Remote Gas Leak Sensor for Underground Pipelines

Vast networks of transmission and distribution natural gas pipelines in the US and abroad demand large resources to be devoted annually to pipeline leak inspection. It is estimated that out of about 1 million pipeline miles in the US, at least 150,000 miles are surveyed each year either by a vehicle or on foot. The present leak sensing technology typically relies on the use of point monitors ("sniffers"), primarily based on flame ionization detectors (FID), and to a lesser degree on Fourier transform infrared (FTIR) spectrometers and optical methane detectors (OMD). Point monitors, however, are rather inefficient for large area coverage. A remote sensing technology for gas leak detection is, therefore, actively sought by gas utility companies looking to reduce the maintenance cost of gas pipelines.

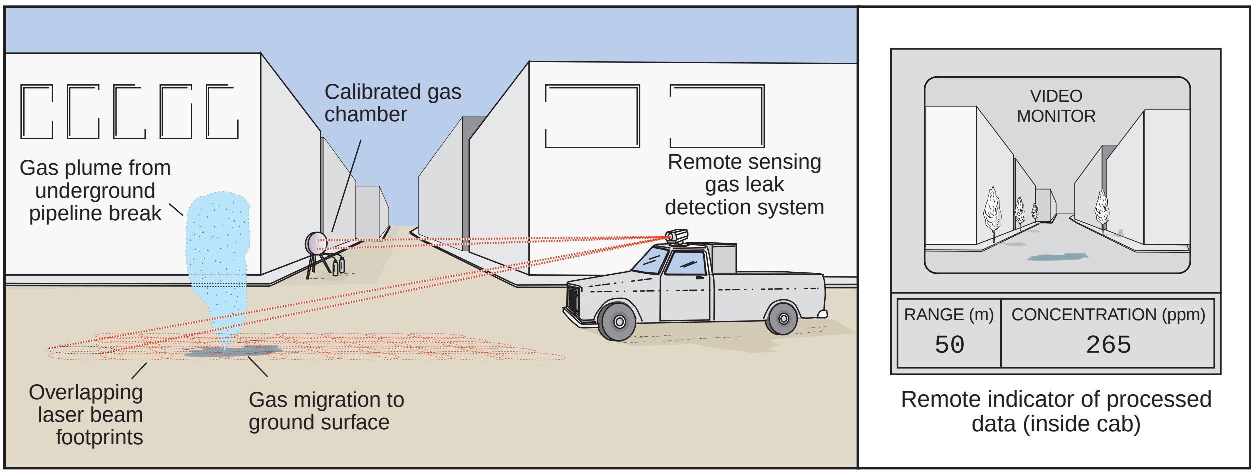

Figure 1: Remote gas leak sensor in operation in urban environment.

Under a contract with the Gas Technology Institute (GTI), SRI International has developed a mobile diode laser-based remote gas leak sensor (Fig. 1). The target gas for detection is methane (CH_4), which constitutes >95% of natural gas. The instrument operates as a long-path, topographic target-return lidar, using the technique of wavelength modulation spectroscopy. A tunable diode laser is used to monitor an overtone absorption line of methane at 1651 nm. The system consists of a mobile platform with a scanning optical head (Fig. 2), and includes a video camera to capture the test scene and a laser rangefinder to measure the distance to the target. The system operates under computer control. The parameters of the system are summarized in Table 1.

TRANSMITTER

- Master oscillator: distributed feedback (DFB) diode laser
- Optical amplifier: Raman-based fiber
- Output power: P0= 5-100 mW, depending on the configuration
- Laser wavelength: 1651 nm

RECEIVER

- Telescope: 7 inch dia., f/2.5
- Detector: InGaAs APD

ADDITIONAL INSTRUMENTATION

- Diode laser rangefinder
- Video camera
- Meteorological instruments onboard

Table 1: Remote gas leak sensor system parameters.

Our remote leak sensor was tested at an outdoor test range, where simulated calibrated methane leaks surrounded by natural target surfaces (asphalt pavement, soil, sand, grass, building walls, etc.) were created. The system was operated with 5mW of output optical power, without the Raman fiber amplifier (the fiber amplifier is currently being implemented to the system). Leaks were monitored by the system mounted on a vehicle. Typical range to the leak was 10 to 15 meters. The lidar continuously recorded methane concentrations along the path of the beam, either from a static vehicle (time evolution of methane concentration measured) or from a vehicle moving past the leak, in which case the spatial dependence of the methane concentration was recorded. Figure 3 presents the experimental results of remote measurements of a methane leak with a building wall as the topographic target. The sensitivity limit of ~0.1 scfh leak flow rate is clearly visible. Figure 4 presents the

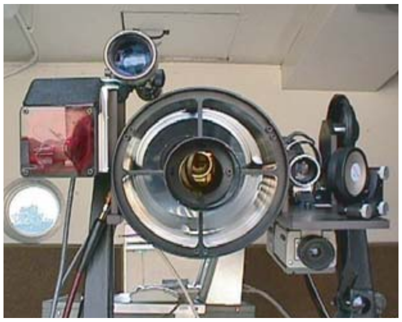

Figure 2: The optical system of the remote leak sensor: receiver telescope (center), laser rangefinder (left), visual finder telescope (upper left corner), transmitter beam expander (right), video camera (lower right).

result of a scan over a gas leak under the pavement, taken from a moving vehicle (in an arrangement similar to the one presented in Fig. 1). In the post-processing of the data, Kalman filter was applied to the time series in order to improve the signal to noise ratio.

Field tests of our mobile diode-based lidar with the output power of 5 mW revealed the detection sensitivity limit of 18 ppm·m, as measured with a calibrated absorption cell in open atmosphere, with a natural topographic target at the range of 10 to 15 m. It was established that the minimum gas leak rate typically detected in open atmosphere was around 0.1 scfh, while the minimum surface gas concentration typically detected in the dynamic open atmosphere was around 50 ppm. In terms of mechanical and environmental stability, the lidar system performance was exceptional. After being exposed both to strong vibrations in a moving truck and to widely varying cabin temperatures, no need for readjustment of any part of the optical system was needed. Our current system, therefore, presents a solid basis for a field-worthy instrument.

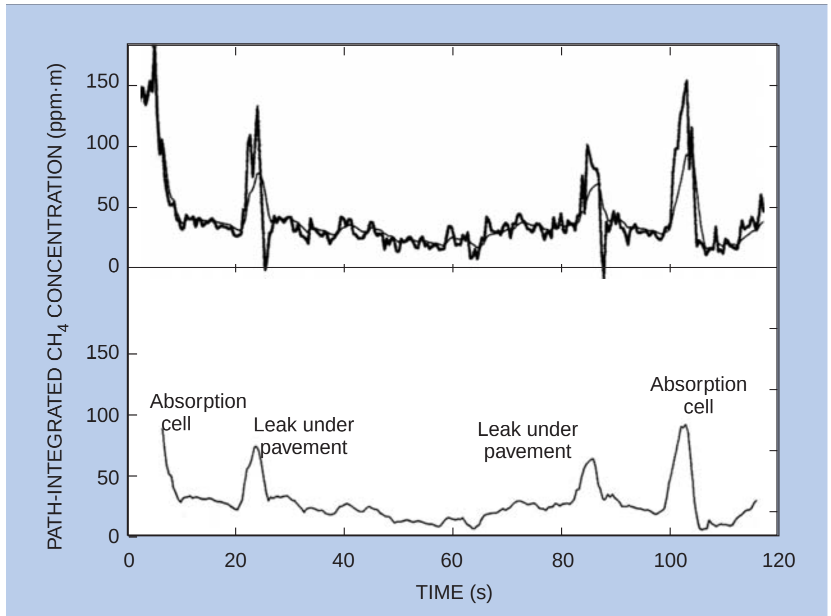

Figure 4: a) Detection of a leak under the pavement, from a moving vehicle; the leak rate is 3.42 scfh; b) same as a) with the Kalman filter applied

With the addition of the optical amplifier currently underway, the output power will increase ten times and both the range and sensitivity will be dramatically improved. We expect the sensitivity limit to go down to low single-digit ppm·m, and the range to at least double. This upgrade will make the system clearly competitive with FID detectors in terms of sensitivity, with the functionality tremendously increased by fast remote detection.

The system prototype described above has demonstrated in field experiments its ability to detect gas pipeline leaks from a moving vehicle. The technology has a great potential to reduce the cost and improve the quality of pipeline gas leak survey.

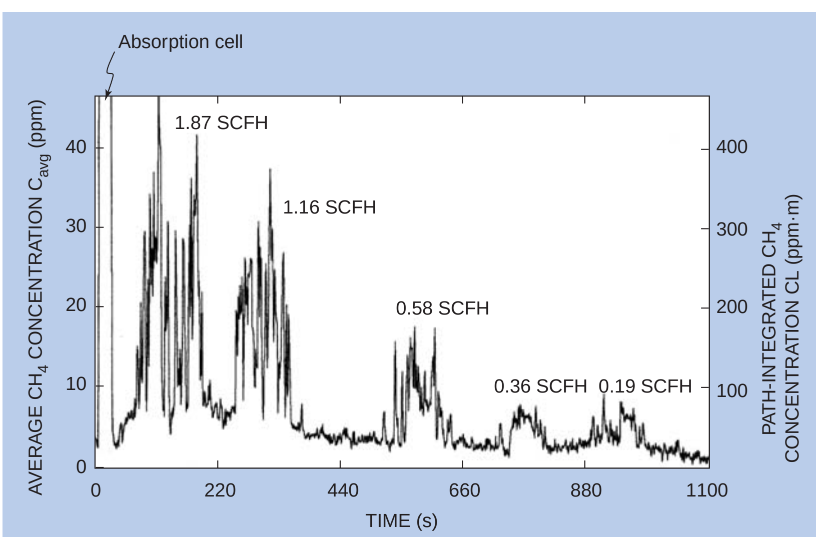

Figure 3: Experimental results of remote measurements of a methane leak with a building wall as target. Flow rates are indicated in the figure.

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