PICARRO Surveyor™

for natural gas leak detection

Content

Executive Summary

Natural gas has the potential to become a leading source of clean energy, yet its safety and environmental risks cannot be ignored. Leaks can be both toxic and explosive, and methane, the primary component in natural gas, has 25-times more global warming potential than carbon dioxide when emitted into the atmosphere. When this is coupled with the aging infrastructure that pervades global utilities, a more efficient method for detecting natural gas leaks becomes an issue of paramount importance.

Picarro Surveyor™ is a disruptive technology that is transforming the way gas utilities detect and manage natural gas leaks along their pipelines. The solution is enabling utilities to dramatically increase the safety of their network by detecting many hazardous leaks they would otherwise miss. In addition, the Surveyor can optimize the surveillance methodology and exponentially speeds up survey rates as well as decreases costs by replacing surveys conducted on foot. Furthermore, Picarro Surveyor data resulting from recent surveys suggest the technology will cause leak detection and management costs to drop significantly.

Gas companies and utilities are increasingly focused on upgrading their natural gas networks to improve pipeline efficiency and safety. Communities around the world will soon see more Picarro Surveyor-equipped vehicles patrolling their neighborhoods to find natural gas leaks, helping to make them safer and more environmentally healthy.

"This gas detection technology is revolutionary. It's going to change the way all gas companies across the world try to find and detect leaks. It is so much more precise, so much more real-time, in terms of the information it provides to us."

- Nick Stavropoulos, Executive Vice President of Gas Operations
Pacific Gas and Electric Company (PG&E)

One of the largest utilities in The United States

Current Challenges

How Traditional Leak Survey Methodologies Fail

Walking the Pipelines

Traditional leak survey methods require skilled operators to walk an entire grid, under the assumption that main and service lines are directly underneath their feet, as they carry tools that are affected by a number of environmental conditions, including sources of methane not caused by natural gas leaks.

Failing by a number of factors, traditional hand-held leak detection tools:

- Lack the sensitivity to detect a large percentage of leaks, including many that are deemed hazardous and requiring immediate repair.
- Are prone to yield false positives, detecting innocuous sources of methane, such as landfills and sewers, in the environment.
- Are impacted by the "human factor" and other variables, such as atmospheric conditions and terrain variation, which impact the consistency and accuracy of survey results.
- Leave uninspected portions of pipelines due to discrepancies and offsets in service line maps and actual installed lines.
- Waste financial and labor resources on non-productive survey hours due to the inefficiencies in the survey process itself. In addition, time-intensive hand written reports can be both inaccurate and unreliable, making it a challenge to properly adhere to compliance standards.

Some industry estimates project the "leak find rate" of traditional methodologies to be in 50 – 65% range. Industry veterans assume, "for every leak we find, there are two more that we don't."

Driving Over Pipelines Using Traditional Equipment

Traditional methodologies have proved inefficient at thoroughly monitoring natural gas distribution networks, leaving undetected hazardous leaks to build up. Traditional drive-by technologies, such as OMD (optical methane detector) and RMLD (remote methane leak detector), measure methane at the ppm level and are inefficient at detecting leaks from a distance.

With traditional methods, the maximum lateral detection range is only within a couple of meters from the vehicle being driven over the pipeline. Vehicles must drive on existing roads, which restricts their coverage area to main pipelines only - assuming the pipelines are underneath the road. This, in turn, results in additional surveys required for service lines. Furthermore, the technology has the same sensitivity-level as equipment used in walking surveys, and thus suffers from the same restrictions.

Picarro Surveyor™ for Natural Gas Leak Detection

Features and Benefits

Picarro Surveyor is a fully integrated solution that combines a hardware platform, the basis of which is an ultra-precise cavity ring-down spectroscopy (CRDS) gas analyzer, and a software platform that runs dedicated, cloud-based data processing algorithms. The easy-to-use, yet comprehensive solution locates, confirms, maps, and logs natural gas leaks at unmatched speeds.

Picarro Surveyor outperforms incumbent technologies in several key areas:

- **Finds more hazardous leaks** - Detects fugitive emissions in the ambient air at parts per billion sensitivity in seconds.
- **Is faster while encompassing a wider survey range** – Covers large areas in less time than traditional methods as personnel drive through an area at traffic speeds.
- **Measures in the distance** – Can view even the smallest leak from up to 100 meter away, with the ability to measure main and the service pipelines directly from the car.
- **Distinguishes among different methane sources** - Measures the stable isotope signature of methane in the environment to eliminate false positives from innocuous, biological, or other sources.
- **Is easy to operate** - Continuously verifies performance with virtually no calibration needed.
- **Provides real-time results** – Provides leak reports immediately to vehicle operators, supervisors, and intervention teams.

  Is scalable and secure – Stores all data and reporting “in the cloud” in multiple secure data centers via Picarro’s cloud-based processing platform, P-Cubed™.
- **Is reliable and consistent** – Ensures dependable and accurate surveys, regardless of who conducts them, and stores survey records indefinitely.
- **Is robust regardless of climate or weather conditions** – Picarro’s analyzers are vetted by leading scientists all over the world and consistently perform in the harshest environments on Earth.

How Picarro Surveyor Works

As the vehicle is driven through an area, the Picarro analyzer measures trace amounts of methane in the ambient air down to one part per billion precision, thus detecting even the smallest leaks from hundreds of meters away.

Surveyor allows operators to patrol at traffic speeds on the road and use the true wind indication to cover a monitoring area, which can extend far away from the vehicle, thus measuring the main pipeline and all services, as well as extension leaks diffusing through pavement.

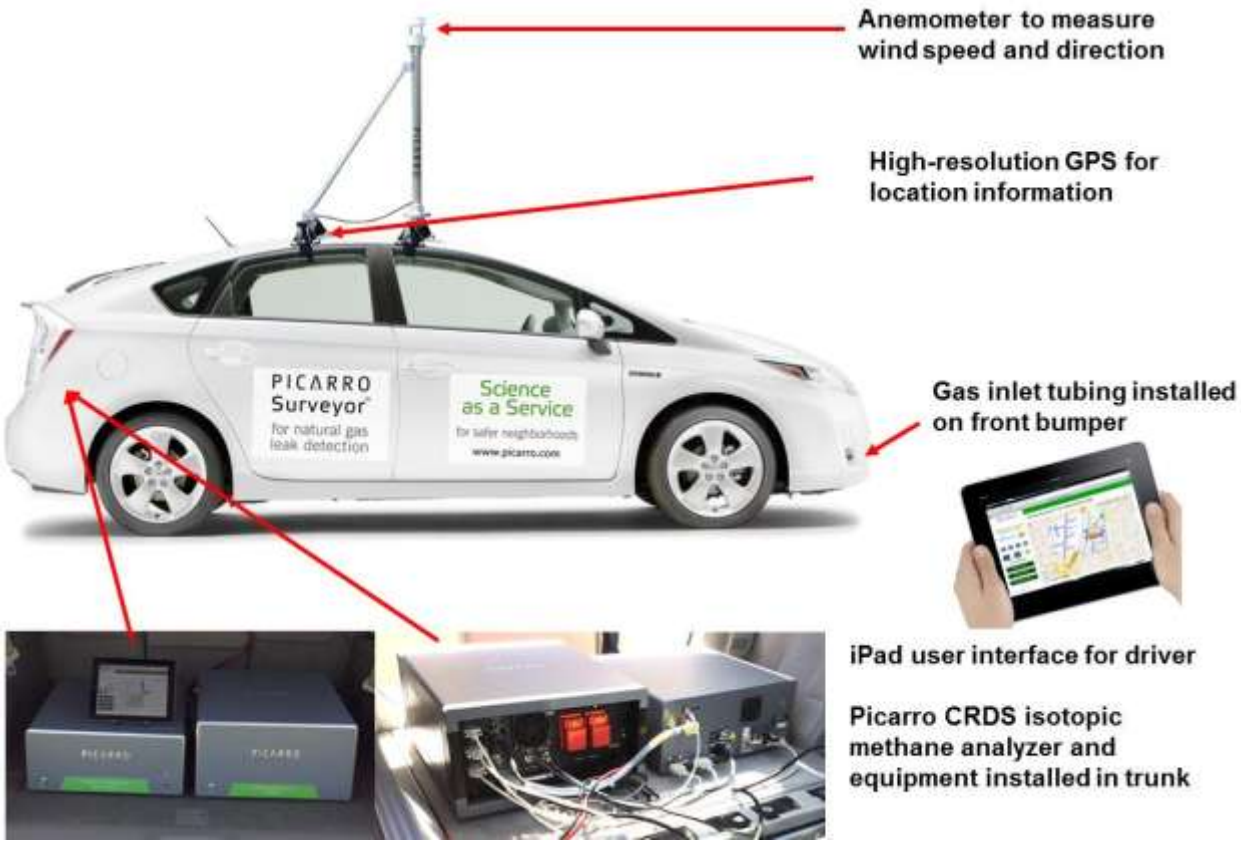
The user also has the option to measure the stable isotopic value of the natural gas leak, differentiating a possible leak from natural gas and other sources, such as sewer biogas.

All gas leak indications are automatically mapped and displayed in real-time in a web browser. The measurement includes leak location, plume characteristics (concentration, amplitude, width), area of coverage, Leak Indication Search Area (LISA), isotopic signature, and survey route. All data are seamlessly uploaded, processed, mapped, and store via P-Cubed™, Picarro's proprietary data process platform.

Information is available in real-time to vehicle operators, supervisors, response teams, or anyone with secured web access. Users can choose to view their information on a tablet computer, a PC, or smart phone.

System Components

Picarro Surveyor is comprised of a high-precision isotopic methane gas analyzer (Surveyor Module 1); Picarro's cloud-based data logging and analysis platform, P-Cubed™; and a mobile kit (Surveyor Module 2), which contains an analyzer pump, a second pump to draw in air for sampling, a DC-AC power inverter, a 12VDC backup battery, a GPS receiver, anemometer and mast, a Wi-Fi hotspot, an iPad, and various valves, cables, power supplies, tubing, and gas handling equipment. All hardware is thermally and shock/vibration tested to military specifications.



Module 1 – Picarro CRDS Gas Analyzer for Methane

Methane is generated from landfills, wetlands, swamps, and agricultural activities, in addition to leaks from natural gas distribution and transmission pipelines. Thus, the ability to distinguish among different sources of methane in the environment helps to identify which are from fugitive emissions.

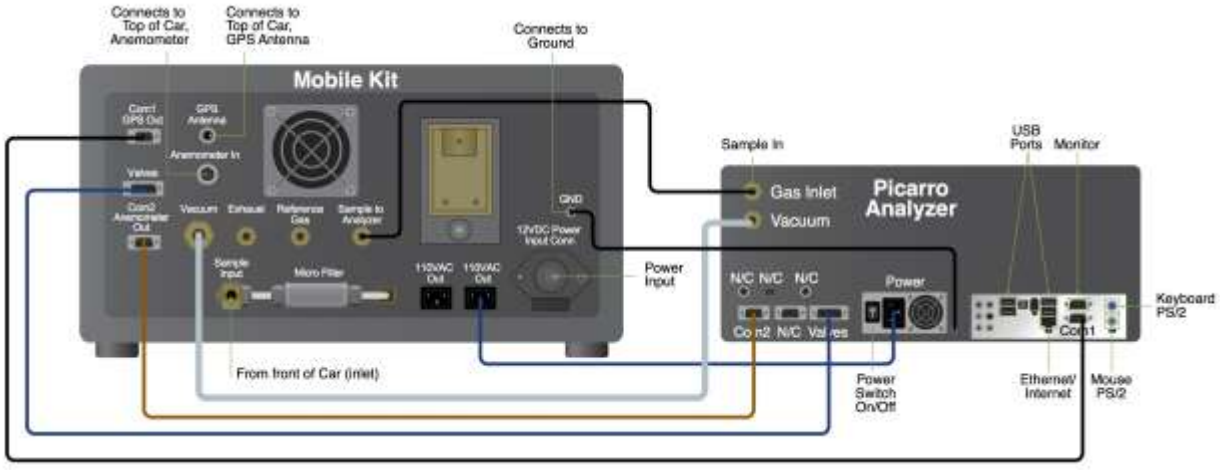
Specific measurements of CH_4 are only possible if the influences of other molecules in a given sample are clearly quantified. Picarro Surveyor's CRDS analyzer enables precise measurements of CO_2 and H_2O concentrations to allow the cross-influence of these species to be quantified and corrected while providing more insight into the sample.

The CRDS analyzer included with Picarro Surveyor provides ultra-precise, real-time CH_4 concentration and $\delta^{13}C$ carbon isotope data from methane at ambient concentrations. Key features include:

- CH_4 measurements with precision down to 2 ppb in one second
- Direct measurement of CH_4 in every environmental condition, with no sample drying required
- Isotopic measurements with superb precision and stability for critical methane source identification
- Rugged, yet reliable, portability - meets military-standard shock and vibration tests while maintaining sensitivity and precision thresholds
- Ease of use – minimal calibration required, little-to-no maintenance, and no consumables

Module 2 – Mobile Kit and Peripherals

Module 2 includes a mobile kit, analyzer pump, a secondary pump to draw in air for sampling, a DC-AC power inverter, a 12VDC backup battery, and electronics to automate the system.



Picarro Processing Platform – P-Cubed™

Cloud-Based Geo-Informatics

P-Cubed, Picarro's proprietary software platform, uses sophisticated, patent-pending algorithms to log and analyze the data it collects from Picarro Surveyor's system components.

The platform analyzes atmospheric and meteorological conditions, gas leak propagation signatures, and dynamic signal processing to compute natural gas leak indications while ruling out most false positive indications.

P-Cubed's data algorithms combine atmospheric information to display the survey area's field of view and the true wind direction to help locate the position of a given leak. The dedicated user interface maps and graphically displays leak location, survey route, relative leak size, and the isotopic value of the leak directly onto a Google map or satellite image.

The platform provides cloud-based data analysis, storage, and processing, with access to detailed informatics via a secure login that is available 24/7, 365 day per year. The results are available in real-time to vehicle operators, supervisors, response teams, and senior executives via a web-enabled device (tablet computer, laptop, smartphone, etc.) and secured, encrypted (128-bit SSL) data communication.

P CUBED™

Picarro Processing Platform

Functionalities

Raw data are recorded and uploaded to P-Cubed, regardless of the settings selected by the user. Data can be reviewed later with any desired settings for minimum amplitude triggering or atmospheric stability.

Peak Bubbles

Peak bubbles are leak indications where the number is the absolute peak concentration in parts-per-million (ppm) of the detected methane peak, and the size of the bubble is relative to the height of the peak above the current ambient methane background level. The location on the map is the location of the vehicle at the time the peak was measured. The background level is continuously being updated. For example, in an area of elevated background, such as near a manure field, the background may be judged to be higher than normal so that only peaks *above* this level will be evaluated as potential leak indications.

Field of View (FOV)

FOV is the area that can be effectively deemed to have been surveyed. The purple shaded area shown in the image above is dependent upon the atmospheric stability class and minimum amplitude selected in “Map Controls”.

Leak Indication Search Area (or LISA)

LISA, also referred to as the “Wind Marker” is the angular extension associated with each leak indication marker (peak bubble), determined by wind variation and atmospheric stability, from which the methane plume is likely to have emanated. The LISA sweeps out a “cone” shaped area in which the potential leak is likely located. Note that the size (length) of the cone scales with the zoom factor on the map, so it is an indication of angle only and not of distance from the leak indication marker.

Isotopic Analysis Result

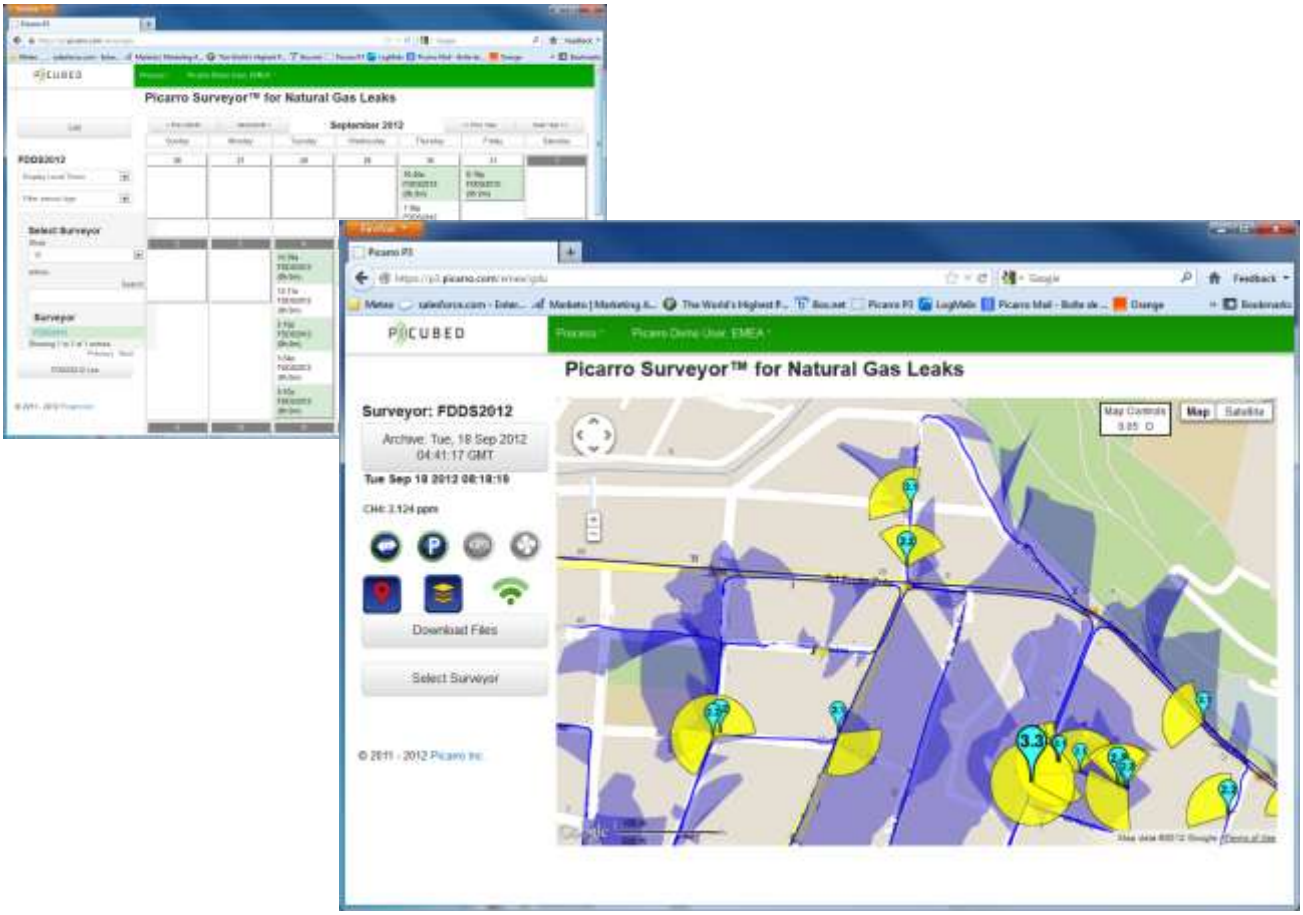
The Isotopic Analysis Result shows the isotopic measurement and its uncertainty in ‰ (permil) or parts per thousand, relative to the PDB standard for the carbon-13 ratio ($\delta^{13}C$) in CH_4. For natural gas, this is around -37‰, whereas ambient air and biogenic methane are lower, around -45‰.

Updates

P-Cubed's algorithms are continuously updated based upon new Picarro research and development in atmospheric chemistry and leak propagation, as well as best practices from Picarro's worldwide customer base.

P-Cubed Data Access

The P-Cubed server provides access to and views of both historical and live data. The interface provides most of the same elements that are seen from the vehicle (i.e. "prime user") and provides additional reporting capabilities.



Reporting

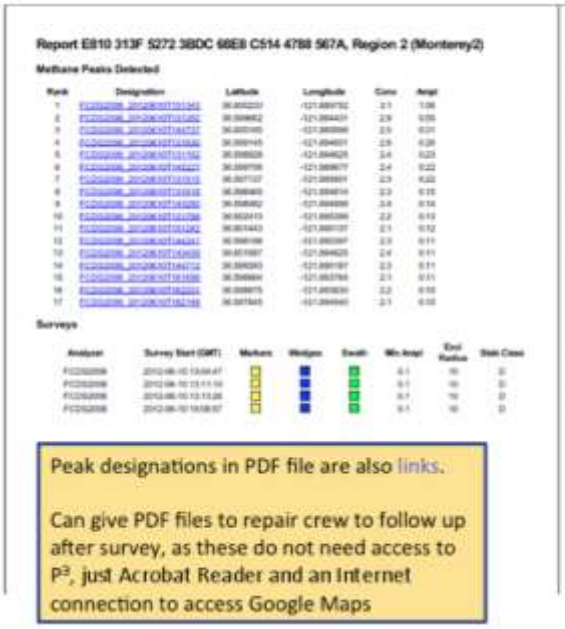
Picarro Surveyor allows consistent comparisons of multiple measurements run over the same region, taking advantage of varying atmospheric conditions (wind direction, wind speed, atmospheric stability) to overlay various fields of view and provide comprehensive territory coverage.

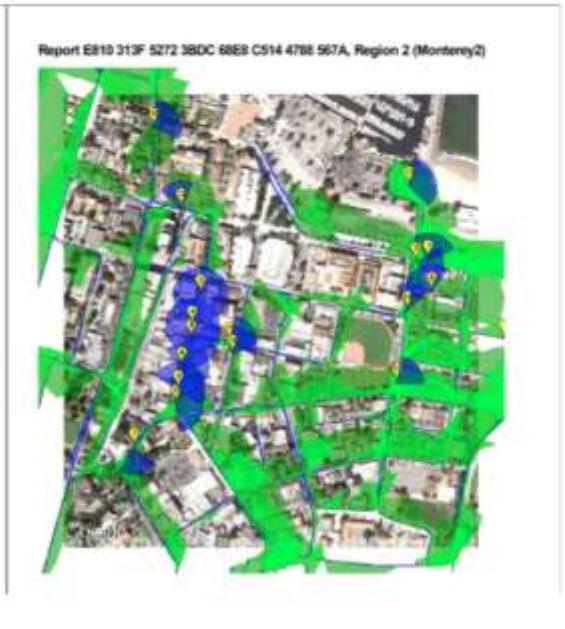
Features:

- Provides historical playback of previous surveys
- Automatically calculates the effective survey area
- Combines surveys from multiple vehicles and/or days into a single report
- Re-analyzes historical data with user-selectable parameters
- Customizes reports based on time, location, magnitude, and amplitude.
- Generates report in PDF or Excel

Orange and green "Field of View" recorded at different times and combined to provide increased territory coverage

Surveyor reporting software generates PDF file with Google Maps links to each leak indication



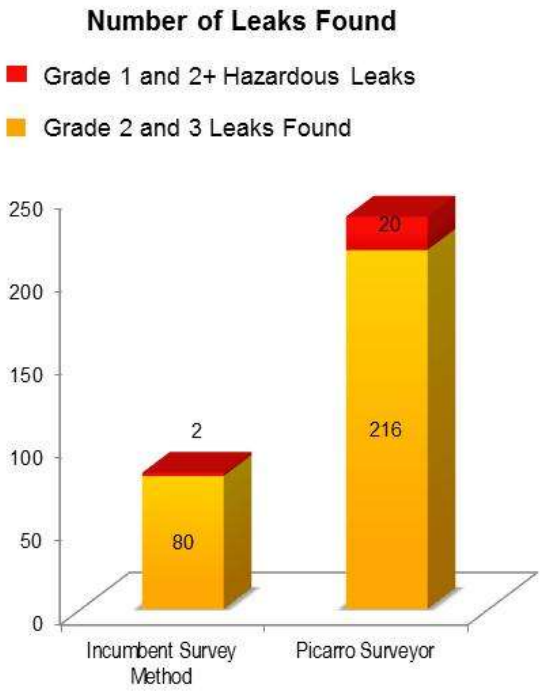


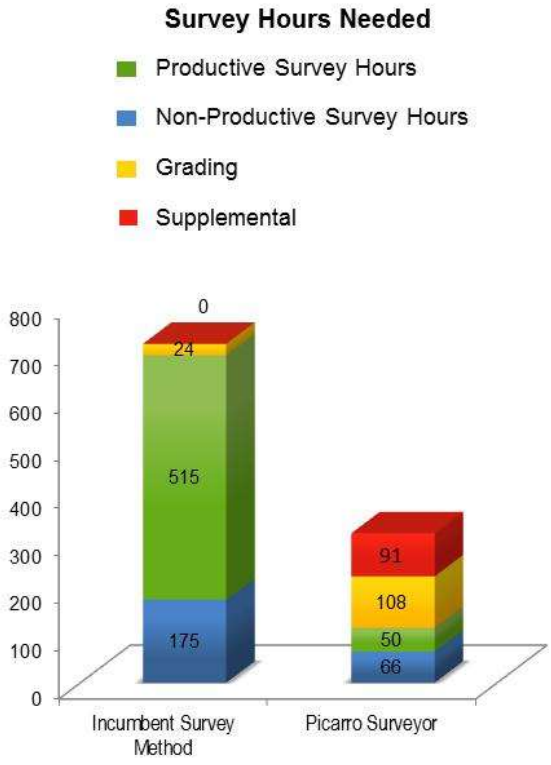
Performance Data

Technology Trials

Real-world data reveals that Picarro Surveyor outperforms traditional survey methods in a number of areas. The following results are from field tests in areas that comprised 32 facility maps with 7,740 services and 104 miles of distribution main.

Independent Study: Pipeline Research Council International, Spring 2012.





Customer Testimonials

"This gas detection technology is revolutionary. It's going to change the way all gas companies across the world try to find and detect leaks. It is so much more precise, so much more real-time, in terms of the information it provides to us."

- Nick Stavropoulos, Executive Vice President of Gas Operations
Pacific Gas and Electric Company (PG&E)

"Picarro Surveyor allows us to not only pinpoint hard-to-find leaks with accuracy that we didn't have before, but distinguish between naturally occurring methane. By deploying this technology in our service area, we are better equipped to manage our pipeline network and enhance the safety of our customers and employees. We have felt all along that this technology would be a breakthrough in our goal to be the safest utility in the U.S., and now that we are using the device in the field, it is exciting to see how it enhances our operation."

- **Steve Redding, Director of Gas Maintenance and Construction**
PG&E

"We selected Picarro as an Energy Innovation Pioneer because of their unique approach to monitoring fugitive emissions. In a world of growing natural gas production and use, they provide accurate information that enables companies to operate safely and sustainably. [Picarro] is addressing the big issues and challenges facing the energy industry today and in the future."

James Rosenfield, Co-founder
IHS CERA

"Without the advances made by Picarro, these autonomous measurements would not have been possible."

Colm Sweeney, CIRES Research Scientist
U.S. National Oceanic and Atmospheric Administration (NOAA)

Best Practices

Climate Conditions

When measuring methane leaks, the best monitoring results are obtained under stable atmospheric conditions (low boundary layer, limited solar radiation, and relatively cool temperatures, resulting in minimal turbulence). Under these conditions, the methane background in the air is very stable and the leak detection system provides the best results. Stable weather conditions most often occur at night into very early morning.

Surveyor performs reliably in very harsh weather conditions, including rain and snow. The system measures water and compensates for its interference – a marked difference from lesser technologies, which fail when exposed to high water concentration interference.

Survey Protocol

Below are recommended steps for achieving the best results with Picarro Surveyor.

For Routine Surveys:

1. Drive both sides of street.
2. Drive all publicly accessible areas in apartment complexes, industrial parks, schools, commercial offices, business centers, etc.
3. Drive each survey area twice (to attain coverage of ~98% main and ~89% service).
4. Survey in the early morning (3am - 10am) so the driver can become familiar with the survey area. A second survey should be conducted after sundown (7pm – 2am).
5. Collect isotopic readings for all leak indications with amplitudes greater than 4 ppm.

Additional Notes:

1. Driving at night greatly increases field of view (FOV) and overall survey coverage.
2. Driving over a survey area more than once also increases FOV and survey coverage.

About Picarro Inc.

Picarro is transforming how, when, and where world-class scientific measurements are made and enabling anyone to make them.

Picarro is the world's leading producer of stable isotope and gas concentration measurement systems for science and industry. The company's products serve a wide variety of applications, including: Earth sciences, air quality, greenhouse gas and fugitive emissions measurements, energy exploration and distribution, and supply chain integrity.

Deployed in 60 countries on all seven continents, Picarro's solutions are unparalleled in their precision, ease of use, portability, and reliability. The company's products are all designed and manufactured at Picarro's Santa Clara, California, U.S.A. headquarters and exported to countries worldwide. Picarro's technology is based on dozens of patents related to cavity ring-down spectroscopy (CRDS). Investors include Benchmark Capital, DAG Ventures, Focus Ventures, Greylock Partners, Mingxin China Growth Fund, and NTT Finance.

Picarro at a Glance:

- Over 35 patents owned by Picarro or exclusively licensed from Stanford University
- Headquarters, R&D, and manufacturing in Santa Clara, California, U.S.A.
- Sales offices:
    - The Hague, The Netherlands
    - Geneva, Switzerland
    - Beijing, China
    - Dealers worldwide
- 95 employees; 35 PhDs in sciences and engineering
- 2012 Awards
    - World Economic Forum Technology Innovation Pioneer
    - IHS CERA Energy Innovation Pioneer
    - U.S. Department of Energy Small Business of the Year
    - *Wall Street Journal* Tech Innovation Award
- Movie: An introduction to Picarro

Appendix

Awards

Some of Picarro's Customers

Leading universities, national laboratories, NGOs, and for-profit enterprises around the world use Picarro to conduct cutting edge science.