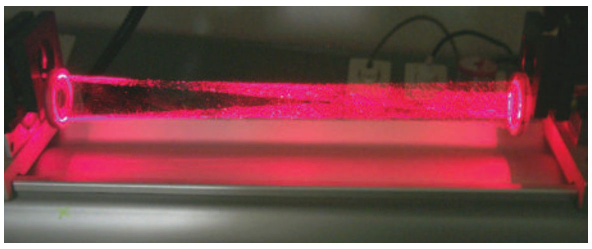
GAS DETECTION : THE LASER APPROACH

When it comes to gas, it is always a serious business. Gas operators' maintenance programs are specifically designed to limit safety hazards through close monitoring of their pipelines and installations. But in addition to the concern for assets and human safety, global warming must now also be taken into account, along with the need of operational cost reductions. Methane, the main component of natural gas, is an odourless, invisible, yet combustible gas. Like CO2, it is a greenhouse gas, but its effect on climate change is far greater than CO2. Methane is responsible for a quarter of the global warming we experience today. In response, the natural gas industry has to proactively deal with methane emissions mitigation all along the gas chain from production down to the end consumers. This is why pipeline operators and gas utilities worldwide are currently reviewing their integrity management system with tougher Leak Detection and Repair (LDAR) programs.

Measurement is the key in gas detection

When it comes to methane leak detection, the performance of the instruments used for the safety/maintenance checks carried out on natural gas installations needs to be constantly upgraded to meet the latest operational and regulatory requirements. In gas measurement, instruments have evolved considerably within the past 15 to 20 years, from the catalytic bead and electrochemical point sensors as well as flame ionisation (i), with the introduction of laser spectroscopy technology.

Why use laser technology in gas measurement?



Laser-based gas sensor technology is an extremely effective tool for detecting and quantifying polluting gases such as carbon dioxide or methane owing to some key advantages.

(i) Flame ionisation consists in passing a gas sample through a hydrogen flame. The presence of gas produces a current between two electrodes. The current intensity is measured and translates to a gas concentration level.

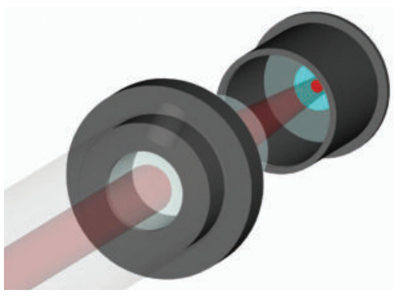
Higher sensitivity…

One of the major advantages of laser-based technology is that it is highly sensitive compared with other sensor technologies.

In the field of gas measurement, laser-based absorption techniques are the most widespread and the leading commercial technologies fall into two categories :

- Tunable Diode Laser Absorption Spectroscopy (TDLAS), including single-pass, dual-pass and multi-pass cells (see box)
- Cavity Enhanced Absorption Spectroscopy (CEAS) under which Cavity Ring-Down Spectroscopy (CRDS) and Integrated Cavity Output Spectroscopy (ICOS) fall. (see box)

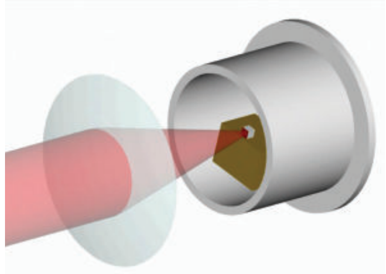
…And other key features make the difference



Newer gas analyser instruments use a laser diode mounted on a thermo-electric cooler in order to tune a laser wavelength to the specific absorption wavelength of a particular molecule. They exploit their high frequency resolution, which results in enhanced sensitivity (in the order of parts per billion, ppb) and selectivity, as they are tuned to a specific compound of gas. In short, the laser remains locked on the specific absorption wavelength of the target gas. The extremely narrow width of the laser beam, coupled with the tuned wavelength of the laser diode, is a key factor to selectivity. The absorption technology ensures precise gas recognition, eliminating the potential for false alarms, which represents a real issue with other gas detection technologies.

Generally speaking, the new instruments feature high speed of response (typically one second), wide dynamic measurement range, extremely precise measurements and low cost of ownership because they are easier to calibrate and maintain with greater operational simplicity.

No gas detection without the LASER



Because of the growing compactness of latest laser-based gas sensors and their capacity of detecting very low concentrations of hazardous gas, even when its source is at a distance, the laser technology has found numerous ways to serve the oil and gas world:

- Stationary real-time continuous monitoring systems of GHG (methane, CO2) to reduce gas emissions, diminish work safety hazards and prevent global warming.
- In-vehicle gas leak detection system to detect gas leaks while

driving a vehicle along the buried gas pipeline network for their inspection. This type of application requires fast response time and low detection limits since the vehicle can be moving at fairly high speeds (around 40 km/hr to match normal traffic speed) and is limited in proximity to leak sources based on roadway as well as pipeline configuration.

- Remote methane leak detection systems (hand-held, built in drones, or easy-to-deploy systems) rendering accessible difficult-to-access and inspect areas. Hand-held and, in particular, drone-based systems impose serious limitations in terms of size, weight and power.
- Hand-held detectors operated by field technicians to monitor at discreet locations points along pipelines or in gas installations.

Focus on a gas operator's experience

Almost 25 years ago, a major European gas operator in charge of the longest distribution network in Europe, felt a real need to renew their stock of detection instruments. At the time, the instruments used for their network surveying and gas leak detection program utilised predominantly the technologies of explosimetry, catharometry and flame ionisation . Since the ionisation detector (FID) detects methane gas at PPM level, it was used in all of their network survey vehicles as well as in a number of their portable detectors. Though very sensitive and relatively stable in measurements, the technology presented, however, some major disadvantages:

- Response to all gaseous compounds indiscriminately,
- Response time too long
- The use of high pressure hydrogen gas bottles with a flame posed serious operational safety concerns (hot point) and rendered the technology unsuitable for detection indoors.

The gas operator's initiative was typical of an overall trend noticeable among a growing number of gas operators worldwide. At the same time, manufacturers of detection instruments were beginning to commercialise optical sensor-based detection systems.

One example is the open path system mounted on a vehicle. The system uses an infrared light spread at the front of the vehicle. When combined with an optical filter, this enables gas detection at the ppm level and eliminates the need for sampling equipment. However the detection device is dangerously exposed to shocks and the optical sensor is exposed to dirt and mud. Measurements may not always be accurate and regular maintenance is required.

Another example is the multipath measurement cell, which multiplies the interaction between a gas sample and a laser beam. This corresponds to the TDLAS technology from which the optical detection systems chosen by the gas operator for network surveying have been developed.

In a first step, the gas operator started replacing its FID Network Survey vehicles with INSPECTRA VSRs. And, as soon as the hand-held portable version was approved, the INSPECTRA Laser portable detector was introduced. Since 2006, the number of INSPECTRA technology equipment has been constantly growing. Today, there are over 400 portable units and over 35 INSPECTRA VSRs in operation for the regular inspection of the more than 200,000 KM of the gas operator's distribution network.

Every day, the gas operator invests 1 million Euros into the safety of the natural gas network, of which 25% goes to the surveying of the network and the training of professionals.

Network Surveying – how it works

Every year, more than 70,000 km of the operator's gas network are being surveyed to detect and localise leaks. And in compliance with European legislation, the network is surveyed according to its classification:

- 3 inspections per year for higher risk sections
- 1 inspection per year for the copper pipeline sections
- 1 inspection within the first operation year for newly laid pipelines
- 1 inspection every 4 years for the low pressure network

Laser applied to vehicle and pedestrian detection

For the network sections accessible to vehicles, inspection is done by the Network Survey vehicles that are being road-driven along the buried pipelines at an average speed of 40 km/hr instead of 20 km/hr previously. Equipped with suctions at the front-bumper, positioned at ground level, the network survey vehicles employed by the gas operator can "sniff" the smallest methane gas concentration, down to the ppm, even at a distance (sometimes up to 8 to 10 meters depending on the wind direction for example).

Any presence of methane gas triggers an audio and visual warning and the data is instantly recorded in the on-board survey-PC. Survey procedures require that the network survey vehicle operator confirms immediately any indication of a gas leak, on foot, using an INSPECTRA Laser portable detector. If the leak indication proves to be an actual leak, the information is recorded. Should the gas concentration exceed 10,000ppm (1% Gas or 20% LEL), the operator will call immediately the Emergency Intervention cell. Under that threshold, the operator will have to determine whether the leak represents a safety hazard, depending on terrain configuration and on the likelihood of a potential gas accumulation building up inside potentially hazardous areas such as a nearby cellar or an underground car park.

Due to the INSPECTRA's selectivity to methane, 8 to 9 leak alerts out of 10 correspond to actual gas leaks, as opposed to 2 out of 10 with the former VSRs. This is a significant improvement when you consider that each VSR surveys an average of 20 to 25 km per day (including gas connection boxes).

For the network sections not accessible to the VSRs such as pedestrian areas, elevated installations along bridges, etc., inspection is performed on-foot by field technicians using the INSPECTRA LASER portable. The same leak alert policy applies during inspections, covering a daily average per operator of 3 to 6 km, depending on urban environment and network specificities.

Tangible benefits along the pipeline

The decision of this European gas distribution operator to equip their leak survey equipment with high-performance optical detection instruments falls within the environment protection commitment policy of the company. And looking back, laser detection clearly supports the strategic challenges to be met by the gas operator, bringing:

- Increased safety :
  - o Shift from FID with removal of hydrogen and "hot point" (furnace and flame). The laser instrument is intrinsically safe and its use can be extended indoors.
  - o No interference from other hydrocarbons, chemicals or water - no false measurements. The laser system delivers a measurement in the presence of methane only.
  - o Accurate , reliable measurements well below the PPM – almost no gas leak goes undetected.
  - o Stable, reliable measurements – Detection system insensitive to temperature variances, vibrations and humidity
  - o Response time reduced from 3 seconds to 1 second enables pinpointing gas leak points, limits gas dilution and increases detection capacity
- Lower maintenance and operating costs
  - o Reduced gas consumption – no hydrogen
  - o Elimination of re-occurring false alarms, saving time-

The GAZPOD monitoring station from GAZOMAT measures on a continuous basis up to 4 gases simultaneously such as methane, CO, CO2, NO, NO2, etc. Monitoring data is transferred via wireless cellular connection to an enterprise management system for storage, processing and analysis.

The GAZOSCAN is a handheld remote methane leak detector with exceptionally long detection distance (up to 100 meters) that supports all professionals in emergency response situations, as well as gas utilities in their gas network leak survey. With built-in Bluetooth® technology, the GAZOSCAN can connect wirelessly to a mobile phone and transfer readings to the GAZOSURVEY application that is compatible with a comprehensive entreprise solution for the management and storage of leak detection data.

consuming and costly investigations and reporting.

- o Servicing once a year only owing to the system's robustness
- o Reduced start-up time from 15 to 5 min for the VSRs and from 15 to 0 min for the portables, making it possible for the gas operator to combine vehicular leak detection and on-foot leak confirmation in one inspection circuit.
- o Reduced training time for operators
- o Increased productivity with a survey speed multiplied by 2 (20 to 40 km/hr) and a larger daily inspection range.
- o Compact, lighter measurement cells that can fit inside the smallest carriers and ensure a greater level of comfort for field technicians operating portable detectors.
- o Reduced acquisition and maintenance costs owing to the removal of a number of components (oxidising furnace, hydrogen gas bottles) and to the simplification of the sampling circuit.
- o All-in-one solution – the laser system covers the entire field detection process from leak detection to leak confirmation, which formerly required the use of several devices.
- o Reduction of the network survey vehicles fleet and of the number of inspection crews, despite the fact that the distribution network continues to expand.

Laser technology, as part of the new BIG DATA approach

Research in laser detection continues actively today, looking into new solutions to improve detection performance. The main, current issue with laser technology is signal noise (laser noise or electronic noise) that hamper the measurement. Integrating detectors such as Balanced Photodetector (BD) or Frequency Modulation (FM spectroscopy) are serious options currently explored. BD, for example, could help reducing the signal noise and improving the measurement to achieve a sensitivity down to 100 ppb (0.1 ppm). A feature most relevant for the survey vehicle, making it possible to detect the smallest methane gas particle regardless of gas dilution in the air and vehicle's speed and making it easier for emergency teams to spot gas leaks.

FM can, by amplifying the signal, improve sensitivity for remote distance detection for which distances beyond 50 meters are no longer a problem, as demonstrated by latest remote methane leak detectors (RMLD) on the market. It is clear that laser technology remains the new frontier it was already some 90 years ago when it all really started, with a potential just as exciting.

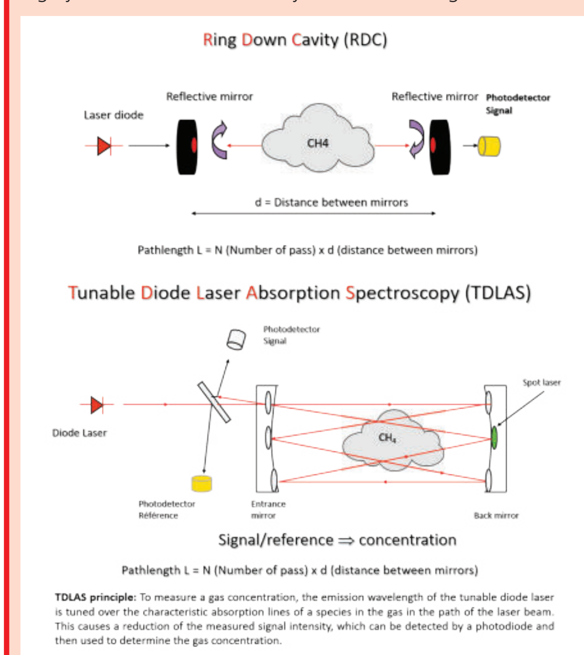
The INSPECTRA LASER technology equips network survey vehicles and portable detectors for the leak inspection of gas distribution networks. New communication technology makes it possible to connect wirelessly detectors, mobile phones, tablets and PC interfacing with a global enterprise management system. Leak data is sent out to concerned parties for immediate analysis and processing.

However, laser technology is only one of the many levers gas operators can activate to achieve their current goals. Investing in state-of-the art equipment to ensure reliable measurements is a first step that makes sense. Managing leak data efficiently as part of a fully integrated integrity management program is but the next major step. This is the true big challenge before the oil and gas players in their digital transformation journey. Tools are available: Real-time measurements provided by modern technologies can now be coupled with GPS and GIS, software and communication solutions can record, transfer, store and analyse the BIG DATA supplied by a larger set of interconnected fixed and mobile detectors. So the future is already with us here today. Gas operators moving in that direction will soon come to realize that the toolkit at their disposal also calls for a broader framework to make the most out of it.

Example of a BIG DATA approach where leak detection instruments and data collecting devices all interface with an enterprise system that can manage hundreds of leak detection systems running simultaneously in different locations with hundreds of users.

The breakthrough of Laser technology

The LASER acronym stands for Light Amplification by Stimulated Emission of Radiation. Lasers are devices that amplify light and produce or emit coherent light beams (light waves emitted are all in step with one another), ranging from ultraviolet to infrared. Laser light can be extremely intense, highly directional and is usually of one wavelength.



Basic principle is the following: A laser oscillator usually comprises an optical cavity in which the light can circulate between two mirrors and a gain medium (such as a laser crystal or laser diode) which serves to amplify the light and compensate the losses it experiences in each round trip inside the cavity.

The laser materials such as dyes, gases, crystalline solids, glasses and polymers are used as gain medium and deciding which one to use depends on the final application. Some lasers are designed to emit light in a continuous mode while others can produce optical pulses with very short durations from femto (10^{-15}s) to nanosecond (10^{-9}s).

The wavelengths of certain types of laser can even be "tuned" for specific applications, making them extremely versatile. Today, lasers are key tools in manipulating and communicating information (in CD and DVD players, supermarket barcode readers and broadband telecommunications), in chemical analysis (foods, medical specimens and materials), in transforming materials (welding, cutting and etching, printing and surgery) and in measurement (surveying and environmental studies). Latest advances made contribute to the development of cheaper, more compact portable device or a more powerful laser used to generate power –giving more applications options and perspectives than ever before in numerous fields and more specifically in gas detection and measurement.

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