White Paper

Night vs. Day Driving

Optimizing data collection efficiency and accuracy

PICARRO

Introduction

Operational efficiency, data quality, and consistency are crucial for implementing an Advanced Mobile Leak Detection (AMLD) program that achieves comprehensive coverage of gas distribution assets. To optimize these aspects, Picarro recommends data collection at night. This white paper highlights the key advantages of night driving by analyzing a set of data collected over the same geographic areas during both day and night. The findings show:

1. Higher pipeline coverage is achieved with less driving when operating at night.
2. Flow rates are more accurately quantified at night, leading to more accurate network-scale quantification.
3. Night surveys result in fewer overall detections per kilometer (or per mile) and more effective identification of large leaks, which leads to more efficient emissions and risk reduction operations.
4. Night driving reduces false positives (i.e., when no leaks are found), which improves operations efficiency.

Background

The effectiveness of the Picarro system in detecting methane plumes relies on stable weather conditions. To this end, the protocol leverages the Pasquill stability class definitions (1) which characterize meteorological conditions such as wind and solar radiation by dividing them into classes.

Daytime conditions:

1. **Class A** occurs under strong sunshine conditions and light winds, which causes significant thermal turbulence and mixing in the atmosphere; ideal for vertical dispersion, not ideal for methane detection and leak flow rate quantification.
2. **Class B** is associated with strong-to-moderate sunshine conditions and light winds, similar conditions to class A, but less intense.
3. **Class C** occurs under cloudy or weak sunshine conditions, with less vertical mixing compared to A and B classes.

Nighttime conditions:

1. **Class D** occurs under overcast skies and can happen any time with moderate winds. This class represents neutral conditions with low thermal

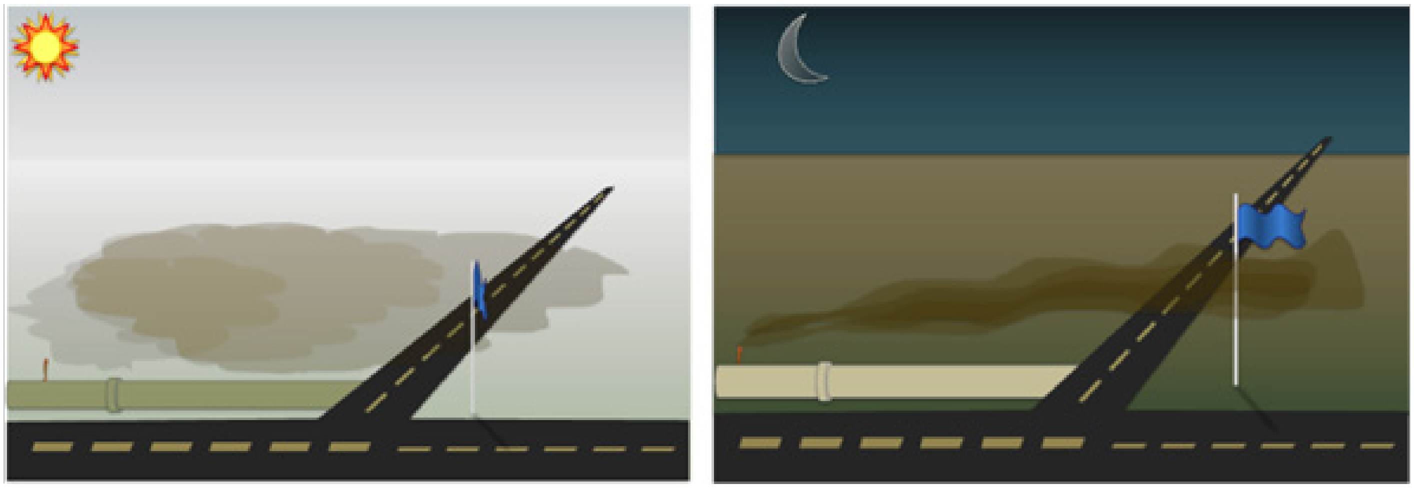

Figure 1. Schematic representation of a methane plume under day and night conditions. Night provides more stable meteorological conditions, which means the plume does not disperse as compared to day conditions.

turbulence and slight mixing. This class may occur during the day as it characterized by clouds obscuring at least 95% of the sky.

2. **Class E** occurs under clear skies during the evening transition with light winds, leading to slightly stable conditions. There is very low thermal turbulence and weak mixing.
3. **Class F** occurs under clear skies late at night or early morning with light winds, creating stable conditions. Characterized by minimal thermal turbulence and very weak mixing.

To maximize the probability of detecting methane plumes and accurately quantifying leak flow rates, Picarro seeks the most stable weather conditions for data collection, which generally occur in stability classes D, E, and F. Additionally, night data collection benefits from significantly reduced human activities such as traffic and pedestrian movement, which enhances the safety and efficiency of field operations. In the sections below, we demonstrate how such conditions can improve the data quality and enhance the cost-effectiveness of the Picarro solution.

Methodology and Results

To establish a baseline for comparison, we analyzed a set of data collected over the same geographic areas within the same year, during both day and night. Night data is defined as driving done during stability classes D, E, and F, and day data as collected under stability classes A, B, and C.

Our analysis includes data from 12 geographic boundaries, representing diverse customers in the northern hemisphere, with surveys conducted in a mix of urban and suburban areas. The data was collected throughout 2023 across various weather conditions, capturing significant temperature variations and a range of climatic scenarios across different seasons. Data was collected over approximately 800 km (500 miles) of network, resulting in approximately 1,900 leak indication search areas, or LISAs. The distance of mains driven during day and night were very similar with 664 km (412 miles) covered during the day and 718 km (446 miles) covered at night, a difference of 7.8%. Both day and night drives were performed using Picarro's standard six-pass protocol.

> Night drives achieve higher asset coverage and shorter drive durations, with less variability in coverage and duration, compared to day drives.

The results show several significant advantages of driving at night over driving during the day.

Below, we review the areas of network covered during the drives and the time required to cover such areas. Next, we review the differences in the Field of View (FOV) and illustrate the benefits of covering larger areas during night drives. We then compare leak sizes quantified from day and night drives. Finally, we review the number of LISAs generated between day and night and the results of their corresponding investigations.

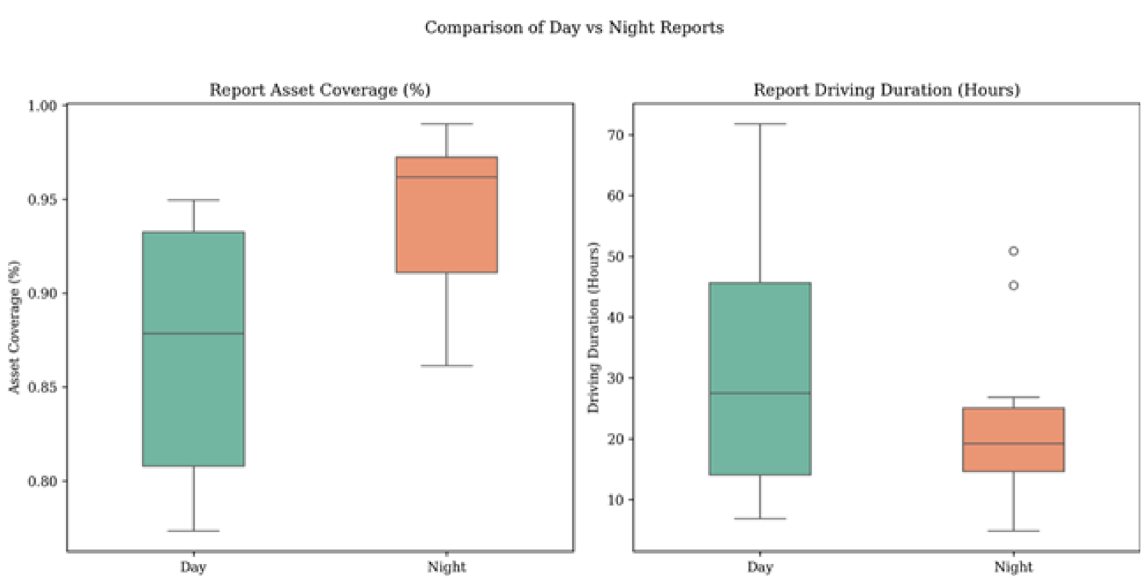

Figure 2. Asset coverage and drive duration for daytime and nighttime data collection. We observe higher asset coverage (left panel) with less driving time (see right panel).

> Night drives not only improve coverage but also enhance overall operational efficiency, optimize resource allocation, and improve cost control.

Network Coverage and Driving Time

Our analysis reveals that night drives achieve higher asset coverage and shorter drive durations, with less variability in coverage and duration, compared to day drives. This improved efficiency is illustrated in the combined box plot shown in Figure 2. The median values in the left plot highlight a 10% increase in the asset coverage for night driving, and the median values in the right plot indicate a 36% reduction in drive duration for night driving. Also, the narrower interquartile ranges suggest less variability and more consistency for night driving. Thus, not only is night driving more efficient in terms of pipe coverage, but planning is made easier due to the increased predictability of drive durations.

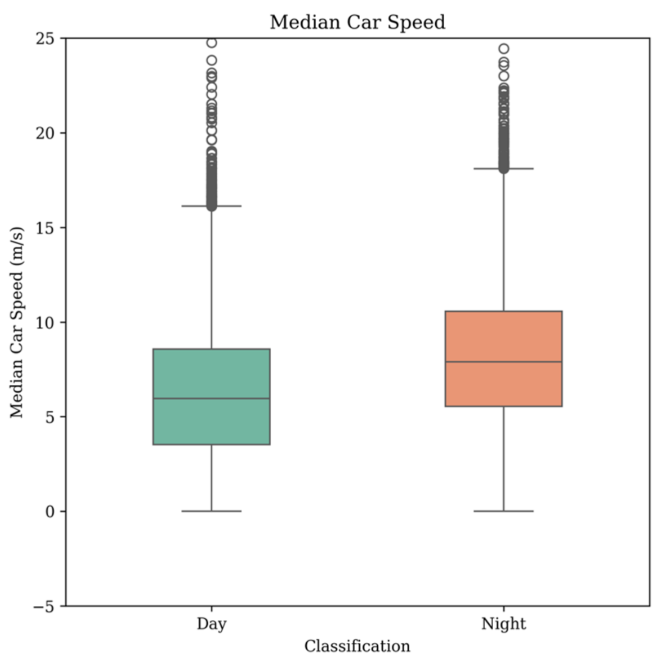

Figure 3. Median car speed for day and night surveys. The boxplot indicates that daytime surveys have lower median speeds, likely due to increased human activity during the day.

The lower median drive duration can likely be attributed to better traffic conditions, as shown in Figure 3, which compares median car speeds during day and night drives. The average median speed is 5.95 m/s during the day and 7.90 m/s at night, indicating an approximately 25% decrease in speed during the day.

These findings suggest that night drives not only improve coverage but also enhance overall operational efficiency, optimize resource allocation, and improve cost control.

Field of View

We examined the Field of View (FOV) between day and night, which indicates the area of leak detectability covered by the car. During night drives, the area scanned by the Picarro system is systematically larger than during the day. Table 1 shows that the median FOV area for night drives is approximately 56% larger than for day drives. Thus, a benefit of driving at night is monitoring larger areas, increasing the potential for emissions abatement and improvement to network safety.

Statistical Metric	Condition	FOV Area (km^2)
Median	Day	2.0
Median	Night	3.12
Mean	Day	2.0
Mean	Night	3.7

Table 1 FOV area day and night comparison.

While the FOV and asset coverage are strongly correlated, it is important to track both parameters. While night driving yields a modest increase in main pipe asset coverage (approximately 10%), it also creates a substantial boost to FOV (>50%, as shown in Figure 3). A larger FOV at night is particularly advantageous to cover assets farther from the street, such as service lines and meter sets, resulting in significantly greater overall asset coverage (mains, services, and meter sets) during night drives compared to day drives. Figure 4 illustrates the overlapping FOV areas of two datasets collected over the same geographic area, with day drives shown in light green and night drives in light red, showing the noticeable difference between day and night.

Figure 4. Overlapped FOV areas day (light green) and night (light red) for two sets of drives over the same geographic boundary.

Leak Detections and Emissions Quantification

Next, we consider the leak detections and their measured flow rates. Of the 1,911 LISAs in the dataset, 880 were detected at night and 1,031 were detected during the day. The difference of 151 can be attributed to atmospheric effects. During the day, solar heating causes increased thermal turbulence and vertical mixing in the atmosphere. This dispersion can spread the emissions over a larger area, increasing the likelihood of detection as the car moves through the environment. Conversely, at night, more stable atmospheric conditions and limited vertical mixing leave the gas concentrated near its source, reducing the chances of the system generating LISAs that do not result in found leaks (see the later section on leak investigation results).

When normalizing by the number of kilometers (miles) of network, we obtain a LISA density of 1.6 LISAs/km (2.5 LISAs/mile) for day drives and 1.2 LISAs/km (2.0 LISAs/mile) for night drives. This further suggests that night surveys can identify potential emissions more precisely by avoiding turbulence effects typical during the day. Despite fewer LISAs at night, the sum of the flow rates was 4% higher at night, as shown in Figure 5.

This difference in the flow rates can also be explained by atmospheric effects. During the daytime, stronger upward convection tends to drive gas plumes upward, reducing the concentration detected at the level of the vehicle's bumper line. This results in lower measured flow rates, even if the plume is still detected. At night, approximately half of the detected sources were measured to be >2 SCFH, compared to only one-

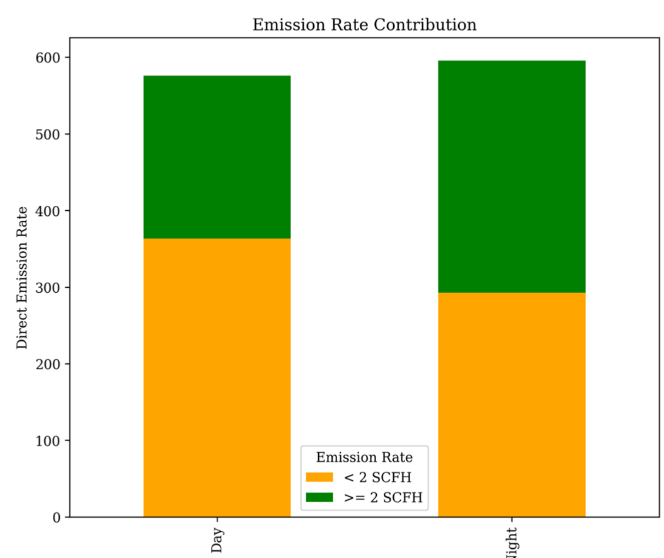

Figure 5. Contribution to the total emissions with a threshold value of 2 SCFH during day and night surveys.

Statistical Metric	Condition	Emission Rate (SCFH)	Maximum Amplitude (ppm)	Persistence
Median	Day	0.24	0.17	0.16
Median	Night	0.26	0.19	0.18
Mean	Day	0.56	0.35	0.26
Mean	Night	0.69	0.54	0.31

Table 2. Day vs night measured metrics

third during the day. This has several implications for operations. Data collected during the day requires field teams to investigate a larger number of LISAs with small flow rates and perform more repairs to achieve the same level of abatement as for data collected during the night. Additionally, Picarro identified almost twice as many large leaks (≥10 SCFH) in the night drives, with seven detected at night compared to four detected during the day.

Table 2 highlights several additional metrics that can help assess the quality of detections for night driving vs. day driving. Specifically, at night the average and median flow rates, as well as the maximum amplitude (amplitude is concentration above ambient background), are systematically higher than during the day. The larger difference between the mean and the median flow rates indicate that larger leaks are more detectable at night, confirming that while large leaks can be detected during the day, they tend to be underestimated. Another important metric in Table 2 is persistence, which describes how often a plume has been detected by the car over multiple drives in the same location. For example, if a plume has been detected six times over six passes, its persistence is equal to one. If it has been detected two times over six passes, its persistence is equal to one-third. A higher persistence indicates more stable plumes, helping the system correctly identify and quantify them, thereby increasing the accuracy and reliability of the measurements. The 20% higher mean persistence at night further supports the conclusion that nighttime driving leads to more accurate and reliable quantification.

Leak Investigation Results

We examined the outcomes of the leak investigations associated with each LISA. While, as discussed above, 16% fewer LISAs were generated during night drives (880 versus 1,031), Figure 5 shows that 67% more leaks were identified from night-generated LISAs compared to day-generated LISAs. Additionally, 'no leak found' cases decreased by 38%. The substantial increase in leaks found, coupled with the substantial reduction in 'no leak found' cases, highlights yet another benefit of conducting night operations.

Conclusion

Picarro analyzed the impact of night driving by leveraging our large AMLD data lake. Our analysis demonstrates that night driving is highly beneficial for accuracy and productivity, making it the recommended mode of operation.

Reduced upward convection currents at night enable Picarro to more accurately detect leaks and quantify flow rates. Additionally, night data collection reduces driving time and increases Field of View coverage, enhancing overall productivity and operational efficiency. By surveying at night, users can achieve more accurate and reliable detection of gas leaks while maximizing utilization and reducing costs.

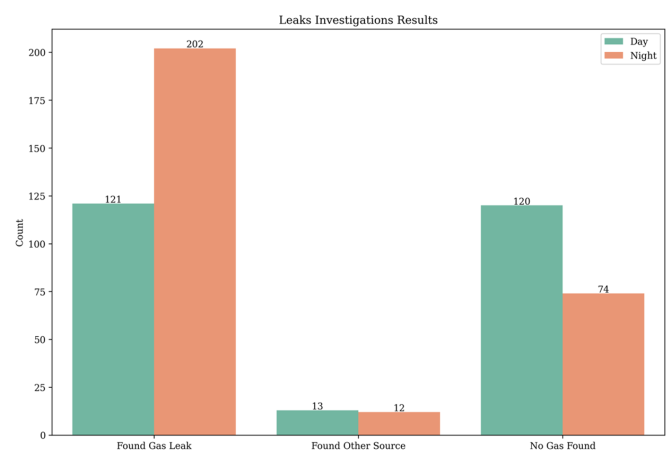

Figure 6. Leak investigation results from the analyzed reports. 67% more leaks were found from LISAs generated at night than LISAs generated during the day, with 38% fewer 'no gas found' cases.

References:

[1] The Estimation of the Dispersion of Windborne Material. Pasquill, F. 1961, Meteorological Magazin, pp. 33-49.

LIT CODE: V1.0-230406

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