

Optimizing Methane Leak Detection on Natural Gas Storage Wells

*Pilot Program Using a Novel Wind-Vane Sensing System
for Continuous Monitoring*



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1. Executive Summary

High Resolution Data and a large U.S. Natural Gas Company conducted a successful pilot program starting in March 2024 to evaluate a novel continuous methane monitoring technology (Centurion™) for natural gas storage wells. The pilot involved a progressive deployment across eight wells and tested both windvane and perimeter-based sensing configurations.

The core innovation is a self-aligning wind vane that positions multiple inlets downwind of the wellhead. This enables accurate source-based detection while reducing dependence on wind direction and minimizing false alarms from off-pad emissions.

The system provided real-time and historical data through a customizable web-based dashboard. Operators monitored methane, wind, and system status live, with automatic summary reports and SMS/email alerts for verified events.

Uptime exceeded 95%, with most interruptions tied to cellular network issues rather than system performance. Both solar and field-powered configurations were validated.

A hybrid configuration—combining wellhead and perimeter sensors—confirmed the system’s adaptability for broader coverage.

Centurion™ proved reliable, scalable, and easy to install with no specialized tools or personnel required. It is well-positioned as a cost-effective foundation for LDAR programs on natural gas storage wells.

Future enhancements include expanded use of wireless sensors (LoRa) and integration of site-specific modeling to support semi-quantitative emission estimates. These improvements will further position the system for broader deployment and regulatory alignment.

Field testing and model analysis confirm that the Centurion™ vane system achieves a minimum detectable concentration of 1–3 ppm (~10–60 g/hr), well below CMS thresholds of 400 g/hr and the common 1 kg/hr reference marker. See Appendix 8.10 for detailed performance curves.

2. Introduction

Methane monitoring on natural gas well pads has become increasingly important for both regulatory compliance and environmental stewardship. With growing public and regulatory scrutiny on greenhouse gas emissions, reliable detection of methane leaks is critical for maintaining regulatory alignment, minimizing environmental impact, and protecting operator reputation.

Recent regulatory developments—including updated EPA rules and more aggressive state-level initiatives—have raised the standards for methane emission monitoring and reporting.

The role of continuous leak detection technologies has expanded significantly in well pad management strategies. Systems capable of providing real-time data and rapid response are now seen not just as compliance tools, but as valuable assets for improving operational efficiency, reducing environmental risk, and limiting the release of climate-harming gases. This evolving landscape has created a need for methane monitoring solutions that are effective, scalable, and economically sustainable in real-world operations.

3. Problem Statement

Traditional methane monitoring approaches on natural gas well pads often rely on periodic inspections, which can leave emissions undetected for extended periods. A recent survey conducted at the Methane Mitigation America Summit (2024) and the Methane Mitigation Europe Summit (2025) showed that 64% of organizations still use hand-held intermittent methane measurements for LDAR activities (Appendix 8.7). To minimize the total volume of released methane and enable faster corrective action, continuous monitoring is essential.

Fixed-position continuous sensors, while an improvement over periodic monitoring, can suffer from significant limitations. Measurements are often highly dependent on wind direction and speed, leading to potential blind spots or delayed leak identification when atmospheric conditions are unfavorable.

Comprehensive continuous monitoring systems, such as optical gas imaging (OGI) cameras or full-site scanning technologies, offer broader coverage but come with significant drawbacks. These systems typically require substantial infrastructure, are costly to install and maintain, and generate large volumes of data that demand ongoing processing and expert interpretation.

For single-wellhead, small multi-wellhead pads, or multiple well pads distributed over a wider area—such as the layout demonstrated in our pilot program (see Figure 4)—a simpler, lower-cost methane monitoring solution is necessary. Effective deployment on these sites demands technology that can provide continuous, reliable leak detection without the need for complex installation, heavy infrastructure, or significant maintenance overhead.

4. Technology Overview

The Centurion™ methane monitoring system developed by High Resolution Data is built around a novel wind-vane-mounted sensing platform (referred to here as the VANE system) designed specifically for natural gas well pad applications. At its core, the system uses a self-aligning wind vane to dynamically position multiple sampling inlets downwind of the wellhead, ensuring that emissions are captured at the highest possible concentration. Note the multiple inlet positions at different elevations, which optimize methane capture across a range of wind speeds and directions.

Figure 1. Centurion™ VANE Assembly Installed at Wellhead (multiple inlet positions for enhanced capture)



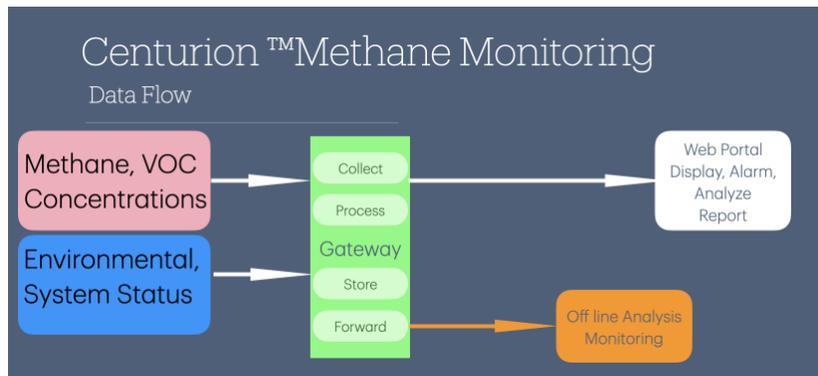
Key design features of the VANE system include the automatic downwind alignment of multiple inlets and a real-time sensing architecture that continuously monitors gas concentrations. The system is lightweight, modular, and operates autonomously, requiring no external power alignment or manual intervention once deployed.

Figure 2. Dual Zone – Combination Vane and Perimeter Multi-zone System



Each VANE system is connected to a field Gateway that houses pumps that draw air samples from the inlets and route them through an internal sensor assembly capable of measuring methane and volatile organic compounds (VOCs), converting concentrations to ppm values in real time. The Gateway also integrates environmental monitoring inputs, including anemometer readings (wind speed and direction), temperature, and relative humidity. Following collection and initial analysis, all data are archived locally and transmitted to a custom web portal for visualization, further analysis, and long-term storage.

Figure 3. Data Collection and Transmission Flow Diagram



5. Pilot Program

The pilot program began in March 2024 with the deployment of two Centurion™ systems at selected wellheads. In November 2024, six additional units were installed, bringing the total to eight systems operating across a single well, multi-pad configuration. Routine maintenance was performed in May 2025, and as of July 1, 2025, all eight systems remain in continuous operation. This configuration now serves as the standard monitoring setup for the site and is under consideration for broader deployment across additional sites.

(See Figure 4: Single-Well Multi-Pad Site for Pilot Deployment.)

The pilot aimed to evaluate core functionality, operational integration, and long-term viability of the Centurion™ system. Key objectives included:

1. Verify easy and rapid installation.
2. Detect both blind test releases and natural emissions quickly and accurately; establish sensitivity thresholds.
3. Evaluate hybrid monitoring using both VANE and perimeter sensors with a multi-zone Gateway configuration.
4. Confirm proper alarm transmission to operators.
5. Minimize impact on field personnel and avoid interference with routine well maintenance activities.
6. Ensure reliable operation under high wind conditions.
7. Verify remote servicing capabilities.
8. Deploy across eight wells to evaluate scalability from a single-well to a multi-pad deployment.
9. Track downtime as a metric of system reliability.
10. Evaluate the new web-based portal for remote access to dashboards, system status, and automated reporting.

Figure 4. Final Pilot Monitoring Configuration



Field Power – Local 24VDC

Perimeter Test - Vane Sensor was supplemented with multiple sensors on the perimeter fence.

6. Key Findings

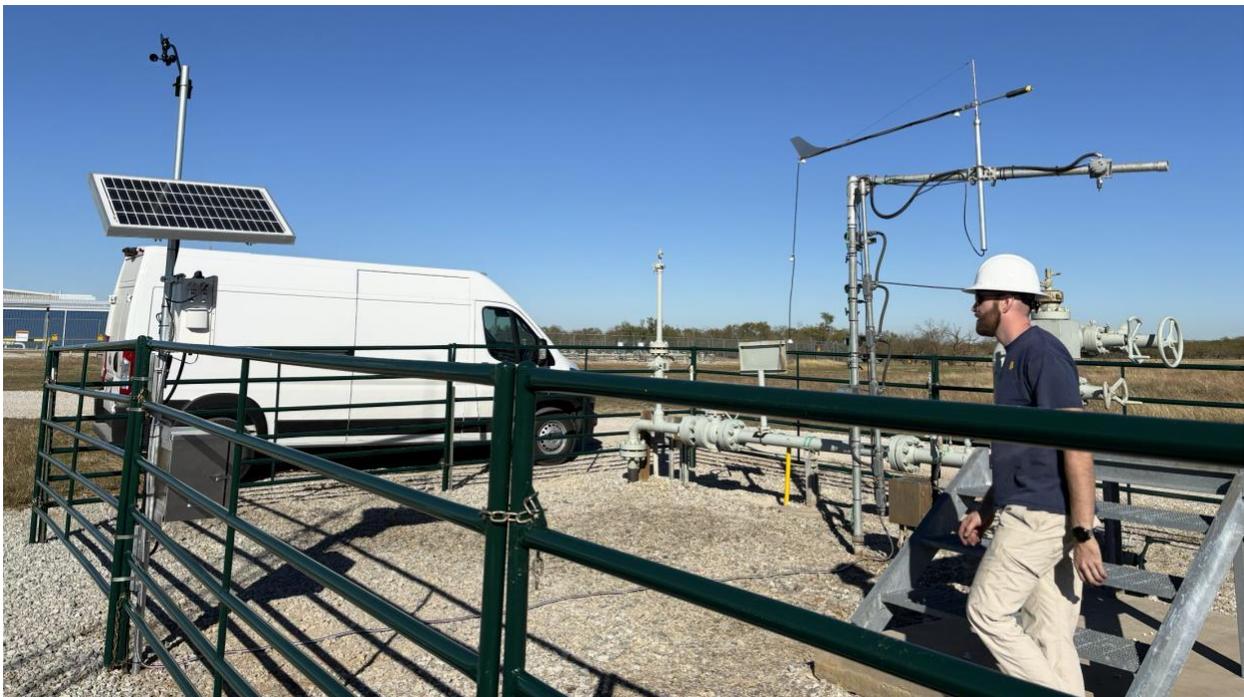
The following key findings summarize the performance, field observations, and user feedback gathered over the course of the pilot program. These results illustrate both the operational value of the Centurion™ system and areas for future development.

6.1 Rapid and Simple Installation

Installation of each Centurion™ system was completed in under three hours using standard field tools and basic mounting hardware. No pad modifications or specialized personnel were required. This streamlined approach enabled fast deployment with minimal disruption to ongoing operations.

During the November 2024 expansion phase, six additional units were installed without delays or site-specific adjustments, demonstrating the repeatability and field readiness of the system design. The modular hardware and single-cable setup also minimized setup error and helped ensure consistent performance from day one.

Figure 5. Completed Installation (solar-powered configuration)



6.2 Sensitive and Accurate Methane Detection with Wind Tracking Vane

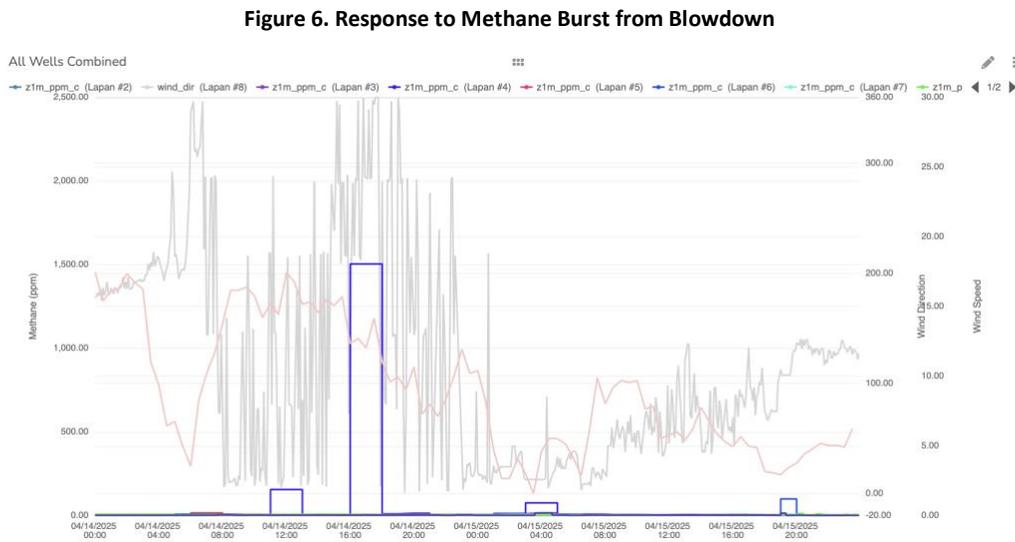
The ability of the Centurion™ system to detect small emissions at the wellhead, even under varying wind conditions, was repeatedly validated throughout the pilot. The system's wind-vane alignment ensured that air samples were captured from the most relevant direction — downwind of the source — improving both sensitivity and response time.

The best example comes from the field operating manager:

*“Hey Guys,
We blew down Unit 2 yesterday at 5:45pm and the wind was blowing 15–20 out of the north. I received this alert of methane detected on well #4 at 5:47pm and we do have gas detectors on every well and the only time we have received an alarm is when blowing down a well through the top of the tree. The HRD methane detectors are much more sensitive and keep proving to be accurate. Thanks.”*

This field confirmation matched the system's internal detection records, shown below in Figure 6.

Below is a chart from the online portal showing exactly what the operator was discussing showing a detected Methane concentration of close to 1500 ppm.



Performance data over the duration of the pilot confirmed detection concentration thresholds beginning at 3 ppm methane, with consistent quantifiable measurements above 10 ppm. Field testing and model analysis confirm that the Centurion™ vane system achieves a minimum detectable concentration of 1–3 ppm, which corresponds to emission rates of roughly 10–60 g/hr under typical near-field conditions. These values are well below the regulatory benchmarks for Continuous Monitoring Systems (CMS), which specify minimum detection levels of 400 g/hr (EPA OOOOb/c) and use 1 kg/hr as a common reference threshold. This performance places Centurion™ comfortably within compliance expectations while extending sensitivity to smaller leaks that traditional CMS systems may overlook. A detailed performance envelope, including modeled sensitivity curves, is provided in Appendix 8.10. (40 CFR § 60.5398b(c)(1)(i)–(ii)).

Practical examples of leak detection, verification, and corrective repair are provided in Appendix 8.9 along with a modeled analysis of vane performance tied to real world measurements is provided in Appendix 8.10.

6.3 Timely Leak Alarming Without False Positives

During the pilot, the system consistently delivered timely alarms in response to intentional gas releases — including controlled valve operations and scheduled well maintenance. These events were reliably detected and automatically triggered notifications via SMS and email, ensuring operators were informed within moments of a verified methane release.

Equally critical, the system demonstrated resilience against false alarms. Non-methane events and routine site activity did **not** trigger unnecessary alerts, avoiding costly dispatches, and preserving trust in system accuracy.

These records provide both a real-time operational view and a historical audit trail of all alarm events. Practical examples of leak detection, verification, and corrective repair are provided in Appendix 8.9.

See **Figure 7**.

Figure 7. Events Dashboard Displaying Real-Time Leak Alarm and Acknowledgment

Status	Device	Message	Trigger	Triggered	Resolved	Comments
Resolved	Well #2	PEV Monitor1008	🔥 0.72	09/24/2025 10:29	09/24/2025 10:38	---
Resolved	Well #2	PEV Monitor1008	🔥 0.73	09/24/2025 12:36	09/24/2025 12:43	---

6.4 Real-Time and Historical Data Access

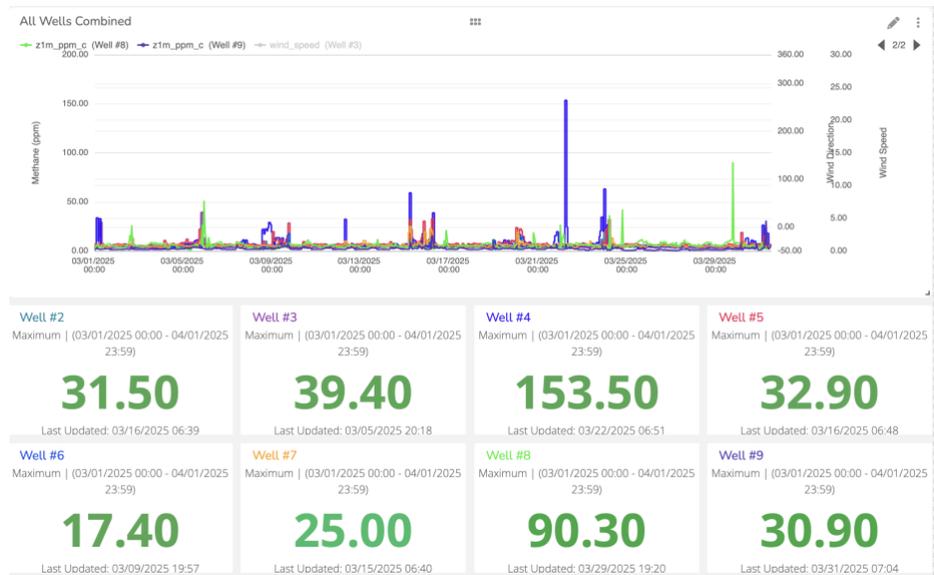
The Centurion™ web portal provides both real-time and historical data access through a secure, cloud-based interface. Multiple built-in dashboards are available for reviewing methane concentration, wind data, and system status. Operators can also configure their own custom views to support site-specific workflows or reporting needs.

In addition to live views, **monthly summary reports** are generated and available for download directly from the portal, providing a convenient record of activity, performance, and any alarm events.

Figure 8. Real-Time Display



Figure 9. Monthly Historical Methane Concentration Plot – March 2025



6.5 Hybrid Monitoring Using VANE and Perimeter Sensors

A hybrid monitoring configuration was tested combining wellhead-mounted VANE systems with perimeter-mounted sensors. This configuration evaluated the Centurion™ system's ability to monitor multiple zones from a single gateway and to assess whether perimeter detection added value beyond source-based monitoring.

While most emissions were detected near the wellhead, perimeter sensors were successfully integrated and confirmed the system's multi-zone capability on Well #3 for a few months. In some cases, perimeter sensors captured elevated background levels that helped correlate vane measurements and interpret off-pad emissions. Simultaneous detection at an "upwind" perimeter sensor is a strong indicator that the source is off pad.

This approach demonstrated the flexibility of the system architecture, where both localized and perimeter coverage could be achieved with minimal additional hardware or complexity. (See **Figure 2**: Dual Zone – Combination VANE and Perimeter Multi-zone System). A limitation of the perimeter system is that for a given location, only one elevation is monitored whereas the vane provides multiple levels.

6.6 Verified Reliable Operation Using Both Centurion™ Solar Power System and Operator Field Power System

Of the eight wells included in the pilot, one was configured to run on existing 24V field power rather than the Centurion™ solar power system. This option eliminated the need for a dedicated solar installation, which reduces upfront cost and ongoing maintenance.

When reliable field power is available, it can serve as a practical and lower-maintenance alternative. While the solar-powered systems have operated successfully throughout the pilot, they do require periodic attention — particularly regarding battery life and seasonal energy availability.

During one extended period of overcast weather, a subset of the solar-powered units was temporarily placed in a lower power mode for five days to conserve energy. Despite this, all systems retained core monitoring functions and resumed full operation automatically when solar conditions improved.

6.7 Easily Removed and Re-installed During Well Testing Operations

For several days starting on 9/10/2024, Acoustic logging was performed on a single well. In addition to larger expected methane levels, the unit needed to be moved away from activity. The operator was able to temporarily remove the system and later restore it without assistance. The vane assembly was easily removed and re-installed when complete. Monitoring functions were suspended to prevent false alarms.

6.8 High System Uptime (>95%)

System availability across the full eight-well deployment was measured at over 95% throughout the pilot. This uptime metric reflected two key components:

1. **Network access** – whether the unit was online and communicating through the cellular network
2. **System operation** – whether the device was actively collecting, processing, and transmitting data

Most of the measured downtime was attributed to intermittent cellular network availability, which occasionally interrupted external communications. One extended event occurred at Well #8, where connectivity was lost for several days, temporarily reducing that unit's availability.

During network interruptions, core system functions—including local data logging and environmental monitoring—continued to operate, ensuring no data was lost.

6.9 Going Forward

Based on pilot results and operator feedback, several forward-looking recommendations and enhancement opportunities have been identified to guide future deployments.

- **Operational Recommendations**

Built-in GPS and environmental sensors (wind and temperature) proved valuable for post-analysis for understanding emission patterns, wind influence, and background behavior. Future deployments should retain these inputs where possible, particularly for multi-well or off-pad interpretation.

- **Deployment Strategy**

The modular architecture and gateway-based design support cost-effective scaling. Future expansion should consider batch deployments (e.g., 5–10 wells) using shared communication infrastructure and multi-zone monitoring.

Perimeter sensors can add value, especially for identifying off-pad emissions or providing a second line of confirmation. Their use is recommended selectively—particularly at sites near compressors, tank batteries, or adjacent pads.

- **System Improvements**

To implement the deployment strategy effectively, include standalone wireless sensors communicating to the gateway via LoRa, reducing tubing and cabling requirements, simplifying installation, and enabling wider spatial coverage across the site.

Add a new coalescer (inlet water filter) to automatically drain accumulated moisture without operator intervention

- **Data Utilization and Integration**

Ongoing integration of wind data, methane concentrations, dispersion modeling, and site-specific information (e.g., pad layout and equipment placement) will support increasingly accurate visualization and enable the progressive development of semi-quantitative mass emission estimates (kg/hr) as more data is collected. This will further position the system for broader deployment and regulatory alignment

7. Conclusion

The Centurion™ pilot program successfully demonstrated a scalable, cost-effective, and field-ready solution for continuous methane monitoring on natural gas storage well pads. Across eight wells and multiple operational scenarios, the system performed reliably, delivering timely leak detection, high uptime, and consistent data access through both real-time dashboards and monthly summary reports.

The system's core innovation—the use of a self-aligning wind vane with multiple sampling inlets—enabled accurate detection while minimizing dependence on prevailing wind direction and speed. Field performance confirmed a minimum detectable concentration of 1–3 ppm (~10–60 g/hr), well below CMS threshold recommendations of 400 g/hr and the common 1 kg/hr reference marker. See Appendix 8.10 for detailed performance curves.

Alerts were delivered promptly via SMS and email and verified against operational events, such as blowdowns and maintenance procedures.

Flexibility was a key outcome of the pilot. The system supported both solar and field power configurations. Units were easily removed and re-installed during well servicing activities, without requiring field engineering support. A hybrid monitoring configuration—combining VANE and perimeter sensors—was validated and confirmed the system's multi-zone capability, enabling broader pad-level or environmental coverage when required.

Uptime performance exceeded 95% across the deployment, with interruptions tied to network availability rather than system failures. Core monitoring and data logging functions continued during offline periods, preserving system integrity and data continuity.

The pilot also revealed opportunities for ongoing enhancement. Built-in environmental sensors and GPS provided valuable context for interpreting emissions and should be retained in future deployments. Expanded use of wireless LoRa-connected sensors, simplified power options, and new coalescing filters are planned to improve installation speed and coverage. Integration of wind, methane, and site-specific data will also support the development of semi-quantitative mass emission estimates, further enhancing operational and regulatory insight.

Based on these results, the Centurion™ system is well-suited to serve as the primary tool for LDAR activities on natural gas well pads. Its modular architecture supports both standalone and hybrid configurations, and its low-maintenance design makes it practical for widespread deployment. High Resolution Data recommends wind-vane-mounted sensing as the foundation of future pad-level methane monitoring strategies, with perimeter sensing used selectively where needed for enhanced coverage and removal of interfering emissions.

8. Appendices / Supporting Materials

8.1 System Photographs

Figures 1 and 5 illustrate the Centurion™ vane system as deployed in the pilot program. Figure 1 shows a wellhead installation with multiple inlet positions designed for enhanced capture across wind speeds, while Figure 5 shows a complete field system including solar power. Together, these images provide context for both basic and full deployment configurations.

8.2 Dual Zone System

Figure 2 highlights the dual-zone configuration, combining the vane-based monitor with perimeter multi-zone sensors. This arrangement demonstrates how multiple sensing approaches can be integrated to strengthen overall coverage in complex well pad environments.

8.3 Data Collection and Transmission

Figure 3 presents the data collection and transmission flow diagram used in the pilot. The figure illustrates the complete data path—from sensor pickup through local processing, cellular backhaul, and dashboard integration—showing how real-time monitoring is maintained and archived.

8.4 Pilot Monitoring Configuration

Figure 4 shows the final pilot monitoring configuration, including the field layout of system components. This figure provides a visual overview of the arrangement tested during the pilot program and supports the operational details discussed in Section 6.4.

8.5 Blowdown Event Detection

Figure 6 demonstrates the Centurion™ system’s response to a methane burst from a blowdown event. The rapid detection and clear time-series signal confirm that the vane monitor can capture sudden high-volume emissions while distinguishing them from background variability.

8.6 Regulatory Context References

EPA Methane Emissions Standards for New and Existing Sources (November 2023)

Inflation Reduction Act - Methane Emissions Fee Section (2022)

Colorado Regulation 7 – Oil and Gas Emission Controls (2023)

Additional regulatory context is provided in Appendix 8.11.

8.7 Industry Survey References

Methane Mitigation America Summit 2024 – “The Methane Imperative: Industry Leader’s Perspectives on Policy, Technology, and Collaboration in a Shifting Landscape”

Methane Mitigation Europe Summit 2025- “The Methane Imperative: Industry Leader’s Perspectives on Policy, Technology, and Collaboration in a Shifting Landscape”



Centurion™ Methane Monitor

Monthly Summary Report - All Sites

04/01/2025 - 04/30/2025

Summary

Sites: Well 2, 3, 4, 5, 6, 7, 8, 9

Dates: 04/01/2025 - 04/30/2025

Configuration: Vane

Maximum Recorded PPM: 1504 (non-calibration)

Number of Event Level Peaks (> 200 ppm): 3 (not including peaks from calibration tests on 4/16/2025)

Identified as Well Leaks: 0

Total Duration Above Event Points (>200 ppm): 0 minutes (max all points)

Uptime: 95%

Reportable: None

Observations:

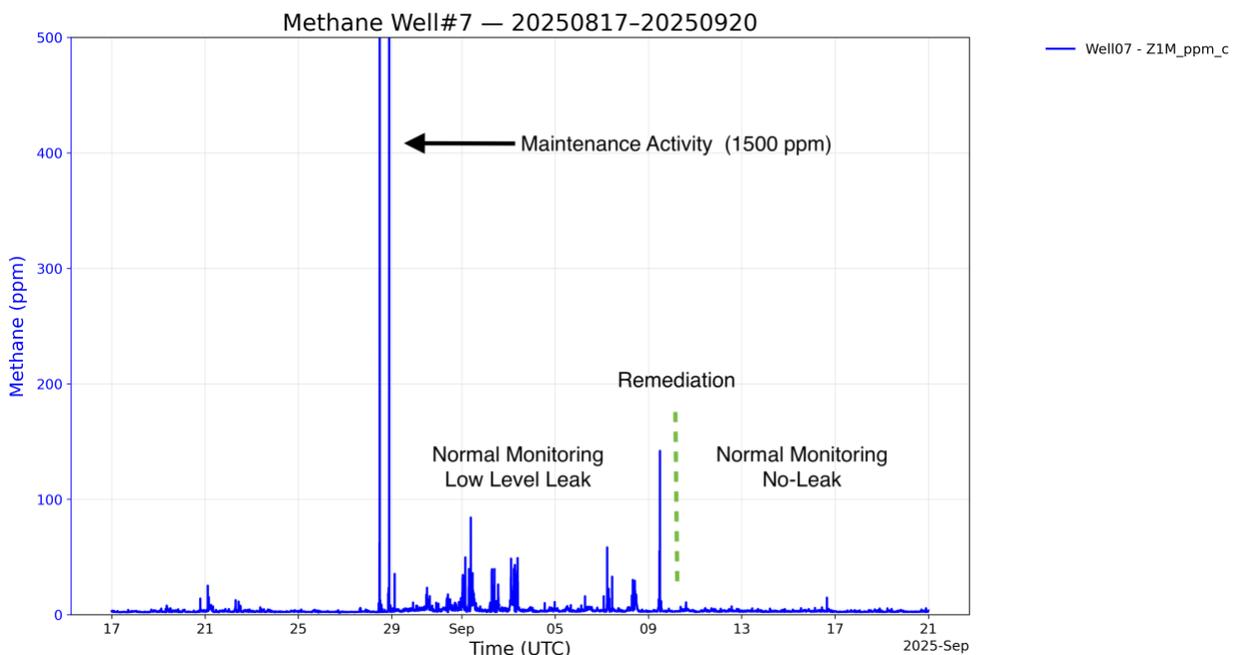
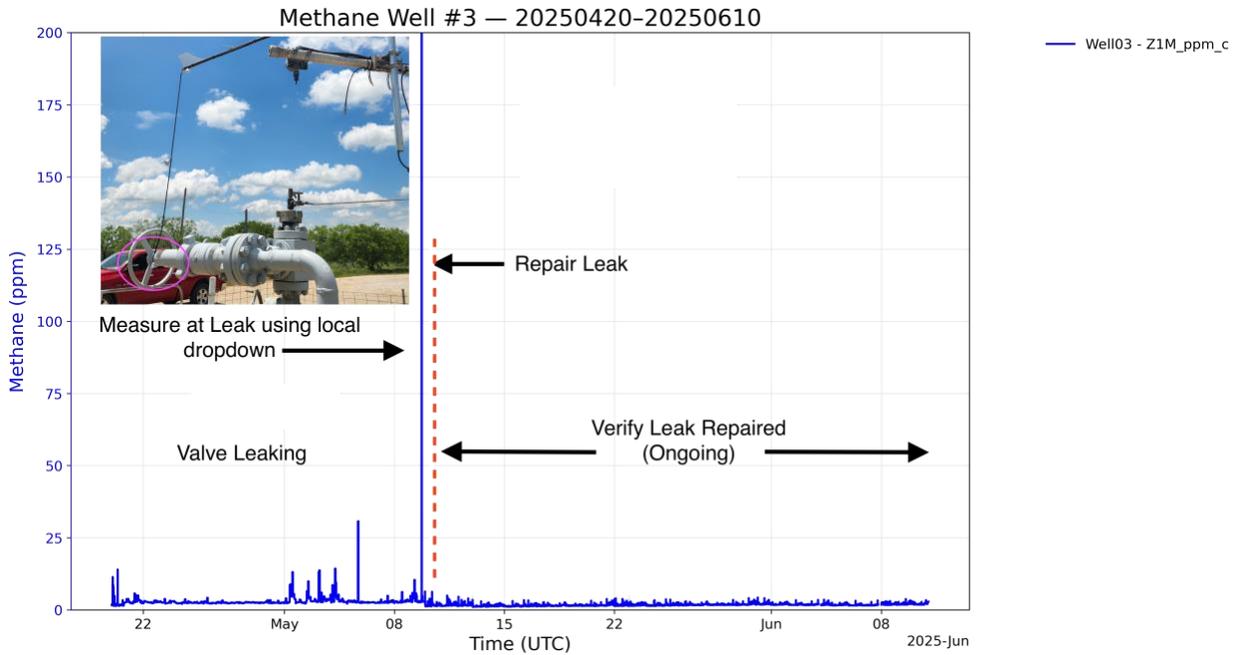
- All wells show intermittent low-level activity-all below the "event" level.
- Well #4 had the highest noted reading of 1504 ppm. This was very short duration (1 20-minute sample period). Operator notified that simultaneous with #2 blowdown and consistent with wind direction (Well #4 with wind out of north).
- Values of 276 on well #6 and 230 were noted on well #8. They were determined not to be ongoing well leak based on wind direction and short duration.

Operational Notes:

- The uptime average was 95% for all 8 wells.
- Well #8 went off-line on 4/27/2025 and is still off-line. Scheduled for evaluation and repair on 5/7/2025 by Colin Stark.
- There were no power issues.
- 6-month maintenance review was completed by Colin Stark for HRD on 4/16/2025.

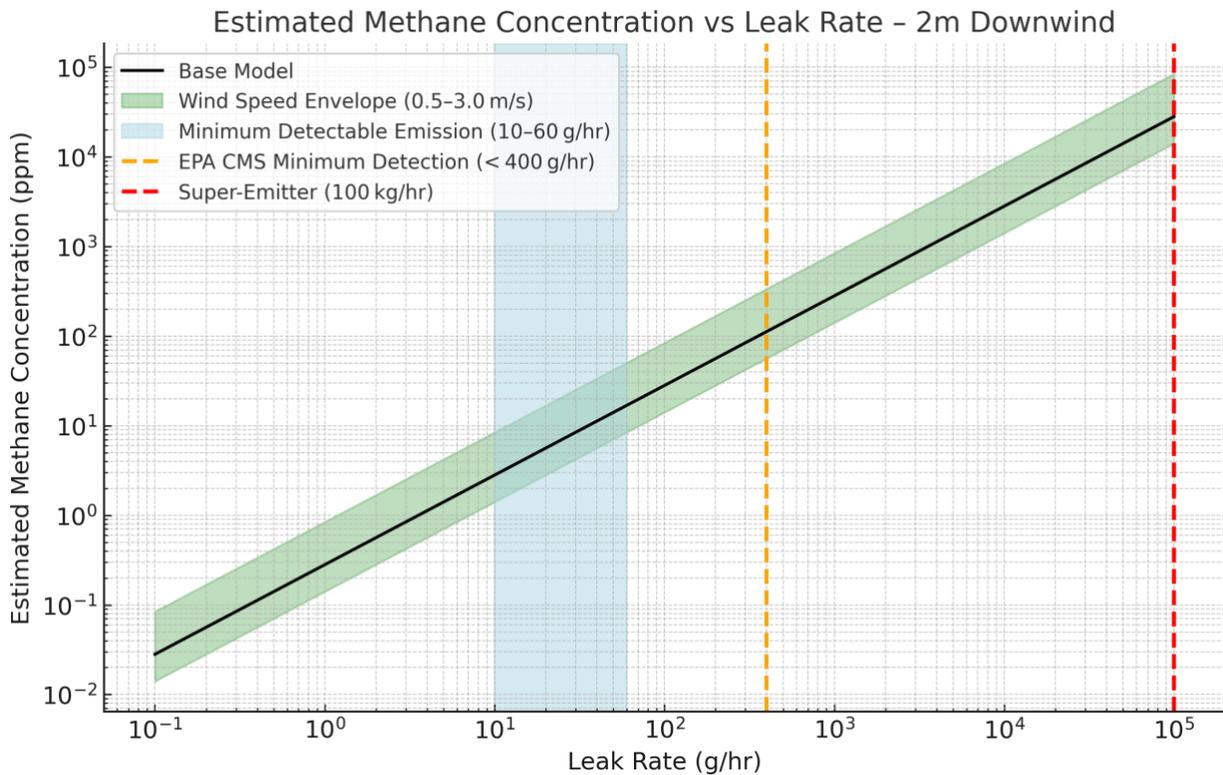
8.9 Leak Detection and Verification

This appendix illustrates two practical cases of leak detection and repair during the pilot program. The first example shows detection of a valve leak, verified by the Centurion™ vane pickup, and subsequently resolved through valve closure. The second example documents a maintenance-related leak that remained after servicing a well. The vane monitor identified the leak, enabling corrective action and confirming the repair. These cases demonstrate how the system supports LDAR (Leak Detection and Repair) workflows with immediate detection, verification, and confirmation of fixes.



8.10 Vane Detection Model and Minimum Detectable Concentrations and Corresponding Mass Rates

This appendix presents the vane detection model, which relates methane mass-leak rates to expected concentrations at the sensor. The plot shows the system's minimum detectable concentrations (1–3 ppm) corresponding to mass rates of approximately 10–60 g/hr, extending upward through super-emitter levels (>100 kg/hr). The overlay and annotations highlight the Centurion™ system's performance relative to regulatory thresholds for continuous monitoring systems (CMS), demonstrating capability well below the U.S. CMS minimum values of 400 g/hr and 1 kg/hr.



8.11 Regulatory Reference Points for Approved Methane Sensing (EPA NSPS 0000b/0000c)

Super-Emitter Definition

A methane release of ≥ 100 kg/hr triggers mandatory notification and mitigation under the Super-Emitter Response Program.

Continuous Monitoring Systems (CMS)

- Detection capability: CMS must achieve a minimum detectable emission rate ≤ 0.40 kg/hr.
- Data completeness: At least one valid mass-rate (or equivalent) per 12-hour block.
- Action-level thresholds (exceedance triggers, above site baseline):
 - Wellhead-only sites:
 - 1.2 kg/hr (90-day rolling average)
 - 15 kg/hr (7-day rolling average)
 - Sites with major equipment / centralized facilities / compressor stations:
 - 1.6 kg/hr (90-day rolling average)
 - 21 kg/hr (7-day rolling average)

Alternative Periodic Screening Technologies

Minimum detection thresholds tied to survey frequency:

- Quarterly: ≤ 1 kg/hr
- Bimonthly: ≤ 2 kg/hr
- Monthly: ≤ 5 kg/hr
- Bimonthly + annual OGI: ≤ 10 kg/hr
- Monthly + annual OGI: ≤ 15 kg/hr

Technology Approvals

EPA's Advanced Methane Detection (ATM) approvals align to these thresholds ($\leq 1, 2, 3, 5, 10, 15$ kg/hr), providing a clear performance ladder for alternative systems.

Note on the Waste Emissions Charge (WEC)

The WEC rule was rescinded under the Congressional Review Act in March 2025. The statutory framework remains, but the implementing regulation no longer applies.

9. Table of Figures

Figure 1. Centurion™ VANE Assembly Installed at Wellhead (multiple inlet positions for enhanced capture)

Figure 2. Dual Zone – Combination Vane and Perimeter Multi-zone System

Figure 3. Data Collection and Transmission Flow Diagram

Figure 4. Final Pilot Monitoring Configuration

Figure 5. Completed Installation (solar-powered configuration)

Figure 6. Response to Methane Burst from Blowdown

Figure 7. Events Dashboard Displaying Real-Time Leak Alarm and Acknowledgment

Figure 8. Real-Time Display

Figure 9. Monthly Historical Methane Concentration Plot – March 2025



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