BOULDER COUNTY PUBLIC HEALTH

Opportunity for a Healthy Life

Leak Inspection and Repair at Oil and Gas Well Sites

Boulder County Public Health Voluntary Inspection Program Results 2014–2018

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Abstract
Public concern has grown in Boulder County regarding the health and safety implications of emissions from oil and gas activity. Boulder County Public Health implemented a voluntary oil and gas inspection program in order to respond to this concern. The program resulted in 1022 inspections at 147 production sites across the county from 2014 through 2018. Cumulatively, gas leaks were detected at 86% of inspected sites, with the percentage each year ranging from 38% to 49%. 64% of the sites with leaks experienced them in multiple calendar years. Most leaks were detected at storage tanks, separators, and wellheads. Across equipment categories, many leaks involved malfunctioning pneumatic controllers. Once reported to operators by the Boulder County Public Health oil and gas inspector, 90% of the leaks were reported resolved by the operator or inspector, and 64% of the leaks were reported resolved within five days. Given that the great majority of the observed and resolved leaks were detected with the aid of an infrared (IR) camera, increasing the frequency of required IR inspections is necessary to improve leak detection and repair (LDAR) and to reduce emissions from oil and gas production sites on the Front Range.

This 2019 version of the report is an update from the 2014-2016 version to include data from 2017 and 2018.

Introduction
In recent years, oil and gas development in Colorado has increased sharply due to advances in drilling and well stimulation technologies, including horizontal drilling and hydraulic fracturing (Figure 1a). While production volumes have generally decreased in Boulder County since 2008 (Figure 1b), oil and gas have been produced in the county for more than a century.[1] Here and in neighboring counties, oil and gas development increasingly takes place near residential areas, which has prompted public, scientific, and local governmental concern about emissions from oil and gas facilities from a health and safety perspective.[2, 3, 4] Concurrently, oil and gas emissions have come under scrutiny as an exacerbating factor in Front Range ozone nonattainment status. Volatile organic compounds (VOCs) and nitrogen oxides (NO_X) released from oil and gas facilities are ozone precursors.[5] Oil and gas development produces approximately 47% of the 2017 VOC emissions inventory and 23% of the 2017

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[1] Pettem, Silvia. 2017. "Boulder County History: A Century Ago, Oil Industry Excited the Locals." *Daily Camera*, July 2. http://www.dailycamera.com/news/ci_31107413/boulder-county-history-century-ago-oil-industry-excited.
[2] Adgate, John L., Bernard D. Goldstein, and Lisa M. McKenzie. 2014. "Potential Public Health Hazards, Exposures and Health Effects from Unconventional Natural Gas Development." *Environmental Science & Technology* 48 (15): 8307–20. doi:10.1021/es404621d.
[3] McKenzie, Lisa M., William B. Allshouse, Tim E. Byers, Edward J. Bedrick, Berrin Serdar, and John L. Adgate. 2017. "Childhood Hematologic Cancer and Residential Proximity to Oil and Gas Development." Edited by Jaymie Meliker. *PLOS ONE* 12 (2): e0170423. doi:10.1371/journal.pone.0170423.
[4] *Ambient Non-Methane Hydrocarbon Levels Along Colorado's Northern Front Range: Acute and Chronic Health Risks*, Environ. Sci. Technol, March 27, 2018. Lisa M. McKenzie, Benjamin D. Blair, John Hughes, William B. Allshouse, Nicola Blake, Detlev Helmig, Pam Milmoe, Hannah Halliday, Donald R. Blake, and John L. Adgate.
[5] Regional Air Quality Council. 2016. "Moderate Area Ozone SIP for the Denver Metro and North Front Range Nonattainment Area: State Implementation Plan for the 2008 8-Hour Ozone National Ambient Air Quality Standard."

NO_X inventory along the Denver Front Range,[6] and measured VOC concentrations across northeastern Colorado indicate that oil and gas operations are a significant source of ozone precursors in the region.[7] A study using data collected with the Front Range Air Pollution and Photochemistry Éxperiment (FRAPPÉ) during the summer of 2014 showed that oil and gas sources along the Front Range contributed about 20 parts per billion by volume (ppbv) of additional ozone on high ozone event days in Rocky Mountain National Park.[8] For comparison, the 2015 8-hour ozone National Ambient Air Quality Standard (NAAQS) is 70 parts per billion, meaning that local oil and gas sources are a significant contributor to ozone in this area. Furthermore, the oil and gas industry is the largest emitter of methane – a potent greenhouse gas that contributes to climate change – in the United States.[9]

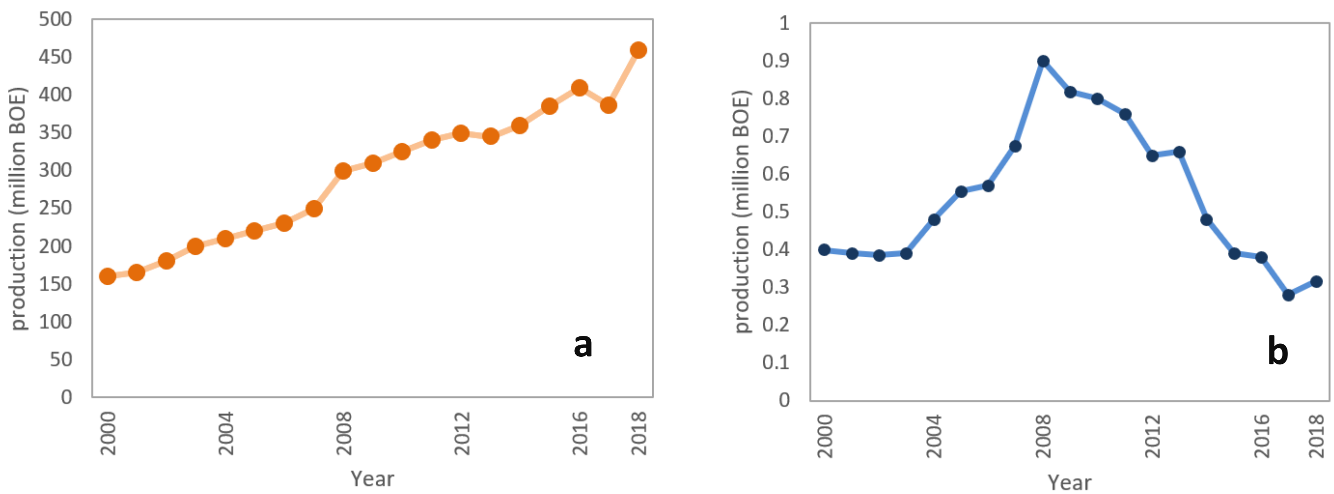

Figure 1. Annual oil and natural gas production in (a) the state of Colorado and (b) Boulder County from 2000 to 2016.[10] Production volumes are expressed in millions of barrels of oil equivalent (BOE), where 5610 ft^3 of natural gas is equivalent to 1 bbl of oil.

Previous research suggests that particular processes and pieces of equipment at oil and gas facilities are implicated in hydrocarbon emissions. Pétron et al. reported that air masses above the Denver-Julesburg Basin in Colorado are likely impacted by venting of raw natural gas and flash emissions from

[6] Garry Kaufman, Colorado Air Pollution Control Division, July 29, 2019, presentation, SB19-181 Stakeholder Meeting: Proposed Rulemaking Before the Air Quality Control Commission.

[7] Gilman, J. B., B. M. Lerner, W. C. Kuster, and J. A. de Gouw. 2013. "Source Signature of Volatile Organic Compounds from Oil and Natural Gas Operations in Northeastern Colorado." *Environmental Science & Technology* 47 (3): 1297–1305. doi:10.1021/es304119a.

[8] Benedict, K. B., Zhou, Y., Sive, B. C., Prenni, A. J., Gebhart, K. A., Fischer, E. V., Evanoski-Cole, A., Sullivan, A. P., Callahan, S., Schichtel, B. A., Mao, H., Zhou, Y., and Collett Jr., J. L.: Volatile organic compounds and ozone in Rocky Mountain National Park during FRAPPÉ, Atmos. Chem. Phys., 19, 499-521, https://doi.org/10.5194/acp-19-499-2019, 2019.

[9] U.S. Environmental Protection Agency. 2019. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017." ES-7. EPA 430-R-19-001. https://www.epa.gov/sites/production/files/2019-04/documents/us-ghg-inventory-2019-main-text.pdf.

[10] Colorado Oil and Gas Conservation Commission. COGCC Reports Portal: Monthly Production Reports.

condensate storage tanks.[11] At the Platteville Atmospheric Observatory in northeastern Colorado, Halliday et al. detected elevated concentrations of benzene and identified emissions from condensate tanks as one probable source.[12] Colorado Department of Public Health and Environment's (CDPHE) Air Pollution Control Division (APCD) reported that 78% of gas leaks and venting at production facilities were from liquid hydrocarbon storage tanks.[13] An air quality study in Fort Worth, Texas, indicated that the most common sources of emissions were tank thief hatches and pneumatic valve controllers. Its authors suggested that improved inspections and maintenance of equipment could greatly reduce or eliminate preventable emissions from oil and gas facilities, especially for sites where increased emissions are attributable to equipment malfunctions.[14] Allen et al. similarly note that many high-emitting pneumatic controllers do not behave according to the manufacturer's specifications.[15]

Boulder County Public Health's voluntary inspection program was instituted in 2014 to evaluate the field conditions of active oil and gas facilities and to supplement inspections by the Colorado Oil and Gas Conservation Commission (COGCC) and APCD. Well sites are inspected by the COGCC under its risk-based inspection program. A routine COGCC inspection evaluates the condition of thief hatches, emission control devices (ECDs), and other production equipment.[16] The COGCC also requires operators to inspect valves, pipes, and fittings at regular intervals.[17] Most oil and gas production facilities in Boulder County emit between zero and six tons of VOCs per year and the operators are therefore required under Colorado's Air Quality Control Commission Regulation Number 7 to perform monthly audio, visual, and olfactory (AVO) inspections. Additionally, facilities emitting between zero and one ton of VOCs per year are required to be inspected per the Approved Instrument Monitoring Method (AIMM) requirement one time in the life of the facility under Regulation Number 7 XVII.F.4.c ,

[11] Pétron, Gabrielle, Gregory Frost, Benjamin R. Miller, Adam I. Hirsch, Stephen A. Montzka, Anna Karion, Michael Trainer, et al. 2012. "Hydrocarbon Emissions Characterization in the Colorado Front Range: A Pilot Study." *Journal of Geophysical Research: Atmospheres* 117 (D4): n/a-n/a. doi:10.1029/2011JD016360.

[12] Halliday, Hannah S., Anne M. Thompson, Armin Wisthaler, Donald R. Blake, Rebecca S. Hornbrook, Tomas Mikoviny, Markus Müller, Philipp Eichler, Eric C. Apel, and Alan J. Hills. 2016. "Atmospheric Benzene Observations from Oil and Gas Production in the Denver-Julesburg Basin in July and August 2014." *Journal of Geophysical Research: Atmospheres* 121 (18): 11,055-11,074. doi:10.1002/2016JD025327.

[13] Colorado Department of Public Health and Environment Air Pollution Control Division. March 2019. "Colorado Optical Gas Imaging Infrared Camera Pilot Project: Updated Assessment." https://drive.google.com/file/d/10aSgd3RAv5AeDJ7gh0Zjm2jyvZbT9nJ1/view, at 5.

[14] Eastern Research Group, Inc., and Sage Environmental Consulting, LP. 2011. "City of Fort Worth Natural Gas Air Quality Study."

[15] Allen, David T., Adam P. Pacsi, David W. Sullivan, Daniel Zavala-Araiza, Matthew Harrison, Kindal Keen, Matthew P. Fraser, A. Daniel Hill, Robert F. Sawyer, and John H. Seinfeld. 2015. "Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Pneumatic Controllers." *Environmental Science & Technology* 49 (1): 633–40. doi:10.1021/es5040156.

[16] Colorado Oil and Gas Conservation Commission. 2014. "Risk-Based Inspections: Strategies to Address Environmental Risk Associated with Oil and Gas Operations." OGCC-2014-PROJECT #7948.
https://cogcc.state.co.us/Announcements/RiskBasedInspection/
RiskBasedInspectionStrategy.pdf.

[17] Colorado Oil and Gas Conservation Commission. 2016. 605.d. Mechanical Conditions. 600-Series Rules. http://cogcc.state.co.us/documents/reg/rules/latest/600series.pdf.

while facilities emitting between one and six tons of VOCs per year are required to be inspected per the AIMM requirement annually under Regulation Number 7 XII.L.2.[18]

In contrast to the suite of required inspections, Boulder County Public Health's inspector conducts inspections on a voluntary basis. The intention is to address community concerns regarding air quality issues related to oil and gas operations. Twelve Boulder County operators are participating in this program. *See* Appendix A.

The goal of the first year of the inspection program (2014) was to access and inventory as many sites as possible while conducting AVO and IR camera inspections. For 2015 through 2018, the focus of the program was to conduct more detailed LDAR inspections and to ascertain – through follow-up inspections and correspondence with the operators – if, how, and when gas leaks were resolved. Reports and presentations of these inspection data have been used by the Boulder County Board of County Commissioners (BOCC) in establishing local oil and gas policies.

Objectives

This analysis aims to determine the number of gaseous leaks, the source of the leaks, and the time required to resolve the leaks.

Methods

The goal of the inspection program is to visit each facility (hereafter referred to as a "site," which may contain more than one well) in Boulder County at least twice per year – one AVO visit and one visit with an IR camera. During every site visit the Boulder County Public Health oil and gas inspector (referred to hereafter as "inspector" unless otherwise indicated) completes a checklist of items that can be inspected visually (*See* Appendix B). These items are drawn from COGCC and CDPHE requirements, and the checklists are similar to those used by state inspectors. In February 2014, the inspector became certified to use an optical gas imaging camera (FLIR GF-320 thermal infrared camera) owned by the Regional Air Quality Council (RAQC) to detect gaseous leaks. This IR camera can detect emissions of methane, ethane, and VOCs from equipment at oil and gas sites.

During visits with the IR camera, the inspector follows a standard operating procedure, which can be found in Appendix C, to take safety precautions and to survey the site for leaks. The inspector first uses the camera in high sensitivity mode (HSM) to perform an initial scan of any large gas leaks from wellheads, tanks, separation equipment, emission control devices, or equipment below the ground surface (e.g., flowlines). The camera is then switched to its automatic mode to pinpoint and confirm the sources of any detected leaks. Sample images collected by the inspector can be found in Appendix D. Hydrocarbons may be emitted with varying compositions and magnitudes across different categories of equipment at oil and gas sites.[19] However, the IR cameras used in this inspection program cannot speciate the gas or quantify the rate at which it is released.

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[18] Colorado Air Quality Control Commission. *Regulation Number 7: Control of Ozone via Ozone Precursors and Control of Hydrocarbons via Oil and Gas Emissions (Emissions of Volatile Organic Compounds and Nitrogen Oxides)*. 5 CCR 1001-9.

[19] Warneke, C., F. Geiger, P. M. Edwards, W. Dube, G. Pétron, J. Kofler, A. Zahn, et al. 2014. "Volatile Organic Compound Emissions from the Oil and Natural Gas Industry in the Uintah Basin, Utah: Oil and Gas Well Pad Emissions Compared to Ambient Air Composition." *Atmospheric Chemistry and Physics* 14 (20): 10977–88. doi:10.5194/acp-14-10977-201.

After each visit, the inspector notifies the operator via email of general inspection findings and of the location of any observed leaks, including from equipment that the operator has already tagged as needing repairs. The inspector then tracks the date of the operator's response and the date of leak resolution reported by the operator. When possible, the inspector will return to the site with the IR camera to confirm that leaks have been resolved as described by the operator.

In analyzing the inspection data, the following state definition of a leak was used: "For infra-red camera and AVO monitoring...a leak is any detectable emissions not associated with normal equipment operation."[20] Therefore, the inspector's descriptions of leaks and correspondence between the county and the operator were manually reviewed to determine if detected emissions were associated with normal equipment operation. If so, the emissions were not considered a leak and were excluded from this analysis. From 2014 to 2018, the inspector notified operators of 32 releases that were later determined to be associated with normal equipment operation. These were not counted as leaks in the analysis.

For the analysis, each leak was defined as either single or recurrent. If a leak was observed from the same equipment component unchanged across consecutive inspections without documentation of repair between inspections, it was defined as a single leak. If documentation showed that a repair had been made or the leak had ceased between consecutive inspections, then the leak was defined as recurrent and counted as a new leak in the analysis.

Beginning in 2015, the inspector also evaluated whether leaks were associated with pneumatic controllers. In Regulation 7 XVIII.B.10, CDPHE defines a "pneumatic controller" as "…an instrument that is actuated using pressurized gas and used to control or monitor process parameters such as liquid level, gas level, pressure, valve position, liquid flow, gas flow and temperature."[21] Pneumatic controllers occur across a variety of equipment categories found at active oil and gas sites. In Boulder County Public Health's inspection program, leaks involving pneumatic controllers have been identified at wellheads, on separation equipment, and on ECDs.

The inspector employs a two-step procedure to aid in identifying pneumatic controllers that are not operating as intended. Per the county's standard operating procedures for IR camera inspections (*See* Appendix C), the camera is first used to identify visible emissions from any pneumatic controller(s) at the site. After making a note of these controller(s) where emissions were detected, performing a full inspection of the site with the IR camera, and completing paperwork for approximately 15 to 20 minutes, the inspector returns to the controller(s) where emissions were noted. If the inspector detects continued emissions from the controller(s) with the IR camera, the emissions are reported to the operator. At this point, the operator is responsible for determining whether the controller(s) are operating normally.

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[20] Colorado Air Quality Control Commission. *Regulation 7: Control of Ozone via Ozone Precursors and Control of Hydrocarbons via Oil and Gas Emissions*. 5 CCR 1001-9.
[21] Id.

Results

Numbers of Visits and Leaks

From 2014 through 2018, Boulder County Public Health conducted 1022 visits to 147 different oil and gas sites (about seven visits per site) (Table 1); 66% of the visits involved an IR camera inspection, while 34% involved an AVO inspection only, and 141 sites (96%) were inspected in multiple calendar years.

Table 1. Numbers of visits and leaks by inspection type and by year of Boulder County Public Health's voluntary inspection program

	2014	**2015**	**2016**	**2017**	**2018**	**Total**
Visits	**243**	**94**	**152**	**276**	**257**	**1022**
IR visits	142	74	111	148	139	614
AVO visits	101	20	41	128	118	408
Leaks	**84**	**55**	**80**	**126**	**88**	**433**
IR leaks	83	55	77	117	67	399
AVO leaks	1	3	3	9	21	34

A total of 433 leaks were detected, and 126 sites (86%) in Boulder County experienced at least one leak during the five-year period (Table 2; Figure 2). Furthermore, 81 of these 126 sites (64%) experienced leaks in multiple calendar years. For the sites at which at least one leak occurred, 48% of sites experienced one or two leaks, while 29% of sites experienced five or more leaks – averaging at least one leak per year of the inspection program, from 2014 to 2018 (Figure 3).

Table 2. Number of sites and percentage of sites experiencing leaks by year of Boulder County Public Health's voluntary inspection program

	2014	**2015**	**2016**	**2017**	**2018**	**Overall**
Sites visited	131	80	111	134	129	147
Sites with leak(s)	52	30	44	66	60	126
Sites with leak(s) as a percentage of sites visited	40%	38%	40%	49%	47%	86%

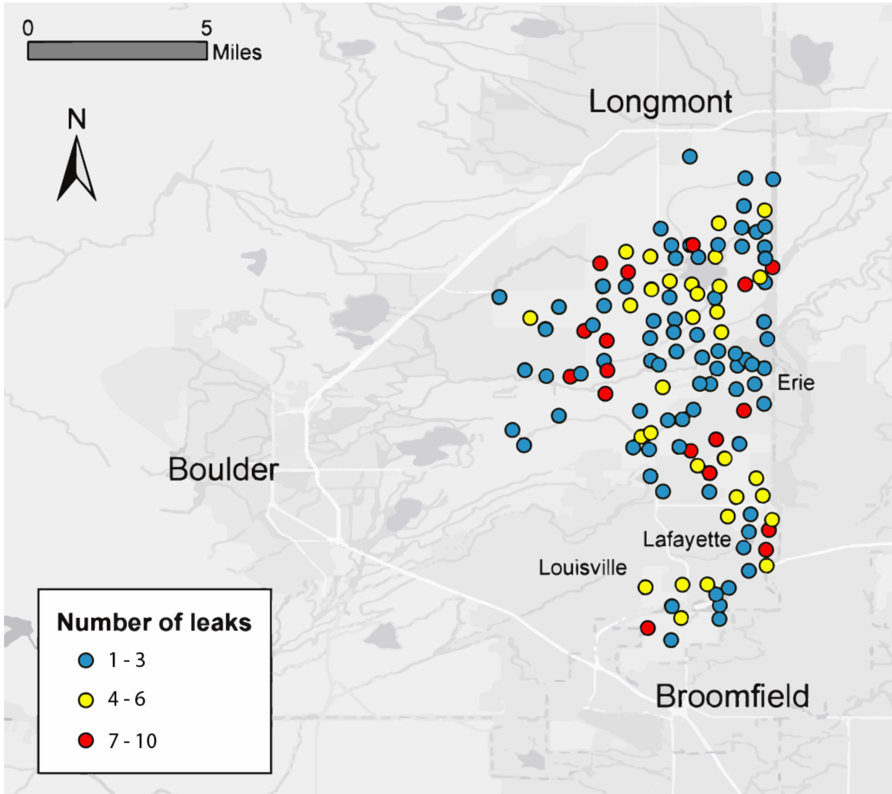

Figure 2. Locations of oil and gas production sites and numbers of leaks

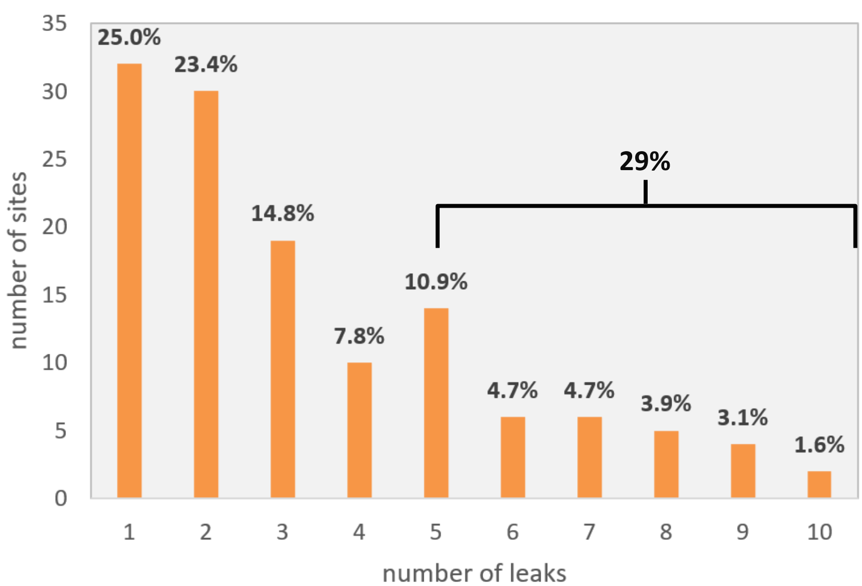

Figure 3. The numbers of sites in Boulder County that experienced one or more leaks from 2014 to 2018

Return Visits and Recurrent Leaks
The inspector returned to oil and gas sites 472 times to conduct IR camera inspections, often to confirm that an earlier leak had been resolved. During 189 of these return visits (40%), the inspector detected one or more new leaks at the site. During seven return visits (1.5%), the inspector observed a new leak that recurred from a previous visit. Of the 126 sites that had leaks, 71 (56%) experienced more than one in a calendar year.

Leak Characteristics
The most common pieces of equipment that experienced leaks at oil and gas facilities were separators, tanks, and wellheads (Figure 4). Leaks were less frequently observed from ECDs, flowlines, and pipelines. Beginning in 2015, more detailed data about leaking equipment were available, including whether a leak affected a pneumatic controller. Since 2015, 113 leaks at 60 sites (32% of leaks at 42% of sites inspected in 2015-2018) involved a malfunctioning pneumatic controller based on correspondence between the inspector and operators.

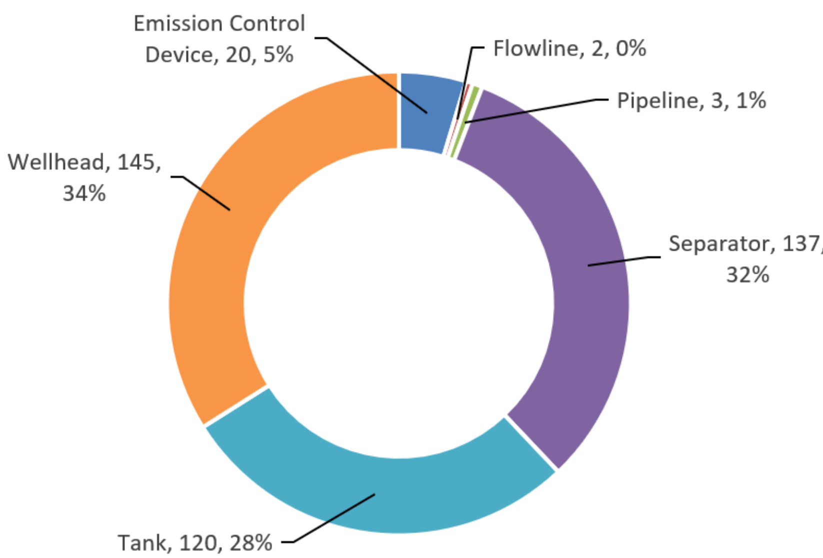

Figure 4. Equipment experiencing leaks at oil and gas sites (type of equipment, number of leaks observed, and percentage of all leaks represented by equipment type)

Time to Leak Resolution
Operators resolved 390 of 433 leaks (90%) after notification from the inspector. The vast majority of leaks were resolved with equipment repairs, but operators reported that 14 leaks were stopped by shutting in a well (temporarily halting production) at the site. Of the resolutions reported by operators, 226 (52%) were subsequently confirmed by an IR camera inspection during a return visit by the Boulder County Public Health inspector.

For 84% of the resolved leaks (n = 324), notification dates and repair dates were available to analyze the time required for leak resolution. The average resolution time was 13 days; however, the data were strongly skewed toward faster resolution times, resulting in a median resolution time of three days. 92% of leaks were resolved in 45 days or less.

109 of the 113 leaks observed from pneumatic controllers in 2015 through 2018 were resolved by performing maintenance or repairs. An operator resolving a leak by repairing equipment indicates that the controller was not operating as intended when the inspector observed the emissions. Examples of these repairs as they were reported by operators are available in Appendix E. The remaining four leaks from pneumatic controllers were not known to have been resolved at the time of the analysis, but correspondence between the inspector and operator indicates that the pneumatic controllers were not operating as intended in these cases, as well.

Discussion
The overwhelming majority of leaks (92%) were detected during IR camera inspections, even though the camera was not always available to the inspector and many inspections did have to be conducted by AVO. By contrast, AVO visits rarely resulted in leak detection. Regardless of how they were detected, leaks were common among oil and gas facilities in Boulder County from 2014 to 2018. At least one leak was observed at most (86%) of the sites inspected over the five-year period. Furthermore, leaks can occur regularly at these sites; nearly half (48%) of sites experienced more than one leak in a year.

Only four leaks persisted without a reported resolution across multiple inspections, which suggests that operators were responsive to notifications of leaks submitted to them by the inspector. During the five-year period of the inspection program, operators were successful at resolving leaks through well shut-ins or equipment repairs, and resolved leaks rarely persisted after they were resolved.

As similarly noted by Pétron et al.; Halliday et al.; Eastern Research Group, Inc.; and APCD, storage tanks appear to be a significant source of gaseous hydrocarbon leaks from well sites.[22] Based on the number of leaks detected from wellheads and separators in this analysis, malfunctions of these pieces of equipment may also have negative implications for regional air quality.

Pneumatic controllers, which are used to control the production process on multiple types of equipment, were implicated in 32% of the leaks observed in 2015 through 2018. Repairing and maintaining malfunctioning pneumatic controllers or using zero emission technologies, then, would potentially provide emissions reductions.

64% of leaks were resolved in five days or less from the date the operator was notified of the leak by the inspector. Compared to the lengthy resolution times for soil or groundwater remediation, this rapid resolution of leaks suggests that equipment repairs can usually be accomplished in a straightforward manner.

In its two-year pilot project involving IR camera inspections across the state of Colorado, APCD observed a marked decrease in the percentage of oil and gas well production facilities that experienced leaks. Leaks or venting were found at 42% of facilities at the beginning of the project in the third quarter of 2013, while only 9% of facilities experienced leaks or venting at the end of the project in the

[22] *See* Pétron et al 2012, Halliday et al 2016, APCD 2016, and Eastern Research Group, Inc. 2011.

second quarter of 2015.[23] By contrast, Boulder County Public Health's analysis indicates that the percentage of sites experiencing leaks in the county increased by just under 10% of sites per year over the course of the voluntary inspection program. At the time of this analysis, the available data were insufficient to discern the reason for the divergence between the results. The divergence may be due to differences between oil and gas sites in Boulder County and those elsewhere in Colorado (e.g., production volumes per site or ages of equipment at each site).

Conclusions

Leaks are common among oil and gas sites in Boulder County, and these sites often experienced multiple leaks during the five-year inspection period. Therefore, more frequent AIMM inspection requirements are important to identify and initiate the repair of leaks from malfunctioning equipment. By increasing the frequency of required inspections, leaks would be discovered sooner, which would aid in curtailing regional emissions of methane and VOCs from oil and gas operations.

Inspections and maintenance should target separators, storage tanks, wellheads, and pneumatic controllers across equipment categories in order to reduce the number of leaks at oil and gas facilities. Furthermore, inspections should be conducted with IR cameras whenever possible. In this analysis, IR camera inspections were much more likely to detect leaks than AVO inspections. Since leak detection is a prerequisite for leak resolution, and because an inspection program is limited by the time required for an inspector to visit individual well sites and conduct inspections, IR camera inspections may be the most efficient strategy for reducing leaks from oil and gas facilities.

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[23] APCD 2016.

Appendix A: Participating Operators

Table A1. Operators who have taken part in Boulder County Public Health's voluntary oil and gas inspection program

Operator	Years Participated
Anadarko Petroleum (Kerr-McGee Oil and Gas Onshore LP)	2014–present
CDM Oil and Gas	2014–present
Crestone Peak Resources	2016–present
Encana Corporation	2014–2016
Extraction Oil and Gas (8 North LLC)	2015–present
Great Western	2017-present
KP Kauffman	2017-present
Noble Energy	2014–2015
PDC Energy	2014–present
Smith Oil Properties Inc.	2016–present
Synergy Resources	2015–2016
Top Operating Company	2016–present

Appendix B: Site Inspection Checklist

Site Visit Checklist

Date:________ Time:____________________

Company:____

Location name: ____

Site Location:____

AIRS ID on/by tanks? (#)____

Access:____

Site Inventory:

Tank Battery:

- Is thief hatch closed?
- Is there air pollution control equipment?
- AIRS ID on equipment?
- Type of control (flare, VRU, other):
- Is flare pilot on?
- Is fuel gas valve position open?
- Is flare enclosed?
- Is flare free of visible emissions?
- Can observer visually observe proper operation?
- Does flare have auto-igniter?

Site Condition:

- Are there waterways or surface waters nearby?
- What is the condition and type of containment?
- Is there proper signage?
- Is there unused equipment or debris on site?
- What is the condition of the access road?
- What BMP's are in place for stormwater management?
- Are there signs of spills or leaks?
- Is the site in close proximity to schools or residential areas?
- Type of produced water storage?

- Anchoring in place?
- Have baseline water tests been conducted?
- Acceptable noise levels?
- Visual impacts?

Appendix C: Standard Operating Procedures for Infrared Camera Inspections

Boulder County Public Health Voluntary Oil and Gas Inspection Program Using Optical Gas Imaging (Infrared) Camera for Leak Detection - Standard Operating Procedures

Boulder County Public Health's voluntary oil and gas inspection program aims to visit each facility at least twice each year; one visit with the infrared (IR) camera and one audio, visual, olfactory (AVO) visit. During the visits, the inspector follows these procedures:

1. Arrives on-site with proper personal protective equipment (PPE): fire-resistant clothing (FRC) outer layer, hard hat, protective glasses, steel-toed shoes, 4-gas monitor.
2. Parks the vehicle facing out, in case of emergency.
3. As a safety precaution, uses the camera in high sensitivity mode (HSM) to perform an initial scan of the facility, looking for any large gas releases from tanks, ground, separation equipment, and emission control devices (ECD).
    a. All equipment is viewed in both auto and HSM modes to identify any releases. Auto is used to pinpoint and confirm the source of release.
4. Scans the facility and observe the pressure relief valves (PRV) on any tanks. If venting is observed, makes a note and checks the PRV again when the entire facility has been inspected in order to determine if the PRVs are operating correctly or still malfunctioning.
5. Moves through the facility, generally starting with the storage tanks, to observe all PRVs, thief hatches, piping that is viewable from the ground, and the ground where the dump lines and flash gas lines enter.
6. Observes the ground between the tanks and separation equipment to check for any gas that may be coming out of the ground.
7. Observes the separation equipment and any ECDs. If any releases are seen at pneumatic devices, makes a note to recheck before leaving. Checks the separator's doghouse (without opening the door) for any gas coming through spaces in the door or ventilation holes.
8. Checks all areas where lines are entering or coming out of the ground.
9. Checks any pipeline equipment that is exposed with the camera.
    - Views all equipment from several different angles to avoid any issues with shadows, wind, etc. and potentially getting a false detect. The wellheads, associated piping, and accessory equipment are viewed from as many angles as possible.
10. After going through the entire facility, completes the inspection paperwork.

11. After completing the paperwork, rechecks any pneumatic devices or PRVs that were noted with the camera. If the equipment still has an observable release, it is then considered to be malfunctioning and is reported to the operator.

12. Reports all findings, including a short summary of the facility that was visited and any identified releases, by email to the operator, usually within one business day.

13. Tracks the operator’s response and repair timing. Keeps the description of the repair provided by the operator.

14. When possible, returns to the facility to confirm all repairs are made and conduct another scan of the facility equipment to identify any additional releases.

Appendix D: Infrared Camera Images

The following still images were recorded at oil and gas facilities by the Boulder County Public Health oil and gas inspector using a FLIR GF-320 thermal infrared camera.

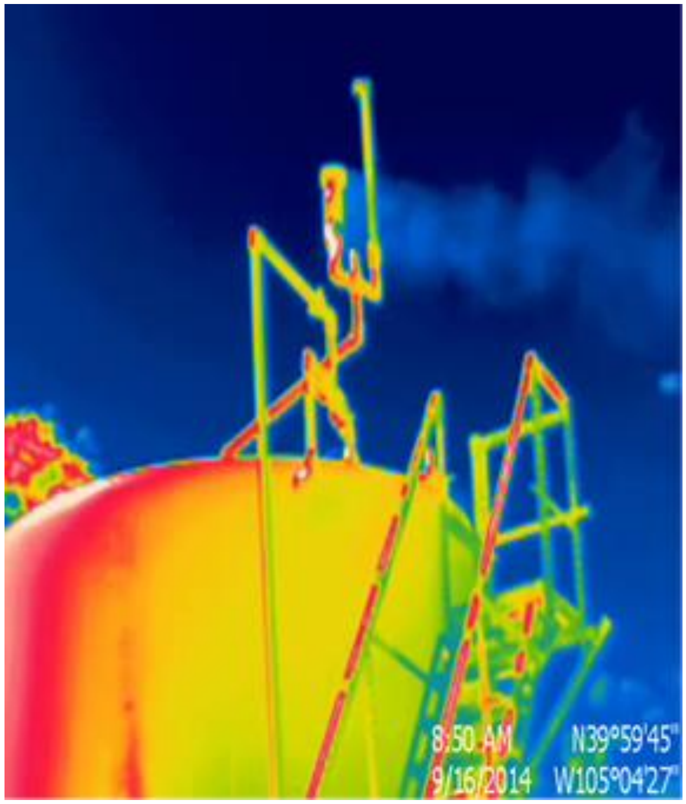

Figure D1. Emissions from pressure relief valve on crude oil tank

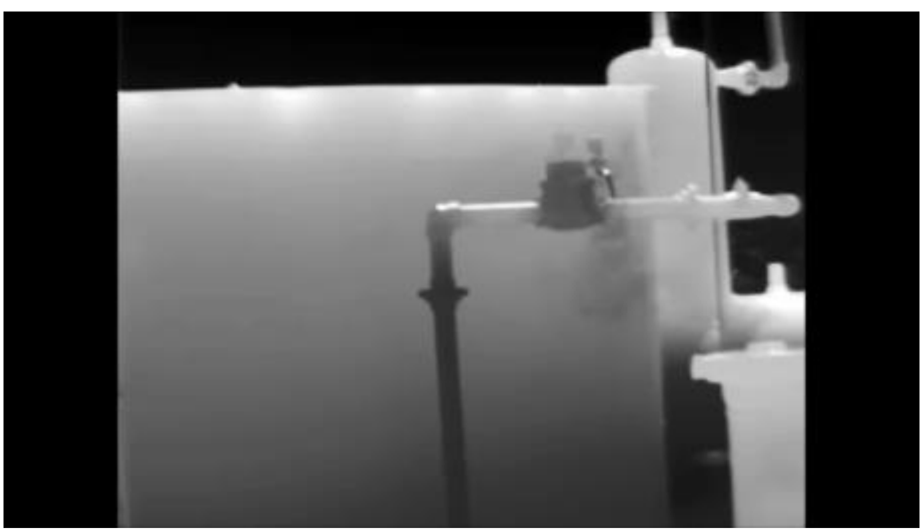

Figure D2. Emissions from back pressure Kimray valve on separator

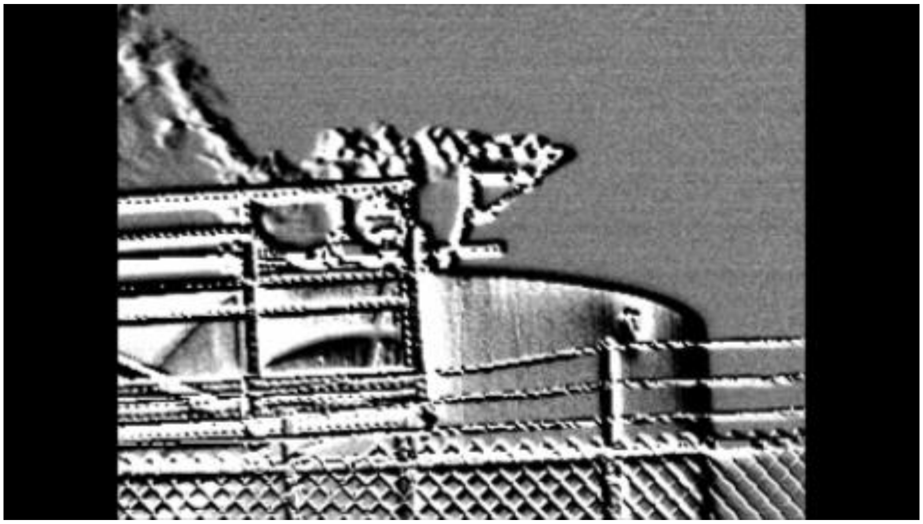

Figure D3. Emissions from blowdown valve on condensate tank viewed in high sensitivity mode (HSM)

Figure D4. Emissions from crude oil tank

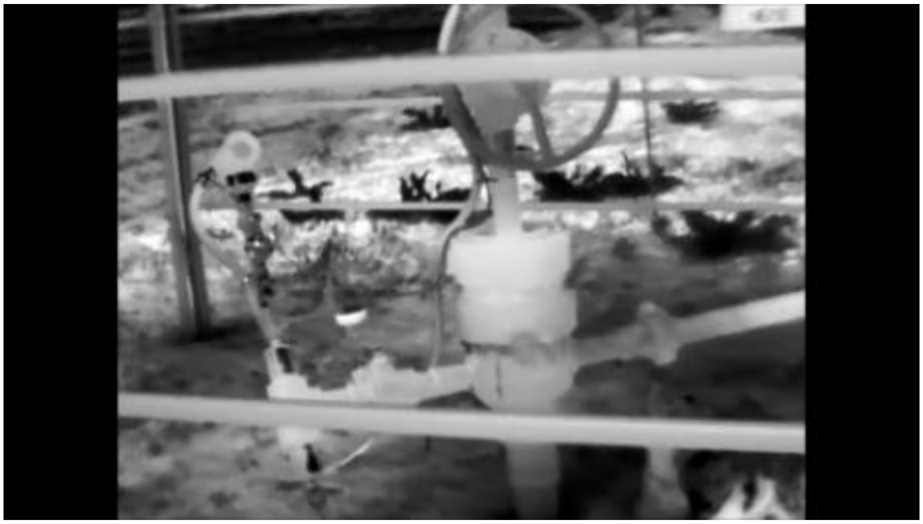

Figure D5. Emissions from tubing hanger on wellhead

Appendix E: Examples of Reported Repairs to Pneumatic Controllers

Examples of repairs to leaking pneumatic controllers (as reported to Boulder County Public Health inspector by operators):

- Actuator (rebuilt)
- Belgas regulator to telemetry system at well (replaced), hi/lo controller on separator (tightened), pressure gauge on supply gas line for horizontal gas run (tightened) on separator
- Combustor (replaced supply gas tubing and fittings)
- Connections jam nut (tightened)
- Controller (rebuilt)
- Controller-hi lo (replaced)
- Controller-hi-lo (replaced)
- Controller-level (replaced mizer assembly)
- Controllers (tightened operator on both)
- Kimray (repaired)
- Kimray (replaced)
- Kimray bolts (tightened)
- Kimray BPR, Fittings (tightened)
- Kimray valve (tightened bolts)
- Mizer-top dump (rebuilt)
- Regulator (replaced diaphragms)
- Regulator (tightened fittings)
- Regulator (tightened fittings on both inlet and outlet of operator)
- Regulator (took apart, cleaned, adjusted)
- Regulator , ECD (repaired)
- Regulator on supply line (replaced) and connections on supply gas line (replaced)
- Separator (fixed on site)
- T12 (adjusted), Pressure release Valve (waiting for parts)
- T12 temperature controller (replaced)
- T12-bottom (rebuilt with new O-ring)
- T12-top (rebuilt with new O-ring)
- Valve (repaired)