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GAS DISPERSION MEASUREMENTS USING A MOBILE RAMAN LIDAR SYSTEM

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Over recent years, the exploitation of natural gas resources to supply energy demands has resulted in the need to engineer pipelines and plants capable of handling extremely high pressures and throughputs. This increase in scale of operation has meant that more attention has been directed to evaluating the consequences of releases of material whether accidental or deliberate in nature. These consequences must be understood in order to develop methods to define the engineering standards required to construct gas handling installations and pipework. An important aspect of assessing the consequences of a release is an understanding of how gas disperses in the atmosphere over a wide range of release and atmospheric conditions. The most cost effective way of providing such information is through the development and use of reliable theoretical prediction methods. Such theories must, however, be validated using experimental data obtained under conditions which not only address the critical physical processes occurring but also relate to the scale of likely full scale incidents. Experience has shown that it is not feasible to carry out sufficiently large scale experiments using conventional fixed probe measurement techniques. Therefore the need for some form of remote sensing device was identified. The various possibilities studied led to the conclusion that Light Detection And Ranging, LIDAR, offered the most suitable method.

This paper briefly describes the system designed and built for British Gas by Optech Inc. of Toronto, and discusses its recent use in monitoring operational ventings from a high pressure transmission system.

In measuring releases of natural gas, of prime importance are the flammable limits within which gas/air mixtures burn. For natural gas these limits are 15% and 5% by volume, the upper and lower flammable limits respectively. In terms of remote sensing, these concentrations are extremely large when compared to pollution problems which generally require the detection of parts per million (ppm) quantities. This high detection limit coupled with a modest range requirement (≤1000m) made it possible to consider the use of Raman scattering as the measurement technique.

The Raman technique provides a direct means of deriving absolute concentration values. A two-channel receiver is used to observe the Raman scattering from the nitrogen molecules in the atmosphere simultaneously with the Raman scattering from any methane gas. The ratio of the methane and the nitrogen signals is then formed producing a self-referencing system. The relative intensity of the methane Raman signal can be converted directly to a concentration using the known concentration of nitrogen in the air. Information on the position or range of the gas cloud is obtained by measuring the time of flight of the transmitted laser pulse as it propagates through the atmosphere. Table 1 outlines the system specifications.

Table 1: LIDAR Specifications

Performance Specification for the Measurement of Methane

Methane concentration 2% - 20%
Distance range 100 - 1000m
Accuracy of Measurement 10%
Spatial Resolution
- transverse to line of sight, 0.05m at 100m range to 0.5m at 1000m range
- along line of sight, 1.4m

Background radiance conditions; clear daylight sky; visibility 13km

System Specification

Laser: xenon chloride excimer operating at 308nm
pulse width 4ns
average power typically 3-5W at 100 pps

Telescope Subsystem: 0.5m diameter f/10 Cassegrain reflecting mirror
Separate detection channels for nitrogen and methane
Data acquisition subsystem: 2 transient digitizers with 2 ns resolution
PDP 11 computer

Vehicle Specification

Ford Cargo Truck 10 tonne gross weight
Body size 2.5m wide 6.1m long
Onboard generator producing 12.5 KVA
Ratcliffe lifting table capable of lifting 1000 kg

The effectiveness of LIDAR as a field instrument is dependant equally on the optical engineering and the development of suitable software to control the system efficiently, collect data and to present this data in a usable format. In particular, for operations in the field, it is essential that the data collected are quickly fed back to the operator in a form which can be easily assimilated. A suite of programs has been developed to provide a rapid and interactive means of using the lidar system. Programs are available to check the system performance following alignment for a particular transceiver optical overlap configuration and to provide the necessary information to select proper settings on the data acquisition equipment. To optimize the collection of data in the minimum amount of time, software has been developed to assist in selecting the minimum number of shots along a line-of-sight for proper averaging and to display the matrix of maximum concentrations occurring along each line of sight. For a 10x10 matrix, this display can be obtained in about 1 minute of acquiring the data. This rapid retrieval of data allows the scanning grid to be adjusted and optimized in order to remove lines of sight which are clearly well outside the gas plume. Subsequently, each line of sight can be displayed and the form and extent of the gas cloud can be studied.

Operational use of the Raman LIDAR will be illustrated with samples of measurements taken at a gas venting operation which took place on a part of the British Gas Corporation's transmission system. Examples will be presented of several presentation formats to illustrate the usefulness of LIDAR in mapping the form of the gas plume. These include data from measurements along an individual line-of-sight, lower flammability limit contours, contour slices and reconstructions of a 3-D picture of the plume contour made using a graphics software package.

The results demonstrate the operational capability of the BGC LIDAR to obtain concentration measurements at a transmission vent where no previous measurement method could be used. Improvements and developments in the software have enabled the system to be used interactively at such operations where time was critical. Use of the Raman LIDAR is continuing in an ongoing research program investigating the dispersion of natural gas plumes.