Pilot Study for Methane Measurement and Emissions Quantification with Next-Generation Sensor Technology at Upstream Oil and Gas Facilities

Final Report

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Best Practices and Tangible Project Outcomes

This pilot project involved a three-week methane field measurement study at the Site 8-8 well pad, along with controlled methane release experiments also conducted at Site 8-8. The project successfully demonstrated the application and utility of innovative, portable methane sensors to characterize methane emissions at an upstream oil and gas (O&G) facility. A high-quality dataset was obtained that demonstrates the capabilities of these next-generation sensors. Based on these data, we found that the Aeris Technologies (Aeris) Pico series methane sensors used in this study had sufficient data rate, accuracy, and sensitivity to support a broad range of applications at upstream O&G facilities, such as the detection and identification of methane releases, and the quantification of methane emission rates. Data from the sensors were successfully used to identify the presence of continuous (as opposed to intermittent) methane emissions from equipment at Site 8-8, and the combination of wind, methane, and ethane data were further used to successfully distinguish methane emissions from two distinct types of sources at Site 8-8 (production tanks, and pump jacks and adjoining equipment). The data were also successfully used to support quantitative methane emissions estimates based on an inverse dispersion modeling method. The measurements collected at Site 8-8 therefore provide a benchmark upon which data quality objectives can be established for similar new and emerging methane sensor technologies.

The sensors and approaches demonstrated in this project can be used to characterize real-world methane emissions at upstream O&G facilities. Collecting data to support these objectives requires methane sensors with appropriate data quality requirements (e.g., data capture rate, sensitivity, and accuracy), co-located high-quality meteorological measurements, the ability to accurately assess local baseline (upwind) methane concentrations, careful instrument siting and placement, and a robust data management system and process. These practical considerations are discussed below.

Establishing Background (Baseline) Concentrations

Establishing a baseline methane concentration is critical for establishing context for methane measurements and quantifying methane emissions at an O&G facility. The baseline can be considered a local background concentration that can vary over time and may be different from a regional, continental, or global marine background concentration. There are two ways to establish baseline concentrations:

- Collect simultaneous methane measurements upwind and downwind of the facility.
- Determine baseline concentrations from a single sensor during periods when the sensor is upwind of the facility.

Both approaches take careful field planning and sensor placement that will be unique to the layout and characteristics of the facility, topographic features in the area, and potential nearby off-site methane sources. In this pilot project, a single baseline methane value for the entire study period was determined by using the lowest 10% of methane measurements. Methane enhancements were determined by subtracting the baseline concentration from the methane observations. Longer deployments would require time-varying assessments of the baseline. Using an upwind/downwind sensor combination, the baseline can be determined directly from the upwind sensor.

Sensor Characterization and Data Quality Objectives

Sensor accuracy and sensitivity directly affect the degree to which methane enhancements can be statistically (and therefore reliably) distinguished from the background (upwind) concentration, and the sensitivity and uncertainty of any emissions quantification method. A high data capture rate can enable the detection and characterization of intermittent releases, and produces data for emission quantification approaches that characterize the emission plume by relating changes in concentration to coincident changes in wind speed and direction. Understanding the capabilities and limitations of both the sensor and the emissions quantification method is key to ensuring that project objectives can be achieved.

In this pilot project, data collected from pre- and post-deployment calibration tests, controlled methane release experiments, and the three-week field deployment were used to evaluate and demonstrate the sensors' capabilities and limitations. These activities are important and appropriate to establish credibility and confidence in any sensor and data analysis approach that may be used in the field.

The recommended data quality objectives for applying methane sensors at upstream O&G facilities depend on the intended application of the measurements. For example, the requirements for detecting methane anomalies from a facility would be less rigorous (i.e., larger precision and error could be tolerated) than the requirements needed to support emissions quantification. The data quality objectives were not formally defined prior to the pilot study, but some general objectives were used to guide the instrument selection. Data from the bench testing, controlled releases, the Site 8-8 field deployment, and the emissions quantification analyses were used to support recommendations that can be used to guide future applications of methane sensor technology at upstream O&G facilities.

Important practical conclusions and recommendations related to the sensor characterization and data quality objectives for applying sensors at upstream O&G facilities include:

- A measurement uncertainty (precision) within about ±4% is needed to reliably detect and quantify methane signals greater than about 0.100 ppm above baseline, and therefore is necessary to support emissions characterization. Larger measurement uncertainties could be tolerated to support field objectives that involve only the identification of anomalous emissions at a facility and do not require accurate quantification.

- A baseline methane concentration of 1.91 ppm was determined for the 3-week deployment. At this baseline concentration, the sensors used in this study can reliably detect a methane enhancement above baseline (measurement minus baseline) as small as 0.027 ppm at 1% measurement uncertainty. A measurement uncertainty of up to 4% would be sufficient to reliably detect and quantify signals greater than about 0.100 ppm above baseline.
- Meteorological instruments are critical and should always be co-located with the methane measurements. The meteorological data should at a minimum include wind speed, wind direction, temperature, relative humidity, and pressure, as all are needed to characterize and quantify methane emissions. The data capture rate should be at least equal to the methane measurements (i.e., at least 1 second). For wind measurements, a 3-D sonic anemometer is ideal, but a 2-D sonic anemometer is still preferred over cup-and-vane measurements.
- Data resolution must match the deployment objectives and analytical approaches being used. Data at 1-minute resolution was sufficient to meet the objectives of this study, but certain emission quantification techniques can use 1-second (1 Hz) resolution data to relate changes in concentration to coincident changes in wind speed and direction to characterize emission plumes.
- To use near-field emissions quantification methods, instruments should be located within about 15 m to 100 m of potential emission sources. At closer distances, gas plumes from elevated releases may travel over the sensors. At further distances, gas plumes may become too diluted to be characterized by the sensor. For larger O&G facilities, multiple sensors may be needed.
- Coincident ethane measurements are not critical but are helpful to confirm natural gas emission sources (as opposed to other biogenic or geologic methane sources) and to differentiate between multiple emissions sources that may have unique ethane composition. To support this type of analysis, ethane measurements should have 1% accuracy, and up to 20 ppb peak-to-peak drift.

Practical Considerations

In addition to characterizing the sensors and establishing data quality objectives, there are several practical considerations for using the Aeris sensors or sensors with similar characteristics in the field. The considerations include:

- **Cost.** Although the methane sensors deployed in this pilot project are not considered a low-cost sensor technology, we expect that the price of these and other next-generation methane sensors will drop over time as the technology matures. These sensors are significantly less expensive than a cavity ring-down spectroscope (considered a gold standard in methane measurement) and meets data quality objectives for supporting methane emissions quantification and other measurement objectives at upstream O&G facilities. When evaluating the potential benefits of the sensor technology, additional costs associated with deployment design and execution, sensor operations and maintenance, data management, data analysis, and data delivery must also be considered.

We evaluated several potential methane sensors for this pilot project. The cost point for the sensor selected for this project provides the necessary sensitivity and accuracy that are needed for methane emission identification and quantification efforts. At this point in time, lower-cost options sacrifice sensitivity and accuracy, and these tradeoffs must be considered in the context of the field deployment objectives.

- **Temperature control**. The biggest concern for the methane sensor was overheating. Customized enclosures were developed to shield the instrumentation from heat and maintain proper laser temperature. In cold-climate deployments, a heater would be needed. In hot-climate deployment, appropriate ventilation and possibly air conditioning would be needed. A climate-controlled shelter or carefully controlled enclosure is needed to deploy this methane sensor long-term.
- **Power**. The original deployment plan included the use of deep-cycle lead-acid batteries charged by solar panels. After bench testing the instruments and planning the field logistics, we determined that using line power would reduce project risk and increase the likelihood of a successful pilot project. Therefore, the deployment requirements for this project were adjusted, and a site was selected that had line power.
- **Data communications and management**. The methane sensors had adequate on-board storage, but real-time measurement systems need robust communications (cellular was used in this deployment) and specialized offsite data management capability to receive and process high-time-resolution (1-second) data in real-time. Appropriate data quality control measures, such as range checks, stuck value checks, etc., are also necessary.[1]
- **Calibration.** Instrument calibration is important to establish and maintain accuracy in the methane measurements. The sensor does not have a published calibration procedure. Pre- and post-deployment checks against standard gases with known concentrations were conducted in this pilot project, and are recommended for any sensor and field deployment. Longer-term deployments need periodic calibration checks to guard against long-term instrument drift. A quarterly calibration check is recommended
- **Instrument issues**. The methane sensors deployed in this pilot project were relatively new to the market. We worked closely with Aeris during the testing phase of this pilot project to address various issues that were initially encountered. Working out these issues during the testing phase helped ensure that no operational issues were encountered during the Site 8-8 deployment.

[1] A range check is used to confirm that a measurement is within a realistic range of concentrations. A stuck value check is used to detect when a sensor has stopped responding appropriately to changes in concentrations.