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Long Term, Periodic Aerial Surveys Cost Effectively Mitigate Methane Emissions

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Abstract

Results of multiple years of periodic aerial methane surveys over Pioneer Natural Resources' operations footprint, comprising approximately 680,000 acres in the Permian basin, are presented, including impacts to operational efficiency, cost, and methane emissions mitigation. Aerial methane detection was performed using a light-aircraft mounted, integrated methane imaging spectrometer. Geo-referenced methane emissions data combined with real-time geo-referenced optical imagery provided accurate methane localization and source attribution. Ground inspection teams used optical gas imaging technology to validate the aerial results and dispatch repair teams. Externally validated leak quantification provided by the spectrometer further allowed accurate measurement of methane mitigation. Aerial methane inspections of nearly 10,000 operations sites per survey, including wells, tank batteries, and all associated equipment, are reported for multiple years of periodic surveys. The data shows a complete picture of the most significant methane emissions from the Pioneer operations footprint over consecutive years and has proven beneficialinvaluable for enhancing operational efficiency. Based on the data, Pioneer has been able to identify the areas of highest impact and focus operational resources on those improvements. Surveys identified types of emission sources that can be addressed immediately within Pioneer operations and areas where Pioneer would need to work with others to improve overall gas takeaway challenges in the Permian basin. Furthermore, Pioneer has reduced leak detection and repair (LDAR) costs significantly by reducing both driving time and ground-based inspection time. We estimate more than 2500 work hours and 1000 driving hours, were saved by each aerial survey. Between 2016 and 2018, the company's methane intensity has declined approximately 41%. Aerial survey results have allowed Pioneer to significantly reduce methane emissions while simultaneously improving safety and efficiency, reducing costs, and reducing vehicle traffic. To our knowledge, this is the first multi-year, comprehensive, aerial periodic methane survey of an entire upstream oil and gas operation's footprint. We're now able to report on the benefits of this paradigm shift away from conventional LDAR surveys. Although the challenge of reducing methane emissions can be daunting, the results from aerial monitoring show that with a technology and data-driven approach,

operators can significantly reduce emissions while simultaneously reducing costs and improving operational efficiency.

Introduction

Detecting and reducing fugitive methane emissions remains a time-intensive, costly endeavor for the oil and gas industry. Currently, leak detection and repair (LDAR) surveys are required periodically to inspect equipment and infrastructure for potential issues (Tyner & Johnson, 2018). Traditional LDAR, while effective for identifying the source of an emission, generally requires personnel traveling to each site to inspect equipment in situ, which can be costly in terms of labor and travel time (Ravikumar et al, 2018). Moreover, prioritizing inspections by a set schedule and available manpower, rather than the known presence of an ongoing methane emission event, creates a situation where fugitive emissions can occur undetected for a long period of time between site visits. This can be especially problematic for a large emission, as the distribution of emissions tends to be skewed, with only a small number of sites responsible for the majority of the volume of methane emitted (LaCount et al., 2015; Brandt et al., 2016; Duren et al., 2019).

An alternative approach is Smart LDAR, whereby large, fugitive emissions are found via some form of cost-effective yet frequent monitoring (Epperson et al., 2007). This reduces overall costs and increases the efficiency and speed with which fugitive emissions can be repaired. A similar implementation is Guided LDAR, when a large area is quickly surveyed for emissions and ground crews dispatched to detection sites. While some approaches use ground vehicles to assess a large area, an airborne or spaceborne approach allows for a more comprehensive survey of a large footprint (Kort et al., 2014; Hopkins et al., 2016; Lyons et al., 2016). Nadir-view emissions monitoring have historically been challenging due to the ephemeral nature of some fugitive emissions, and the need to identify a precise point source of the emission while also discriminating between those due to malfunction (which can be repaired) versus proper function (such as relieving pipeline or tank pressure). Additionally, such surveys require technology that can remotely detect methane emissions across a variety of meteorological and illumination conditions, and thus represent the cutting edge of current remote sensing methodologies. In this paper, we present two years of results from an ongoing multi-year initiative consisting of periodic, large-scale aerial methane surveys paired with ground crew inspection, validation, and prioritized repair.

Description and Application of Equipment and Processes

Annual aerial surveys of Pioneer Natural Resources' complete operations footprint in the Permian Basin (~680,000 acres) were conducted in 2018 and 2019 (a 2020 survey is ongoing at the time of publication). The 2019 data was part of a larger survey for methane emissions across 11,000 mi^2 of the Permian Basin, conducted by Kairos Aerospace. The 2018 Pioneer survey was completed in 38 flight days over a period of 19 weeks, while the 2019 survey required 24 flight days over a period of 11 weeks. Approximately 100 – 150 mi^2 were imaged each flight day, producing between 20-70 GB of imagery daily. Surveys were conducted aboard a light aircraft platform (Cessna 172 or 182) flown at an altitude of approximately 3000 ft above ground level during daylight hours. Imaging did not occur on certain days due to poor weather, dangerous flight conditions, or crew requirements. Overall, the survey investigated a total of 9,218 sites ("assets") in 2018, and 9,574 assets in 2019. Assets consisted of multiple infrastructure types, including well pads, tank batteries, and salt water disposal ponds, among others.

The sensor payload consisted of an integrated imaging spectrometer, optical camera, inertial motion unit, and GPS (Sherwin et al., 2020). The integrated sensor suite was affixed to the plane wing strut using a customized clamp and angled directly at the ground to collect nadir-view imagery of the survey area. On-board telemetry was used to ensure data quality. The imaging spectrometer measured reflected, near-infrared solar energy in order to detect known methane absorption features. Data was collected over a swath-width of 0.5 miles and a pixel resolution of approximately 10 feet. The optical camera allowed for visual identification of the asset most likely to be the emission source as well as real-time on-the-ground information about the site. Optical images are stitched together to create a composite image of the entire flight area with a spatial resolution of ~1 foot. The location provided by the GPS allowed for precise georeferencing of imagery data, while also generating accurate coordinates for ground crew deployment.

The post data-collection processing pipeline for identifying methane emissions sites consisted of methane retrieval, georeferencing, checking for image quality, automated plume tagging, and analyst verification. Detected plumes were visually confirmed and associated with likely source assets. This information was then compiled into a report that included date, time, location, size of emission detection, and an image of the plume overlaid on the optical imagery of the asset, an example image as shown in Fig. 1. The report was relayed to ground crews who were deployed to each asset to verify the presence of a methane emission, using optical gas imaging technology, and dispatch repair teams if necessary. Ground crews reported a verification of the detection (observed or not observed), the cause of the emission, and if repair was warranted/conducted. We then conducted further analysis to better understand the aggregate nature of emission causes and long-term results of repair work.

Figure 1—Example of plume detection. A methane plume image, colored by methane concentration from blue (low) to white (high), generated by the imaging spectrometer, is seen to emanate from a well pad that was imaged using the high-resolution optical camera.

Presentation of Data and Results

Detections by asset and cause

Of the nearly 10,000 assets surveyed, a total of 146 assets in the Pioneer study area were reported in 2018 as potential sources of methane emissions using the aerial survey method, 77% of which were confirmed by ground crews. The following year, the number of reported potential emissions declined to 121, of which 96% were confirmed. Detected emissions that could be attributed to a specific cause by ground crews fell into one of two categories. The first was emissions related to midstream downtime or other capacity challenges, where the amount of methane being forced into the gathering line exceeded the capacity of the line to safely convey it. In 2018 this represented 51% of detections, declining to 41% in 2019. In these cases, the detection indicated that equipment was working as designed to lower pipeline pressure by venting excess gas. The second category of emissions sources were those determined to be repairable as shown in Fig. 2. The repairable causes of fugitive emissions included (but were not limited to) malfunctioning clamps, flares, flow lines, open top tanks, pressure regulators, thief hatches, and tubing. In 2018 and 2019, open or damaged thief hatches were the primary cause of repairable emissions, representing 28% and 27% of detections, respectively. Valves were another commonly detected cause—back pressure valves, dump valves, and enardo valves in combination were the source of 34% and 38% of repairable detections in 2018 and 2019, respectively.

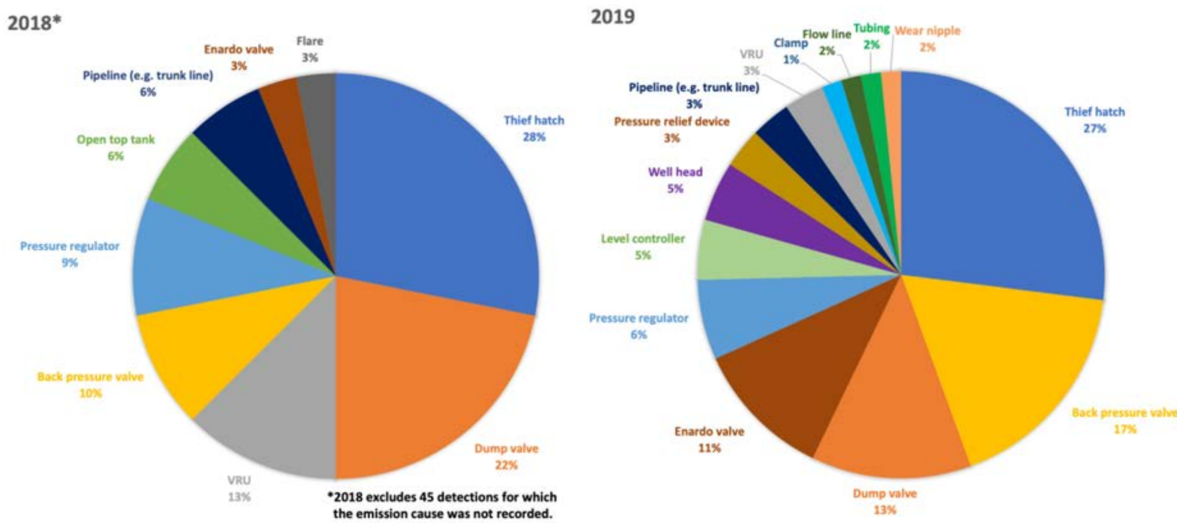

Figure 2—Percent of detections associated with different repairable causes for 2018 and 2019. This data excludes detected emissions associated with midstream downtime or other capacity challenges.

Emission volume by cause

While the 2018 survey data could identify instances and relative sizes of methane emissions, by the 2019 survey the process had been improved to allow for quantification of the size of a detected emission (Sherwin et al., 2020). Emission volume was extracted from survey imagery, calculated as a rate of emission using publicly-available wind speeds (Dark Sky, www.darksky.net), then quantified as a percent of overall emissions. In total, 41.1% of emissions in 2019 were attributed to limited takeaway capacity. Of repairable causes, thief hatches were the cause of 32.6% of emissions, followed by back pressure valves (12.5%), enardo valves (12%), pressure regulators (9.4%), and dump valves (8.1%) as shown in Fig. 3. These 5 categories collectively represented about 75% of the total volume of methane emissions, with the remaining quarter of volume emitting from level controllers, tubing, pipeline damage, vapor recovery units, well heads, and clamps.

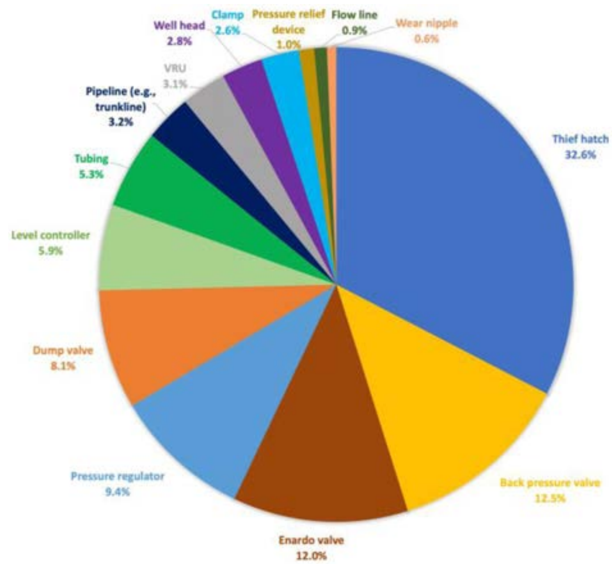

Figure 3—Volume of repairable emissions by cause, quantified in the 2019 survey. This excludes volume produced by midstream downtime or other capacity challenges.

Repairs and Improvements

Of the nearly 10,000 assets surveyed in both 2018 and 2019, very few required repeat repair from year to year. Only 7 assets were found to be experiencing emissions due to infrastructure capacity limits in both years of the survey, and no assets were found to have the same repairable cause in both 2018 and 2019. A total of 21 assets were found to be emitting methane in both years, however the sources of the emissions were different (*e.g.*, a site with emissions from a dump valve in 2018 was found to have emissions from a back-pressure valve in 2019).

Furthermore, given the pinpointed location information for the areas experiencing infrastructure capacity limits, Pioneer was able to work with midstream partners to further reduce emissions. While there are no repairs that can eliminate emissions due to takeaway capacity limitations, load balancing and pipeline capacity planning do allow for further emissions reductions.

LDAR-equivalent inspection time

We used a conservative, hourly-based estimate of repair-times to calculate the amount of administrative, ground inspection, and driving times that would be required to conduct an equivalent ground survey (Table 1). For each work hour calculated, we assumed an 80%/20% split between ground inspection hours and administration hours, and for every 2.3 work hours we assumed 1 hour of driving. We focused on assets that included tank batteries, wells, and battery-well combinations, totaling 9,574 assets imaged in 2019. We estimated that the aerial survey replaced the equivalent of approximately 3,100 working hours, including over 2,500 hours of ground inspection time. Additionally, over 1,000 hours of driving, necessary for transporting inspection crews to a site, were replaced by the aerial survey.

Table 1—Estimation of LDAR-equivalent work accomplished in the 2019 aerial survey.

Asset Type	Assumed repair time per asset (h)	LDAR Ground Inspection Hours	LDAR Admin. Hours	Total LDAR Work Hours	Total LDAR Driving Hours
Tank Battery	1	223.8	895.2	1119.0	389.2
Well	0.1667	249.6	998.3	1247.9	434.1
Well & Tank Battery	1.1667	148.4	593.6	742.0	258.1
Other	0.1667	10.4	41.6	52.0	18.1
Total	632.2	2528.8	3160.9	1099.5	

Conclusions

Impact of airborne methane survey

The aerial surveys proved to be an efficient method for detecting methane emissions across a large area, covering 100 – 150 mi^2 of the study area each day and replacing considerable effort that would have been required to assess all assets on the ground. This included over 3,100 hours of labor as well as over 1,000 hours of driving necessary to survey all field assets. Combined, this is the equivalent of 513 FTE days which is considerably more than the 38 days and 24 days required to complete the aerial surveys in 2018 and 2019, respectively. In addition to time savings, accomplishing a full-field survey remotely had considerable safety benefits. Significantly reduced driving hours reduced the opportunities for motor vehicle break-downs and accidents. Furthermore, directing crews to actively emitting sites (rather than requiring site visits to assess every asset in the field) reduced overall exposure of personnel to on-site hazards.

Rapid generation of a complete, full-footprint survey led to additional operational benefits. Primarily, the efficiency of ground crew deployment was significantly improved. Ground crews could focus the majority of their efforts on targeted repair of active fugitive emissions sites, rather than splitting it between surveying for potential issues and repairing identified emissions. A secondary benefit of a full-footprint survey was that it increased the confidence of operators that no large emissions were present across the operational area in the period following the survey. Such confidence is difficult to achieve with ground-based LDAR surveys, because of the staggered schedule of rolling inspections combined with the potential for a site to be emitting undetected for the duration of the time period between inspections.

Over the period of this study, the speed and accuracy of the aerial survey detections noticeably improved. From 2018 to 2019, the total time period required to survey all assets across the survey area (including days where imaging did not occur) declined by 42%, while the number of assets surveyed increased by 5%. The ability to accurately attribute a point source for an observed emission proved critical for dispatching crews to the correct asset. In addition to covering more ground in less time, plume detection accuracy improved year over year, from a ground verification rate of 77% to a rate of 96%. Furthermore, in 2019 the technique was further refined to allow for precise quantification of detected methane emissions. Assessment and further prioritization of high-impact repairs based on measured quantity of methane emissions maximized the overall reduction in emissions from the survey area.

Operational considerations

Needed repairs identified by the survey proved to be robust—no assets were observed to be emitting methane due to the same repairable cause in both years. This suggests that large fugitive emissions, once they are detected and properly repaired, may not reappear in the short to medium-term. Interestingly, the overall percentage of assets with detectible emissions remained constant at 1.2%, even as the overall number of assets surveyed increased. This indicates that new maintenance issues may tend to arise at a relatively constant rate. This finding, similar to those of others, supports the argument for periodic monitoring of infrastructure for new point source emissions (Ravikumar et al., 2020).

This study also highlighted areas where operational capacity could be expanded. For example, identifying and addressing emissions related to midstream downtime or infrastructure capacity remains a significant challenge across the industry. The aerial surveys were able to identify assets emitting methane due to capacity limitations and showed that Pioneer had an overall 10% reduction in the number of methane emissions due to takeaway capacity limitations year over year. Repeat aerial surveys can further help to pinpoint areas for improvement. For example, 7 locations were observed to be emitting methane due to exceeded infrastructure capacity limits in both 2018 and 2019, representing primary candidates for targeted future improvements.

Pioneer's 2020 annual aerial methane survey is underway. Preliminary data analysis shows that efficiency and methane reduction gains continue to improve year over year.

Concluding Remarks

Today, standard methodologies for monitoring methane emissions are a logistical challenge that do not always allow for prioritization of the largest, most critical emissions. In this study, we have demonstrated over the entire Pioneer Natural Resources' operations footprint the ability of aerial surveys to detect and quantify methane emissions, identify emissions sources, direct targeted repair, and monitor long-term repair efficacy. As this technology continues to develop, the benefits of transitioning to aerial surveys for consistent and cost-efficient monitoring will continue to grow as well.

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