Technology Brief

Picarro Natural Gas Asset Management Solution

PICARRO

Introduction

Picarro's Asset Management solution is a combination of hardware, software, and data analytics. The vehicle-mounted Picarro systems conduct multiple patrols through a natural gas infrastructure, collecting methane plume data and sending it to the Picarro cloud where analytics then transform thedata into actionable results fora number of asset management applications, from leak survey to pipe replacement to risk reduction.

Picarro System Overview

The Picarro system identifies the characteristic signatures of natural gas leaks by analyzing the methane plumes as they propagate in the atmosphere and intersect with the path of the vehicle. The system also measures atmospheric and meteorological conditions and uses algorithms to identify the origin and degree of hazard of the natural gas leak indication while virtually eliminating indications triggered by other non-natural gas sources of methane.

The most powerful feature of the Picarro system is its ability to combine information from multiple measurement sessions over a region, taking advantage of varying atmospheric conditions (wind direction, wind speed, atmospheric stability), to produce aggregated survey results over a certain period of time. This unique capability increases territory coverage with successive passes by the vehicle and allows statistics to be built up on location and risk for every leak indication. Reports and other data outputs can be generated from this processed data specific to the intended use case – leak survey, forecasting, targeted emissions reduction, risk management, etc.

Picarro System Hardware

Picarro's mobile natural gas leak detection system is driven through a natural gas infrastructure, gathering methane, wind, atmospheric and GPS data which is later processed by Picarro's algorithms to detect and localize leaks and calculate methane emission rates. The Picarro hardware consists of the following elements (shown in Figure 1 on page 2) forming a completely integrated solution mounted in a vehicle:

- A parts-per-billion sensitivity gas analyzer based on Cavity Ring-Down Spectroscopy (CRDS) measuring atmospheric gas composition and other tracers such as ethane.
- An anemometer mounted on a mast for detecting wind speed, direction and wind variability.
- Two antennas on the vehicle roof, one for the 4G wireless connectivity and one for sub-meter GPS vehicle positioning.
- A 4G wireless router enabling the internet connection and data transmission to and from the Picarro Cloud and WiFi connection to the in-vehicle tablet.
- A tablet computer which allows the operation and visualization of the system and data.
- A supporting equipment module containing pumps, a GPS receiver and various power supplies and gas handling equipment.
- A gas inlet system mounted on the front of the vehicle.

Air is continuously collected on the front of the vehicle routed to the gas analyzer via tubing. The entire system and accessories are directly connected to the vehicle battery. The system can be installed on almost any vehicle.

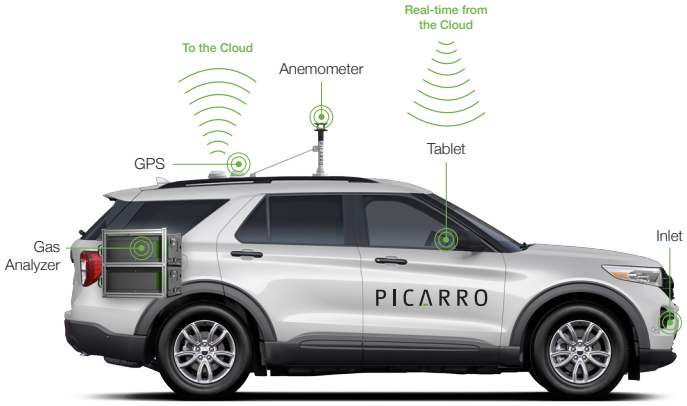

Figure 1. *Picarro System Hardware*

Data Collection Methodology and Protocol

Picarro pioneered the Advanced Leak Detection concept that utilizes the wind to bring methane plumes to Picarro's vehicle-based methane and atmospheric sensing platform. Picarro's data collection methodology is based on the ability of Picarro system to detect methane emissions below as well as at distances of hundreds of meters away from the vehicle when the methane emission point is upwind of the vehicle. The reach of Picarro's Field of View (FOV™) coverage area is calculated at each point along the vehicle path to provide documented record of survey coverage. In this way, both mains and services can effectively be surveyed. If methane is detected, the system computes a Leak Indication Search Area (LISA™) indication marker whose location and footprint is determined by wind direction and variability. The LISA markers indicate likely leak locations that require further investigation on foot to pinpoint each leak. This patented concept is shown in Figure 2.

> Data is taken at night to maximize plume detectability and minimize measurement noise due to higher atmospheric turbulence that is present during the day.

Picarro recommends a "three-drives" protocol that prescribes that each street along which gas assets are located be driven twice (one pass on each side of the street) and that this be repeated three times on at least two different nights (so that either two or four passes were completed on one night) between sunset and sunrise. This results in six passes per street along the defined sections of main.

Data is taken at night to maximize plume detectability and minimize measurement noise due to higher atmospheric turbulence that is present during the day. Nighttime survey also avoids traffic that disturbs plumes.

The reasons for multiple passes over multiple nights is to collect data in a variety of wind conditions (multiple wind directions) to achieve high Field of View coverage of the gas assets. Multiple passes also ensure that the leak detection rate is >95% since the single-pass detection for a given leak is generally only 25-35% and the detection probability scales as the probability of independent events, reaching >95% for leaks within the Field of View.

Figure 2. *Picarro Advanced Leak Survey Technique*

There are qualities of methane plumes that the system measures (size, emissions, concentration, ethane content, etc.) that allow Picarro's Risk Ranking and Emissions Quantification Analytics to predict the locations, flow rates and relative risk of leak indications (i.e. if an indication is likely originating from a hazardous leak or not).

Data can be collected in a mode that is intended for use in leak survey – whereby leak indications are produced for follow-up investigations. For applications other than leak survey (such as for pipe replacement or emissions mapping), data can be taken in a mode that does not produce leak indications but instead spatially aggregates methane emissions data to produce regional "heat maps" (see Figure 3) or aggregated emissions or predicted leak density information along entire pipe segments. In this mode, individual leak indications are neither calculated nor displayed.

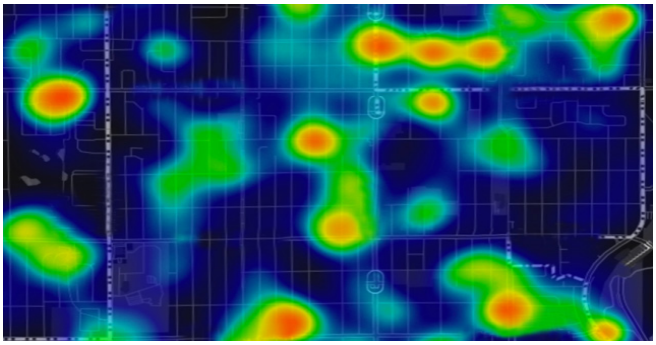

Figure 3. *Methane emissions map showing regions of high emissions instead of individual leak indications.*

Picarro's Emissions Quantification Analytics calculates emission (flow) rates of measured methane plumes in the following way. After multiple passes are driven in an area of interest where the vehicle path intersects methane plumes typically multiple times, the analytics make a prediction of emission rates by directly multiplying the measured crosswind concentration profile by the measured wind speed. Accurate emissions estimates are achieved through a combination of enhanced spatial resolution of the concentration profile, accurate measurements and models of the instantaneous vertical wind speed gradient, and averaging of multiple plume transects downwind of the leak.

The fast response time (4 Hz) of the Picarro methane gas analyzer provides high spatial resolution in the crosswind direction. This produces a high-resolution concentration map without loss of spatial information content.

Data Analytics, Visualization and Reporting Platform

Picarro provides customers with real-time access to leak survey visualization and reporting services via a cloud-based platform. Customers have remote access to the platform that provides report generation functionalities, outputs of various formats, and data visualization tools.

The Picarro solution combines data from multiple Picarro vehicles in a central repository where that data can be analyzed and transformed, producing customized reports on leak indications and methane emissions across a utility's infrastructure.

The system enables two-way communication with the Utility GIS/ERP systems so that leak surveys and leak indication investigations can be scheduled and dispatched, and so that the results of leak investigations can be centrally collected and managed in repair, replace, monitoring or risk management decisions. This connectivity also allows data to be shared with multiple departments for multiple purposes beyond leak survey such as for pipe replacement and DIMP.

The Picarro software suite also includes Mobile View, allowing leak indications to be visualized on a mobile device for follow-up investigation in the field. This drives efficiency as it allows bi-directional, real-time connectivity to field personnel. Mobile View improves the leak indication confirmation process itself by allowing leaks details to be recorded and leak locations tagged with GPS coordinates. Utilities can elect to share leak data with Picarro which helps in making Picarro's predictive machine learning algorithms more accurate for all Picarro customers.

Comparison to Traditional Survey Equipment and Methods

The Picarro system takes methane data at a speed and scale not possible with traditional instrumentation, eliminating human bias and operator error associated with these legacy methods. It has been shown in over 60 field studies to consistently identify an average of three times more hazardous leaks as compared to traditional survey equipment and methods. In comparison to traditional leak survey equipment, the Picarro hardware is 1000 times more sensitive, with the ability to detect methane and ethane at better than one part-per-billion. Traditional systems typically have only 1-part-per-million methane sensitivity and do not use ethane to remove false positive leak indications from biogenic methane sources (sewer, etc.) as the Picarro system does. The system can take data at vehicle speeds over 40mph and in rain and snow conditions. The system's reliance on the wind enables it to sense leaks without driving directly over the gas main, and the analytics can rank methane plumes according to their potential hazard, emission rate and likelihood of emanating from an aboveground or belowground leak.

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