Portable Laser Gas Detector Systems for Landfill CH_4 and CO_2 Monitoring

There has recently been a marked increase in interest in detecting and quantifying emissions of the greenhouse gases (GHG) carbon dioxide (CO_2) and methane (CH_4) from landfills in North America and Europe. The primary drivers for this increased interest include: i) new and pending legislation requires demonstrated reductions in GHG emissions; ii) permits to expand existing facilities require more accurate estimates of emissions; iii) financial incentives in the form of emissions trading credits; iv) increased corporate responsibility enabling development of technologies to improve landfill gas capture and minimise GHG emissions.

In general, a barrier to effective implementation of emissions reduction and trading plans is the absence of real emissions measurements with which to establish baselines and confirm reductions. This is especially true for fugitive emissions from important area sources such as landfills – which produce about 13 percent of global anthropogenic CH_4 emissions. Traditional point monitoring technologies are either too laborious, too expensive or provide insufficient coverage to enable cost effective area monitoring. Engineering estimates are very conservative by design and tend to significantly over-estimate emissions.

Two new measurement systems based on laser gas detection have been developed by Boreal Laser in conjunction with industry and government partners to overcome the limitations of existing methods. Laser based gas detectors using room temperature tunable diode lasers (TDL) are now well established for many critical safety, environmental and process monitoring applications. The laser technique has several distinct advantages over traditional gas detection techniques. It uses single line absorption spectrometry in the near infrared, which results in a direct measurement of the gas of interest with no cross interference from other gases. In particular, the absence of water vapor absorption interference enables long path ambient monitoring – up to 1 km. Response times are of the order of one or two seconds. Boreal's laser detector designs have the added benefits of being self validating, portable and robust. With no moving parts and no consumables, maintenance costs are very low.

During the past three years, Boreal Laser has cooperated with the waste management industry and environmental regulators in North America and Europe to adapt its GasFinder™ TDL-based gas detection technology for better quantification of CH_4 and CO_2 emissions from landfills and other area sources.

GasScanner – a Scanning Open Path TDL system

The GasScanner is the result of cooperative R&D with the US Environmental Protection Agency. USEPA had previously developed a method to quantify fugitive emissions from area sources using multi-path optical remote sensing. Recognizing that Boreal Laser's GasFinder™ open path TDL technology is ideally suited to this measurement protocol, Boreal and USEPA worked together to develop the new concept of a scanning TDL system for real-time fugitive emissions assessment and monitoring.

The GasScanner is a portable, high precision, scanning open path monitor, consisting of the GasFinder2 TDL spectrometer mounted on a precision scanning platform that is controlled by a host computer using motion control software. Figure 1 shows the components and interconnectivity of the scanning TDL system. The GasFinder2 is a combined transmitter and receiver (transceiver) which relies on a reflector to return the laser light to the transceiver for real time analysis. The distance of the reflector from the GasFinder2 transceiver defines the system path length, which can range from 10 cm to 1 km. The wavelength modulation technique used to achieve maximum sensitivity normally requires phase matching that must be repeated every time the path length is changed. However, the Boreal GasFinder system employs a "No Phase Adjustment" detection technique that removes the need for this procedure. This enables the GasScanner to scan through any number of paths of various lengths with no path length compensation – a unique feature of this particular system.

The programmable scanner has 360° of horizontal movement and 120° of vertical movement with a step precision better than 0.006° per step. The robust packaging of the system allows it to operate from -30 C to 50 C in rain, snow, or fog – provided that visibility remains good enough for sufficient laser energy to traverse the measurement path. The system can tolerate a factor of 20 turn-down in transmitted light energy from ideal conditions before a "low light" condition occurs. The GasScanner can be programmed to scan up to 36 different paths in succession. Typically, the system will measure on one path for between 10 and 60 seconds before moving to the next path. Transition time between paths is normally 2 or 3 seconds. In scanning mode, path averaged concentrations are transmitted back to a central logging computer. During flux measurements, the computer is also configured to accept wind speed and wind direction data. The computer can then use one of several commercially available algorithms to compute concentration profiles and emissions fluxes from the multiple path averaged concentration data.

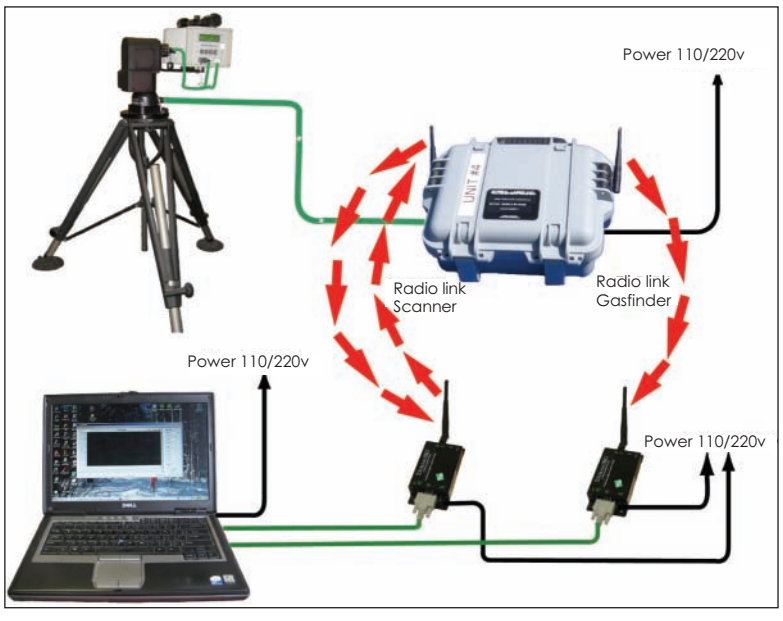

Fig 1: Scanning Open Path TDL spectrometer

GasFinderAB – a Vehicle Mounted TDL Gas Monitor

The GasFinderAB is an alternative version of Boreal Laser's TDL technology configured for mobile, vehicle mounted monitoring applications. This configuration has been used for over 10 years in a helicopter mounted arrangement for the reliable detection of CH_4 leaks from high pressure natural gas pipelines. During the past 2 years, the airborne system has been adapted with different sensing probes for ground based CH_4 and CO_2 monitoring with road-going and off-road vehicles. The vehicle mounted systems enable the acquisition of ambient CH_4 or CO_2 data with high concentration and spatial resolution.

The GasFinderAB vehicle mounted system comprises the elements shown in Figure 2 below. The heart of the system is a fibre coupled TDL gas analyzer which houses a laser diode, drive electronics, and micro-computer subsystems. A fibre-optic cable carries the laser light to an external measurement probe. The laser light makes multiple passes through this probe and is focused on to a photo-detector. The resulting photo current is returned to the TDL analyzer via coaxial cable for analysis. A variety of different probe designs are available, each best suited for different vehicle types. All probes employ a robust mechanical design with simple, stable optical components. A foam shroud minimizes dust and debris entering the measurement path, but allows free passage of ambient air into the measurement zone.

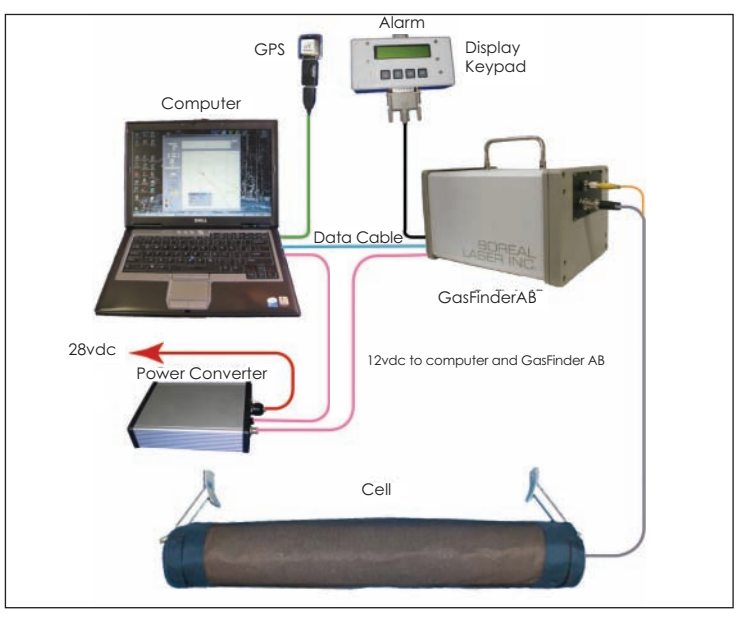

Fig 2: Schematic of vehicle mounted laser gas analyzer

Real time readings are provided on a local display unit and transferred via serial interface to a data logging PC. The serial signal includes comprehensive system diagnostics. The local display unit is mounted such that it is readily viewed by the vehicle driver or pilot. A GPS system provides spatial coordinates to the data-logging PC, which enables CH_4 or CO_2 data to be mapped along the survey route. Readings are typically updated once per second. Sensitivity to CH_4 is 0.2 ppm; to CO_2 is 5 ppm.

CO_2 versions of both the GasScanner and GasFinderAB instruments uniquely operate at longer IR wavelengths near 2000nm enabling higher CO_2 resolution than previously achievable with TDL gas detectors.

Measurement Campaigns

The Boreal GasScanner and GasFinderAB systems described above have been used to monitor and quantify emissions of CH_4 and CO_2 from several landfills in North America and Europe during the past two years.

The GasScanner system is used in conjunction with EPA Test Method OTM-10 and Radial Plume mapping (RPM) algorithms to characterize CH_4 emissions from landfills. The configuration for emissions flux measurement requires that the scanning laser system is set up to define a flux plane through the use of multiple ground and elevated reflectors within a vertical plane at the downwind boundary of a study area. Vertical RPM analysis of the multiple path integrated concentrations yields a vertical CH_4 concentration profile (see Figure 3). Integrating wind speed and direction data allows determination of total CH_4 flux through the boundary plane. An alternative horizontal scanning configuration, using multiple reflectors deployed across or around the landfill enables Horizontal RPM analysis to generate horizontal CH_4 concentration profiles and identify leak sources or "hot spots" (Figure 3). A landfill is divided into sections, and the survey equipment can effectively be used to determine flux emissions from different cells within the landfill.

A GasFinderAB CH_4 system mounted on an all-terrain-vehicle (ATV) has been used for rapid surveying of several landfills in Europe to determine near ground concentration profiles and pin-point leak sources. Figure 4 shows CH_4 concentration variations along the survey route on a landfill in Spain. The ATV was driven at speeds between 15 and 25 km/h. Note the relatively high levels of CH_4 encountered at many locations on the survey route. Values shown in red are between 100 ppm and 150 ppm. Values in blue are in excess of 150 ppm.

While these data are useful for identifying high CH_4 levels, further data processing including meteorological data and regressional analysis is needed to pinpoint leak sources and quantify emissions. Algorithms to enable such analyses are currently under development and test.

Figure 4: GasFinderVM survey of near ground CH_4 concentrations at a landfill in Spain

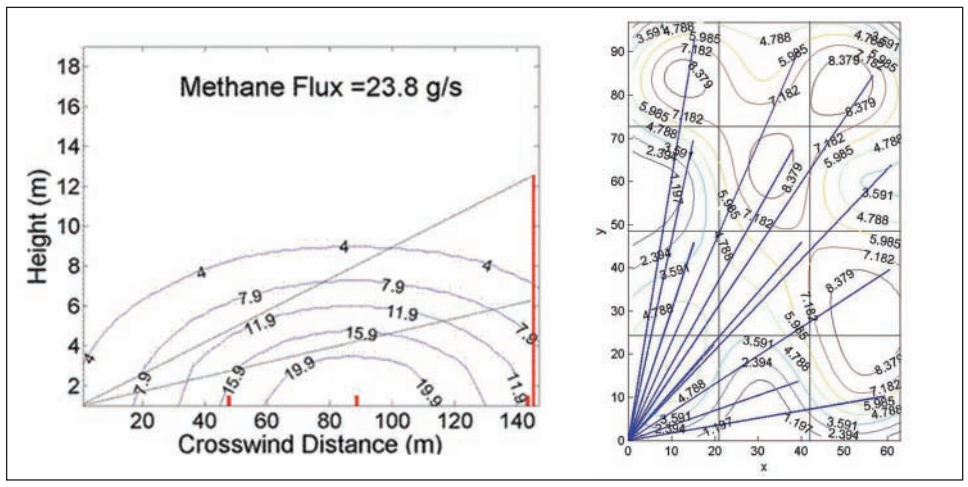

Fig 3: Landfill CH_4 emissions generated by a scanning TDL spectrometer system and Radial Plume Mapping with Vertical RPM on the left and Horizontal RPM on the right.

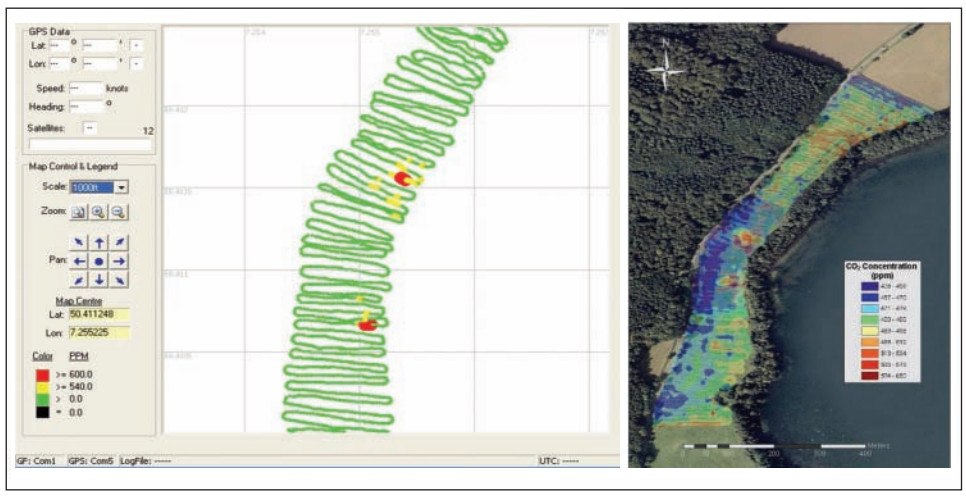

Fig 5: GasFinderVM survey of ground level CO_2 on edge of Caldera

Other Applications – such as CO_2 Sequestration

The GasScanner and GasFinderAB systems have been used for measuring emissions from many other types of area source. Examples include: CH_4 and NH_3 (ammonia) from agricultural operations, especially intensive animal feeding operations; CH_4 and CO_2 from oil and gas producing and processing operations; NH_3 and HF (hydrogen fluoride) in fertilizer manufacture; and CO_2 in enhanced oil recovery and Carbon Capture and Storage (CCS) projects.

CCS projects have significant potential for laser gas detection. Boreal Laser initially developed the high resolution CO_2 GasFinderAB system for the British Geological Survey (BGS). BGS is involved in developing European Union protocols for monitoring the integrity of proposed CO_2 sequestration projects – where CO_2 captured from industrial processes is pumped underground into oil and gas reservoirs and salt aquifers. In order to validate proposed protocols, BGS conducted surveys of volcanic geologies in Italy and Germany with the high resolution CO_2 GasFinderAB system. Figure 5 shows data from a survey on the edge of a caldera lake in the Eiffel region of Germany. This survey identified the location of CO_2 plumes not previously known and confirmed the ability of the GasFinderAB system to rapidly survey large areas with high spatial resolution.

Summary

As a result of cooperation with the EPA and industry in the US and Europe, Boreal Laser has developed new laser gas detection tools for more accurately quantifying emissions of the greenhouse gases CH_4 and CO_2 from landfills and other area sources. Field experience with these tools over the past two years confirms that they are robust, easy to use and enable the rapid acquisition of gas concentration data over large areas. When combined with meteorological data, one of several commercially available algorithms can be used to enable the identification of hot-spots and the estimation of emission fluxes.

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Detect Hydrogen Sulphide to Eliminate Pungent Odours

Noxious smells have long been associated with low concentrations of hydrogen sulphide (H_2S) but these nuisance odours can now be avoided with the new H_2S DraegerTube. Able to detect extremely low levels of H2S before the aroma becomes apparent, this easy-to-use device is of particular benefit to the water and waste industries where the gas can accumulate in sewers and stagnant water. Ideal for use in any odour control application, it can also be used to monitor H_2S levels in a number of chemical processes.

With a measurement capability as low as 0.2ppm, the **Drager** (Germany)H_2S DraegerTube not only provides odour control but it can also be used to reduce the risks of exposure by early detection. For example, because there is a rapid accommodation to the smell that occurs with low level concentrations, increasing levels of H_2S may not be noticed until the symptoms of ill health become apparent. These ill health effects can be significant with exposure to low concentrations causing irritation to the nose and throat, headaches, blurred vision, vertigo and, possibly, total collapse. High level exposure can cause death by paralysis.

DraegerTubes are designed to provide on the spot gas measurement and are suitable for monitoring personal exposure, spot check measurements, leak checks and confined space investigation. The range comprises over 250 short term tubes to enable fast, accurate measurement of some 430 different types of gases and vapours. Used in conjunction with a hand bellow pump, they enable rapid measurements to be taken and provide optimum volume and flow specifications.