CERIN
Canadian Emissions Reduction Innovation Network

CANADA EMISSIONS REDUCTION INNOVATION NETWORK (CERIN) PUBLIC REPORT

1. PROJECT INFORMATION:

Project Title:	Quantification of Transient Methane Venting through Fixed Roof Liquid Storage tanks
Emissions Reduction Scope/Description:	
Applicant (Organization):	Carleton University Energy & Emissions Research Lab.
Project Completion Date:	March 31, 2023

2. EXECUTIVE SUMMARY:

Uncontrolled oil production storage tanks are important but poorly understood sources of methane emissions in the upstream oil and gas sector. This study reports and analyzes directly-measured, temporally-varying, methane emission rates, total gas vent rates, and vent gas methane fractions from storage tanks at eight active upstream oil production sites in Alberta, Canada. Using a built-for-purpose optical mass flux meter (VentX) supplemented by an ultrasonic flow meter and QOGI camera where possible, mean vent rates (whole gas) among tanks in the study ranged from 37–598 m^3/d; however, at some individual tanks, instantaneous flow rates could vary significantly from zero to over 4,000 m^3/d for minutes at a time, while unsteady methane volume fractions varied by up to 41% absolute. Root cause analysis revealed the limits of estimating vented emissions from oil production volumes using an assumed gas oil ratio (GOR), especially in cases where produced gas from wells fully or partially bypasses separators. Analysis of the acquired data also demonstrated how 1-hour duration vent measurements recommended in some regulations are insufficient to reliably estimate emissions from unsteady tanks. These two factors are the likely reason for significantly underreported vent rates in the present sample and are thought to be a key cause of the mis-measurement / underestimation of tank venting that has driven persistent gaps between bottom-up inventories and top-down measurements. Finally, detailed statistical analyses were completed to suggest minimum sampling durations and instrumentation requirements for direct measurements of tanks, and minimum sample sizes for discrete ("snapshot") surveys of both individual tanks and multi-tank surveys under different scenarios. Results show that caution is warranted when interpreting snapshot measurements of individual tanks, but aggregate emissions of multiple tanks should be accurately measurable with readily achievable sample sizes. These

results are expected to be especially valuable to ongoing efforts seeking to develop robust protocols for gas certification and measurement, reporting, and verification (MRV) of methane emissions in the oil and gas sector.

3. KEY WORDS

Storage tanks, methane, venting, unsteady venting, time-resolved measurements, sampling guidelines, measurement guidelines, statistical analysis

4. APPLICANT INFORMATION:

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6. PROJECT PARTNERS

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A. INTRODUCTION

Sector Introduction:

The oil and gas sector is a dominant source of methane emissions in many parts of the world and a key focus of near-term mitigation efforts. Moreover, recent field studies have consistently observed much higher methane emissions than suggested in official national inventories across multiple jurisdictions including the United States, Canada, and Mexico. One specific oil and gas sector source – production storage tanks – has been suggested as a key contributor to these discrepancies while identifying an area with potentially significant mitigation potential. Aerial measurements combined with on-site investigations in British Columbia[1,2] recently determined that both controlled and uncontrolled storage tanks were a significant contributor to oil and gas sector methane emissions in this province despite regulations mandating three times per year leak detection and repair (LDAR) surveys. However, in general storage tank venting remains poorly understood, with most studies relying on qualitative observations rather than quantitative measurements[3–6]. In particular, there is a dearth of continuous measurement data for tanks, which is a further gap considering studies highlighting potential uncertainties in relying on discrete (snapshot) measurements when quantifying intermittent sources[7–11].

Project Specific Information:

The objectives of this study were to: (i) complete, direct, on-site, time-resolved measurements of unsteady methane and total gas (whole gas) venting from uncontrolled oil storage tanks at upstream production sites; (ii) to investigate and better understand the characteristics and root causes of storage tank venting with a specific focus on their variability and intermittency; and (iii) to complete statistical analysis to glean insights into measurement and sampling requirements to improve the accuracy of tank emissions estimates under different scenarios. Results of this work provide insight into the drivers of emissions, the limits of current estimation approaches based on gas-oil ratios (GOR), and the adequacy of 1-hour measurement guidelines in some current regulations. In addition, results of the sample set of tanks are used to provide guidance on frequency response requirements for instrumentation used in tank measurements, on interpreting data from discrete measurements of individual tanks, and on conducting broader surveys of multiple tanks.

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B. METHODOLOGY

Study Area

On-site, field measurements of methane venting from eight liquid storage tanks were conducted over two separate campaigns in a region near Sundre and Rocky Mountain House, AB: the first four from September 28th to October 8th, 2021, and second four from November 3rd to 12th, 2021. In collaboration with producers operating in these regions, viable field measurement sites were identified by the field team as preferentially having a single uncontrolled production storage tank that was thought to be venting, with a well pad layout conducive to accessing the tank. Importantly, the tanks were preferentially chosen because they were known to be uncontrolled and venting, pursuant to the main goals of understanding the character of tank emissions, root causes, and potential implications for current measurement and estimation approaches. The candidate tanks were identified via a combination of operator knowledge, observations from the field team, and results of past aerial methane surveys in these regions. These sites were a mix of single and multi-well oil batteries, all using conventional production methods. Seven out of eight sites operated with beam pumps (commonly called pump jacks), while one site with significant gas co-production used a plunger lift system. These various encountered site configurations, each with an uncontrolled production tank, are found across oil producing regions of both Alberta and Saskatchewan, however the relative frequency of each is not publicly known. All sites were actively producing during this study period, although one well’s pump was turned off for maintenance midway through measurements as elaborated below. Total measurement time at each site varied from 4.2 h to 68.8 h. While the present sample size is small and further on-site measurement studies building upon the approaches and analyses presented in this paper should absolutely be pursued, to our knowledge the presented results are the only source of high-fidelity temporal methane emissions data for uncontrolled storage tanks available in the literature to inform improved regulations and guide measurement requirements for future studies.

Measurement Methodology

Time-resolved methane and total gas (whole gas) emission rates were measured by directly connecting to the vent outlet on each site's uncontrolled oil production storage tank using a VentX methane flux meter. This instrument uses wavelength modulation spectroscopy with second harmonic detection targeting methane absorption at 1659 nm to simultaneously and non-intrusively measure both total vent flow rate (via Doppler shift) and methane volume fraction (via selective absorption) at up to 2 Hz with a methane mass flow rate precision of ±0.40 kg/h at 95% confidence.[12] Due to the intermittent nature of tank venting and mixing of ambient air into the tank's vapour space, the ability to continuously monitor methane content in the vented vapours is critical for accurate methane emission rate quantification. The VentX meter was connected to the tank's atmospheric vent, either directly on the tank top or at ground level using a 9 m length of 100-mm ID flexible duct. The latter method was preferred for simpler access to instrumentation, ease of collecting extractive samples, and improved safety by minimizing work performed at height. The ground-level flow measurements were further supplemented with an ultrasonic flow meter (Khrone, Optisonic 7300 C/i-Ex) at three of the four sites (space constraints precluded also installing it on the tank top). As further discussed below, at the fourth site back pressure concerns during periodic spikes of high venting precluded use of the ultrasonic meter. This study shared resources, such as an articulated lift, with an independent industry-led study using turbine meters to measure the same storage tank vents.

A custom-instrumented thief hatch was installed when possible/permitted in place of the tank's original thief hatch to ensure an adequate seal. Consistent with these being uncontrolled tanks with open gooseneck vents, the thief hatches at most sites either had failed gaskets or did not close properly, with most left open. Failed gaskets were replaced at sites where the custom thief hatch could not be installed. All tanks in the study also featured a small hole, ~1–2" in diameter, to allow for the operation of a level float. These holes were sealed to the best of the field team's ability by stuffing them with a rag or with tape. A handheld OGI camera (FLIR, GFx320) was used at all sites to visibly inspect the entire tank to ensure that vent gas primarily flowed through the gooseneck vent and any secondary leaks or emission points were minimized.

The custom thief hatch was instrumented with a radar level sensor to measure tank fill level and a gauge pressure sensor. At some sites, a position sensor was also installed to log any potential openings of either the vacuum or pressure plate within the thief hatch, as well as an RTD to record the head space temperature inside the tank. All instruments on the thief hatch system were intrinsically safe and protected by appropriate isolation barriers to permit deployment in flammable gas environments. In addition, parallel attempts were made to measure venting rates using a QL320 quantitative optical gas imaging (QOGI) system consisting of the FLIR GFx320 camera (f=23 mm lens) combined with a QL320 tablet. All QOGI measurements were made using a response factor for pure methane (0.297) in the QL320 software (v. 1.4.1) to reflect an assumption that would be made during a QOGI survey where gas composition was unknown. At six of the eight sites extractive gas samples were taken using a hand pump for gas chromatography (GC) analysis by a third-party laboratory. These GC results confirmed the key capability of the VentX in tracking potentially variable methane volume fraction of the emitted gas for accurate methane emission quantification.

C. PROJECT RESULTS AND KEY LEARNINGS

As detailed in our parallel peer-reviewed journal publication[13], the results and analyses of this project support several recommendations to improve the accuracy of tank vent measurements and GHG reporting, to support robust design of emission surveys and monitoring protocols, and ultimately to enable more efficient regulations and operational decisions to reduce methane emissions from production storage tanks. First, the use of gas in solution (GIS) measurements to estimate vented gas volumes should be limited to wells operating with a separator, where it can be reasonably assumed that the vented gas is driven by flashing from the liquid delivered to the tank. Venting estimates for wells producing gas and oil directly to their storage tank should instead be measurement-based; detailed analysis demonstrates how vent volumes may not always be well-correlated with produced oil volumes, suggesting that some GOR-based estimates can be similarly problematic. While current regulations in Alberta Direct 60 already indicate that the use of a GOR should be limited to cases where "gas volume estimates will vary in conjunction with oil volumes", no guidance is provided on how to distinguish between the two scenarios. Selective direct continuous or time-averaged measurements can provide this necessary information with the parallel benefit of enabling accurate GOR or measurement-based estimates where appropriate.

Second, when making direct measurements of tank venting, a detailed analysis of minimum sampling durations using the collected temporal data suggests that the current Alberta-recommended minimum measurement duration should be increased from 1 hour to 24 hours (consistent with the duration of GOR measurements in current regulations in Alberta and Utah [14,15] and the required measurement duration for storage tank emissions in the state of Texas [16]), to ensure $\lesssim$10% measurement precision can be expected at least 95% of the time. Alternatively, if the employed direct measurement technique provides similar time-resolved data to that presented here, then starting from an initial minimum sample duration of 1-hour, concurrent statistical analysis of the real-time measured data could be used to determine convergence within a target level of precision (i.e., stopping time) in conjunction with common-sense consideration of any relevant site operating characteristics such as the frequency of plunger lift actuations. This latter approach (when feasible) would ensure that a measurement will be accurate considering the specific characteristics of the tank being measured.

Third, meters used to measure vented emissions from storage tanks should be capable of responding to the intermittent venting spikes as seen from certain storage tanks or risk underestimating the average emission rate. The shortest duration spikes observed in this study had an average total duration of ~26 s. As further supported by spectral analysis of the temporal vent data recorded in this study, this suggests that a suitable meter for this application should have a frequency response of at least 0.1 Hz and in the case of non-totalizing meters, a recording resolution of at least 0.5 Hz (i.e., 2-s integration time).

Fourth, from an emissions perspective, for wells that are already conserving produced gas, venting can be reduced by minimizing the separator operating pressure where possible and hence the amount of gas remaining in solution with the oil that subsequently gets released in the atmospheric pressure tank. Use of dual stage separators or vapour recovery towers, can further reduce gas emitted from tanks with the added benefit of enhanced gas conservation. Correspondingly, noting the much lower venting rates from tanks operating with versus without separators in the present study, the latter scenario should be avoided wherever possible. Assuming that in these cases the economic feasibility of gas conservation has already been explored and ruled out consistent with current Alberta regulations, the present data suggest that significant mitigation potential could still exist via use of combustors to destroy methane.

Finally, future studies using discrete sampling approaches to measure tanks via aerial surveys, vehicle based techniques, or other remote approaches should be cognizant of the influence of tank vent rate variability and intermittency on required sample sizes. In the extremes from the present data, individual tanks could require between just one and more than one thousand discrete measurements to accurately resolve the mean. Statistical analysis is thus especially critical when interpreting measurements for individual tanks. However, more encouragingly, our analyses demonstrate that in larger surveys of multiple tanks/facilities, precision in the total emission rate of better than 5% should easily be achieved for sample sets larger than ~100 (although depending on the chosen technology, quantification uncertainty and detection sensitivity can still be additional important factors). This result is especially important for developing protocols for measurement, monitoring, and verification (MRV) under programs such as under OGMP 2.0. Adoption of each of these recommendations should significantly improve the accuracy of vent reporting from tanks, enable identification of key mitigation opportunities, and ultimately help close a key and persistent gap between bottom-up inventories and measurements.

D. PROJECT AND TECHNOLOGY KEY PERFORMANCE INDICATORS

Organization:	Current Study	Commercial Deployment Projection
Project cash and in-kind cost ($)	140,500	N/A
Technology Readiness Level (Start / End):	TRL7	TRL8
GHG Emissions Reduction (kt CH4/yr):	N/A	N/A
Estimated GHG abatement cost ($/kt CH4)	N/A	N/A
Jobs created or maintained:	1	N/A

E. RECOMMENDATIONS AND NEXT STEPS

The project results and key learnings described previously in this report mark a significant leap in understanding of tank venting. Most notably, results have enabled development of evidence-based measurement guidelines and sampling recommendations to improve quantification of tanks emissions, helping to close a persistent gap in current bottom-up emissions inventories and enabling informed mitigation decisions and regulatory policy.

However, the project would benefit greatly from further on-site measurements of tanks to expand the current data set. A larger sample would not only strengthen the recommendations made by this project but also allow for more precise analysis of the distribution of intermittently venting tanks and their impact on snapshot measurements. Our team remains ready to perform further field measurements anytime during summer and fall of 2023 if operators willing to provide the necessary site access can be identified.

This project has also demonstrated the VentX optical meter as a uniquely valuable tool for measuring high-volume, unsteady vent sources where both flow rate and methane fraction can be simultaneously varying. However, the field measurements also revealed several deployment challenges including a sealing issue of optical components at low temperatures, optical window fouling due to condensation, and simplicity of cable management. A redeveloped flow cell has already been produced to address the sealing issue, and an updated opto-electrical system has been integrated into an explosion-proof enclosure to make a single compact unit. This newly integrated unit no longer requires the 30 m of fibers and signal cables used by the previous iteration which greatly simplifies setup in the field for rapid deployment in temporary on-site measurement scenarios. With these improvements, we believe the VentX sensor could serve as a reference standard for studies of tank venting, casing gas venting at CHOPS sites, or other similar sources. Although this project was focused on improving understanding of tank venting and creating evidence-based recommendations for improved quantification rather than development and commercialization of the VentX meter, there is a potential commercialization path recognizing the potential of the instrument as a reference standard. In particular, the VentX meters could be a valuable tool for use by service providers performing contracted GOR, CHOPS engine shed, or tank measurements as part of periodic measurement and reporting requirements or ongoing identification of mitigation opportunities. Especially for vent mitigation applications, the ability to collect simultaneous time-resolved methane fraction and vent rate data would be particularly valuable to support subsequent engineering decisions to design and correctly size mitigation solutions (e.g., combustors, compressors, vapour recovery units, etc.) greatly improving mitigation efficiency and reducing deployment risk.