL analyser offers several advantages for applications in the hydrocarbon process industry (HPI). It is small enough to permit convenient installation virtually anywhere in a process plant. The long optical path of the cell enables highly sensitive measurements of trace gases in small volumes. Measurements of contaminants

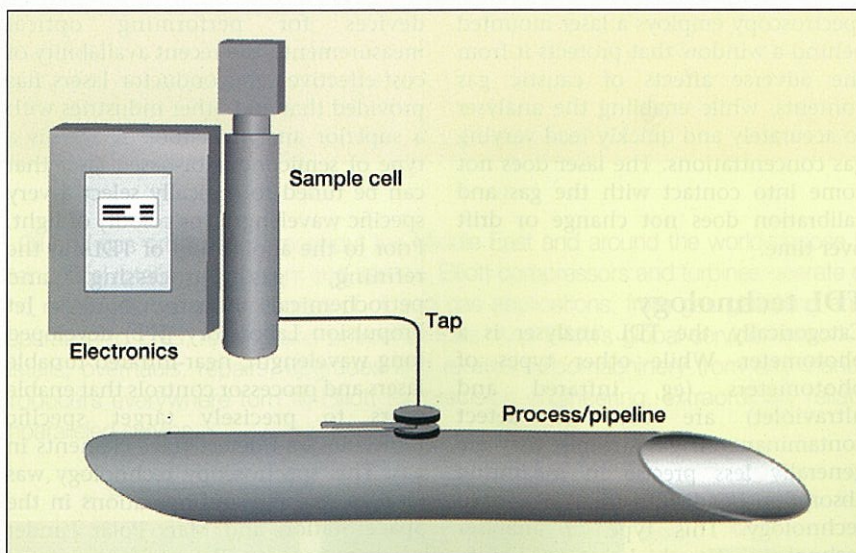


Figure 3 A simplified extractive TDL gas analyser. The installation requires a sample conditioning system to drop the pressure to the cell while maintaining a representative sample of the stream. The laser alignment is stable, allowing for long path lengths and, due to stable optics and low pressures, the spectral features are sharper

such as moisture, hydrogen sulphide and ammonia can be detected down to ppm and ppb levels. Since it is operating outside the stream being measured, the extractive TDL is not subject to particulate matter flowing in the stream.

Perhaps most significant, particularly where used to analyse streams under high pressure, the offline design of the spectrometer cell folds a very long absorption path in a compact space. This enables the extraction of gases such as process chemicals in the vapour phase at about 10–20 psi. This low-pressure environment gives the system the resolution and specificity needed for fast and accurate trace level measurements, while also minimising maintenance requirements.

Dependable H₂O analysis

Impurities such as moisture and corrosive acids found in many gas streams are the nemesis of conventional sensors, which are directly exposed to the gas stream and those harmful elements. Over time, and sometimes within a few weeks, those probes become damaged and inaccurate, resulting in costly repair or replacement. In the meantime, corrosion and contamination from problematic impurities can damage equipment, catalysts, desiccants and processes.

The TDL-based analyser allows the gas processors, whether they are sweetening, dehydrating or removing various impurities, to monitor and measure the inputs and outputs of their processes. Furthermore, it takes repeatable measurements within seconds, whereas conventional devices often take many minutes (Figure 4).

Excessive dehydration costs may be incurred because of inaccurate moisture readings or concern on the part of the operator that the gas may be too wet. In many cases, it is necessary to over-process the gas in order to achieve quality specifications for multiple customers when taking into consideration the risk of inaccurate measurements and potential false shut-ins. The availability of a fast and reliable measurement allows the plant to confidently deliver gas that is within specifications.

The TDL-based technology is very fast and does not drift, thereby enabling operators to keep dehydration costs to a minimum without fear of a shut-in.

Accurate H₂S measurements

For monitoring and measuring H₂S in gas streams, lead acetate tape analysers are frequently the technology of choice. In that design, gas is sent directly through the lead acetate tape, which changes colour when reacting with sulphur. The system analyses the colour change with a photometer. However,

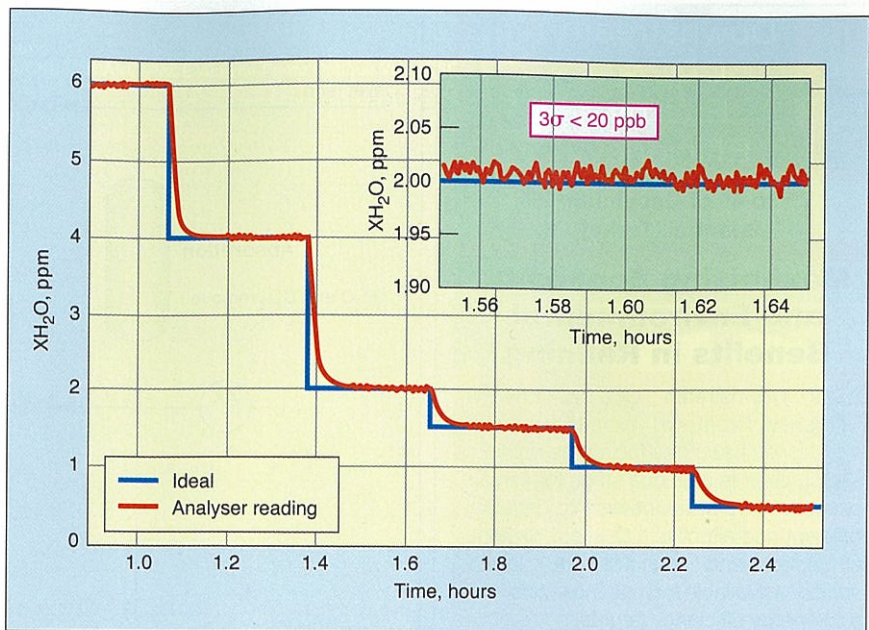


Figure 4 Moisture concentration over time, with 1000 and 200 ppb step changes. The analyser responds quickly to change. The only dry downtime is associated with the purging of the sample system and desorption of moisture from its components

the lead acetate tape is a consumable that is directly exposed to the gas stream. Tape reels must be changed weekly or monthly and, if there is a system leak, it exposes the whole tape. Also, the used tape is considered hazardous waste and must be disposed of accordingly.

Some processors use a UV photometer for measuring H₂S. Natural gas may have varying percentages of methane, propane and possibly more than a dozen other components. The measurements results of UV photometers are susceptible to gas composition changes. When the background matrix of the gas changes, that often causes erroneous readings and consequential problems.

For H₂S applications, the TDL-based

analyser measures sour gas going into processing and sweetened gas coming out (Figure 5). Fast analysers enable better control of processes by letting the processor know instantly how much processing is needed and provides for faster shut-off when the sweetened gas is not up to required standards. Changes in gas concentrations can be seen immediately, with TDL analysers preventing false alarms, false readings and unwarranted shutdowns.

LNG applications

The presence of even trace amounts of H₂O or CO₂ can threaten the integrity of processing equipment during compression and liquefaction of natural gas due to ice formation. It is essential to have very fast H₂O or CO₂ detection

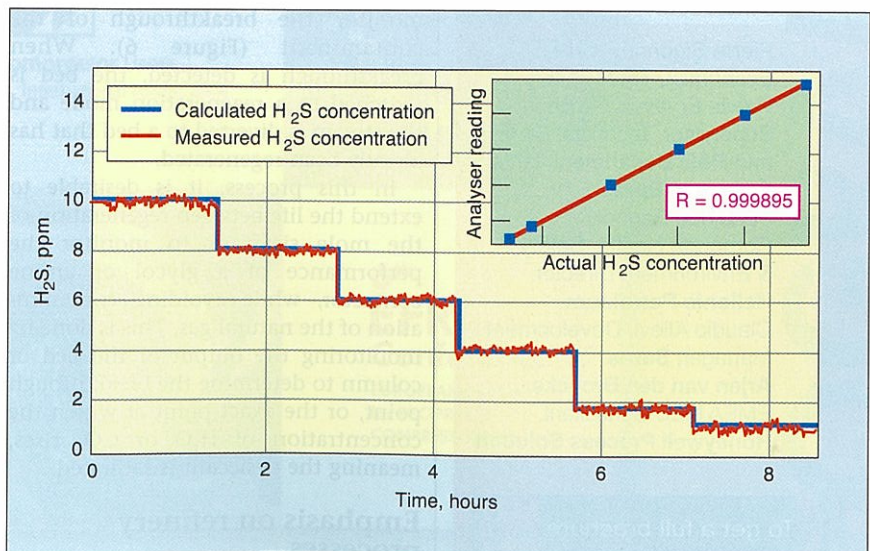


Figure 5 H₂S concentration over time with 2 ppm step changes. Very good signal-to-noise is demonstrated. The TDL-based H₂S analyser does not require carrier gas and does require light source replacement over time, which decreases maintenance costs

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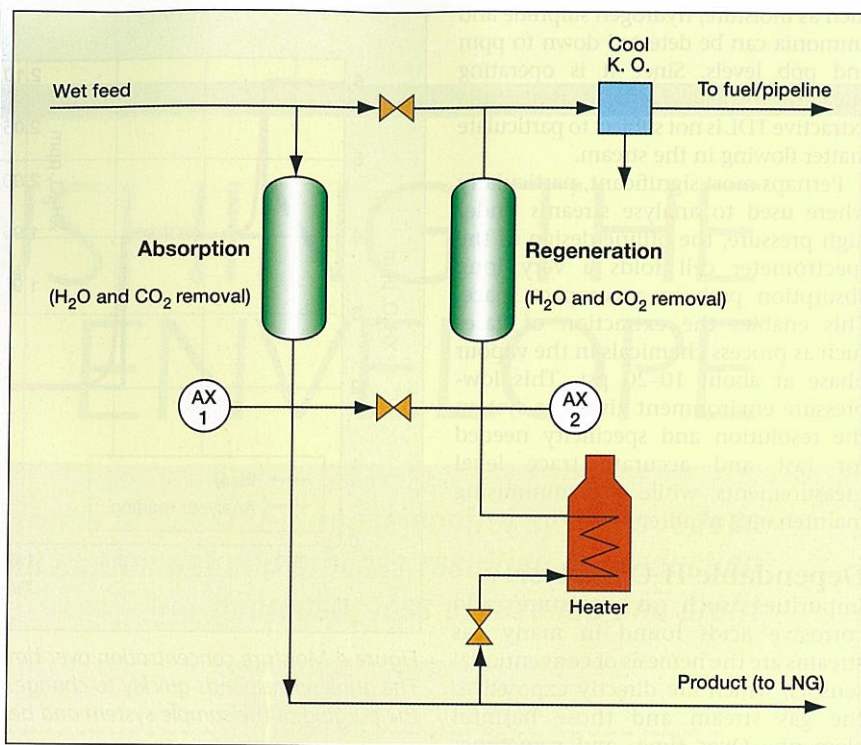


Figure 6 Typical placement of measurement points (marked AX) for monitoring moisture or carbon dioxide breakthrough

to improve the life of the desiccant while retaining product quality.

In the past, LNG and NGL gas processors have relied on surface-based analysers such as electrochemical and quartz crystal cells to measure trace amounts of moisture in process streams. Although these devices may perform with acceptable accuracy at first, the confidence level in their measurements soon becomes low due to drift, the inability to read high concentrations of moisture and the tendency for their sensor probes to become desensitised by the gas streams they are measuring.

Moisture and carbon dioxide analysers are deployed at the output of the mole sieve beds and are used to monitor the breakthrough of the contaminant (Figure 6). When breakthrough is detected, the bed is switched to a regeneration mode and the stream is diverted to a bed that has already been regenerated.

In this process, it is desirable to extend the life between regeneration of the mole sieve or to monitor the performance of a glycol or amine contactor, while avoiding contamination of the natural gas. This is done by monitoring the output of the bed or column to determine the breakthrough point, or the exact point at which the concentration of H₂O or CO₂ rises, meaning the desiccant is saturated.

Emphasis on refinery processes

Extractive TDL-based analysers have been widely applied in the natural gas production and pipeline transmission

industry, and have been highly integrated into gas processing plants (dehydration, sweetening, and LNG & NGL plants). Although cross-stack TDL gas analysers have been adopted by many refineries, especially in Europe, the extractive TDL is fairly new to the downstream markets. However, because the need for improved process control and reduced costs are equally if not even greater among refineries, there has been immediate interest in applying this technology throughout the petrochemical industry. TDL absorption spectroscopy is used in an array of applications, such as for moisture (H₂O), oxygen (O₂), hydrogen sulphide (H₂S), carbon dioxide (CO₂), methane (CH₄), hydrogen chloride (HCl), ammonia (NH₃), acetylene (C₂H₂) and ethylene oxide (ETO).

The future

According to Dale Langham, an expert process analyst, in the past many companies in the natural gas, petrochemical and process industries were flying blind as far as moisture and other contaminants were concerned. That is changing quickly, because companies in those industries must squeeze technologies to maximise profits. They simply cannot afford the expensive shutdowns, shut-ins and other penalties resulting from slow and inaccurate analysers.

Sam Miller is Product Manager for SpectraSensors in Houston, Texas.
Email: smiller@spectrasensors.com