

NRMRL QUALITY ASSURANCE PROJECT PLAN

Office of Research and Development
National Risk Management Research Laboratory
Air Pollution Prevention and Control Division (APPCD)
Emissions Characterization and Prevention Branch (ECPB)

Uinta Basin Well Pad Pneumatic Controller Emissions Research Study

QA Category: B / Measurement

Extramural Research

QAPP-1J16-019.R1

Revision Number: 1
December 9, 2016

Prepared by
Jacobs Technology Inc.
Research Triangle Park, NC 27709

JACOBS®

Contract EP-C-15-008
WA 1-037

Approvals

QA Project Plan Title:	Uinta Basin Well Pad Pneumatic Controller Emissions Research Study	
NRMRL QA Tracking ID:	QLOG No. G-APPCD-0030050, QTRAK No. 16006	
If Intramural or Extramural, EPA NRMRL Project Approvals		
Name: Technical Lead Person (TLP) Eben Thoma	Signature/Date:	
Name: TLP's Supervisor Richard Shores, Branch Chief	Signature/Date:	
Name: QA Manager Libby Nessley	Signature/Date:	
Name: EPA R8 Lead Michael Stovern	Signature/Date:	
Name: Other EPA	Signature/Date:	
If Extramural, Contractor Approvals		
Name: Contractor Manager/Lead Parikshit J. Deshmukh, WAL	Signature/Date:	
Name: Contractor QA: Zora Drake-Richman, QAO	Signature/Date:	
Name: Other Contractors: Chris Winterrowd, Department Manager	Signature/Date:	
Name: Other Contractors:	Signature/Date:	

Change History

Change No.	Description	Date Submitted	Date Approved	Revised Section	Changes
0	Initial QAPP	8/23/16	9/2/16		
R1	Revision 1	12/9/16		Entire document	Response to minor comments; adding field forms; minor programmatic and technical adjustments

Table of Contents

Approvals	2
Figures	5
Tables	5
List of Appendices	6
Distribution List	7
Disclaimer and Acknowledgments	7
Acronyms and Abbreviations	8
1.0 Project Description and Objectives	10
1.1 Background	10
1.2 Description and Purpose of This QAPP	12
1.3 Project Objectives	13
2.0 Project Organization and Responsibilities	14
2.1 Project Personnel	14
2.2 Project Schedule	15
3.0 Scientific Approach	16
3.1 Uinta Basin ONG Operators and Site Selection	16
3.2 Understanding Emissions from PC Systems	18
3.3 Scientific Approach Overview	18
3.4 Example Field Measurement Sequence	20
4.0 Information, Measurement, and Analysis Procedures	26
4.1 Information-Gathering and Measurement Systems	26
4.1.1 PC, Process, Application, and Classification Information	27
4.1.2 Optical Gas Imaging and Hand-Held Leak Detection Probes	28
4.1.3 PC Actuation Counters	29
4.1.4 PC Emissions Measurements by Flow Meters	30
4.1.5 PC Emissions Measurements by Augmented BHFS	31
4.1.6 Evacuated Canister Acquisition and Analysis	32
4.1.7 Temperature and Pressure Measurement	35
4.2 On-Site Procedures	35
4.3 Critical Measurements	35
5.0 Quality Assurance and Quality Control	36
5.1 Data Quality Indicator Goals	36
5.1.1 Accuracy	38
5.1.2 Precision	38

5.2	Assessment of DQI Goals	38
5.2.1	Flow Meter Assessment.....	39
5.2.2	Bacharach Hi Flow Sampler and QA Measuring Instrument Assessment	40
5.2.3	Optical Gas Imaging (OGI) Camera Assessment	41
5.2.4	PC Actuation Counter Assessment.....	41
6.0	Data Reporting and Validation	42
6.1	Reporting Requirements.....	42
6.2	Data-Related Deliverables.....	42
6.3	Data Reduction Deliverables	43
6.4	Data Validation Deliverables.....	43
6.5	Data Storage Requirements	43
7.0	References	44

Figures

Figure 2-1.	Organizational chart.....	15
Figure 3-1.	Locations of ONG sites and operators in the study region	17
Figure 3-2.	Examples of well pad PCs: (a) separator PC and (b) thermostat PC on tank	18
Figure 4-1.	FLIR GF320 OGI camera.....	28
Figure 4-2.	Model SERN-5 pneumatic counter (not fully installed)	29
Figure 4-3.	Fox Thermal flow meter FT3 (left) and Alicat flow meter (right)	31
Figure 4-4.	Bacharach Hi Flow sampler (BHFS) with some attachments	32
Figure 4-5.	TVA-1000B (left), PPM Gas Surveyor 500 (middle), and Gas Rover (right)	32
Figure 5-1.	Mensor APC-600 with actuation counter attached.	38

Tables

Table 4-1.	Information-Gathering and Measurement Systems	26
Table 4-2.	Equipment Used for PC Emissions Flow Meter Measurements.....	30
Table 4-3.	List of PAMS Target VOCs.....	33
Table 4-4.	Critical Measurements.....	35
Table 5-1.	DQI Goals for the Project	36
Table 5-2.	Procedures Used to Assess QA Objectives	39
Table 5-3.	Sample BHFS Calibration Check Test	40
Table 6-1.	Data-Related Deliverables	42

List of Appendices

Appendix A: Pneumatic Controller and Site Information-Gathering Procedures

Appendix B: Optical Gas Imaging Procedures

Appendix C: PC Actuation Counting Procedures Using the SERN-5

Appendix D: Operating Procedures for Flow Meter Measurements

Appendix E: Operating Procedure for Augmented Bacharach Hi Flow Sampler Measurements

Appendix F: Evacuated Canister Analysis Procedures

Fa: GC/FID Analysis of Hydrocarbons Using Method TO-14A

Fb: EPA Method 18 Bag and EPA ALT-100 Canister Analysis

Distribution List

Copies of this plan and all revisions will be sent initially to the following individuals. It is the responsibility of the U.S. Environmental Protection Agency work assignment contracting officer's representative (WACOR) and the Jacobs Technology Inc. (Jacobs) work assignment leader (WAL) to make copies of the plan available to all project personnel.

EPA

Eben Thoma, ORD/NRMRL/APPCD WACOR and Technical Lead

Richard Shores, ORD/NRMRL/APPCD Branch Chief

Libby Nessley, ORD/NRMRL/APPCD QA Manager

Michael Stovern, EPA Region 8 Technical Lead

Jacobs Technology Inc.

Parik Deshmukh, Work Assignment Leader

Chris Winterrowd, Department Manager

Zora Drake-Richman, Quality Assurance Officer

Stacy Henkle, Technical Editor

Disclaimer and Acknowledgments

Any mention of trade names, products, or services does not imply an endorsement by the U.S. Government or the U.S. Environmental Protection Agency (EPA). EPA does not endorse any commercial products, services, or enterprises. Draft versions of portions of this document were prepared by EPA and provided to Jacobs Technology Inc. for use in preparation of this quality assurance project plan. We would like to thank the technical reviewers from the American Petroleum Institute for helpful suggestions and information on pneumatic controller types and assessment approaches.

Acronyms and Abbreviations

ACE	Air Climate and Energy Program
AF	activity factor
API	American Petroleum Institute
APPCD	Air Pollution Prevention and Control Division
BHFS	Bacharach Hi Flow [®] sampler
BLM	Bureau of Land Management
CH ₄	methane
cfm	cubic feet per minute
COC	chain of custody
DP-IR	Detecto Pak-Infrared
DQI	data quality indicator
EF	emission factor
EPA	U.S. Environmental Protection Agency
FID	flame ionization detector
GC	gas chromatography
h	hour(s)
HASP	health and safety plan
HC	hydrocarbon
HHP	hand-held probe
Hz	hertz (rate of once per second)
in. Hg	inch(es) of mercury
IR	infrared
Jacobs	Jacobs Technology Inc.
lpm	liter(s) per minute
MET	metrology
MFC	mass flow controller
min	minute(s)
NG	natural gas
NRMRL	National Risk Management Research Laboratory
OGI	optical gas imaging
ONG	oil and natural gas
OIPA	Oklahoma Independent Petroleum Association
OR	operator representative

ORD	Office of Research and Development
PAMS	photochemical assessment monitoring stations
PC	pneumatic controller
ppm	part(s) per million
psi	pound(s) per square inch
psig	pound(s) per square inch gauge
QA	quality assurance
QAO	quality assurance officer
QAPP	quality assurance project plan
QC	quality control
R8	EPA Region 8
RARE	Regional Applied Research Effort
RLS	Research Laboratory Support
scf	standard cubic feet
scfm	standard cubic feet per minute
slpm	standard liter(s) per minute
TFS	Tunable Filter Spectroscopy
UDAQ	Utah Division of Air Quality
VOC	volatile organic compound
WA	work assignment
WACOR	work assignment contracting officer's representative
WAL	work assignment leader

1.0 Project Description and Objectives

1.1 Background

Oil and natural gas (ONG) well pad operations employ natural gas–driven pneumatic controllers (PCs) for production process control and safety functions. As part of regular operation, most well pad PCs are designed to emit a small quantity of natural gas to the atmosphere. Because of the large numbers of PCs in use, emissions associated with this source category contribute significantly to greenhouse gas and volatile organic compound (VOC) emission inventories for the ONG sector. To support environmentally responsible development of U.S. energy assets, it is of ongoing importance to improve information on the number, type, use, operational conditions, and emission characteristics of well pad PCs, as well as methods to characterize their emissions. This quality assurance project plan (QAPP) describes a collaborative emission measurement and method development study, to be conducted in the Uinta Basin, Utah, that seeks to contribute information on this important source category.

Typically, a well pad PC converts a sensed process variable (e.g., mechanical float level, temperature, pressure) to a pneumatic valve actuation in order to control a process or execute a safety function. Well pad PCs come in a variety of designs and are used in many different process applications. The expected air emission profile of a PC system depends on its operational design (including the connecting tubing and actuator) and physical dimensions, how it is used in a specific application, the process characteristics of the well pad, and the maintenance state of the PC system. Due to varied models and applications and the lack of standardized terminology, the development of PC system emissions categories is a difficult task. As of August 2016, the American Petroleum Institute (API) and subcommittee members are working on a PC Technical Standard that will assist with classification of PCs and determination of emission profiles based on engineering calculations. This QAPP does not attempt to define a detailed PC system type classification approach, but the project will acquire information such as PC make, model, retrofit status, and process information to allow later assignment using the best available reference data and categorization schemes.

Regarding basic type classification for PCs that are designed to emit natural gas to the atmosphere, four major categories based on the depressurization method and service type can be described (Simpson, 2014). The depressurization method of a PC can be either continuous bleed or intermittent vent. A continuous bleed PC emits supply gas continuously to the atmosphere as part of its operation. An intermittent vent PC has a physical barrier between the supply gas and the atmosphere and emits periodically in short bursts, only during valve actuation. There are also two major service types of regularly emitting PCs. Some well pad processes require valves to be actuated in an “on/off” fashion, whereas other processes require a “throttling” action where the value set point varies in response to the control loop signal. The two depressurization methods and the two service types comprise the four major categories for regularly emitting PCs.

Within these four categories are several PC subtypes (e.g., high bleed or low bleed continuous, or snap action or proportional action on/off intermittent vent). For properly operating and maintained simple continuous bleed PC control loops, average emissions are relatively constant in time, determined primarily by the flow orifice, so a “snapshot” emission measurement can be representative of long-term emissions. The time-dependent emission rate (or bleed rate) of

simple continuous PCs will decrease and increase slightly during actuation and de-actuation of the control loop, so ideally the measurement time period will span these events.

The emissions profile of intermittent vent PCs, also called intermittent pilots if the PC and actuator are separated, differ greatly from continuous vent PCs. Intermittent vent PCs primarily emit natural gas (NG) to the atmosphere when the control loop is actuating/de-actuating. The actuation results in a discrete emission event of limited temporal profile and therefore knowledge of both the emissions per actuation and the number of actuations per unit time are required to determine emissions. Well-maintained intermittent PCs emit a very low continuous “seepage” of NG to the atmosphere between actuation events. This seepage is expected because it is not possible to make pilot seals completely tight in real-world conditions. While the designed seepage rate is not published by all manufacturers and will differ by model and process, it is believed to be typically less than 0.05 scf/h for most intermittent PC designs.

More complex types of PC control loops are also possible. For example, a proportional-type continuous PC can be combined with an intermittent pilot, effectively superimposing event-driven emission on a continuous emission baseline. Control loops can also include add-on “relays” that execute some process or control function and can serve as additional emissions points for the PC system. Finally, retrofit devices designed to reduce emissions may be added to the PC system so that the make and model information on the PC itself might not reflect expected emission performance. For these reasons, it is necessary to acquire detailed information on each PC system and process, including photos and optical gas imaging (OGI) video records. The details need to be gathered in collaboration with knowledgeable ONG site representatives.

For all well pad PC systems, emissions to the atmosphere might be increased if the PC system is malfunctioning or not well maintained. Emissions from a PC system can also be greater than expected if the process or equipment the PC is associated with is not optimized. Well pad emissions can also originate from fugitive sources that are nearby but not part of the PC system (e.g., pneumatic supply gas or downstream tubing leaks). All of these categories of emissions (and techniques for their identification and mitigation) are important and add complexity to the development of PC emission factors (EFs). Activity factor (AF) information on well pad PCs is also complicated by the varied actuation frequencies (emission events) within this source category due to the range of application services. This collaborative project seeks to improve information on a variety of factors affecting well pad PC emission characterization, for the benefit of multiple parties.

The broader project team for this effort includes EPA’s Office of Research and Development (ORD), EPA Region 8 (R8), Utah Division of Air Quality (UDAQ), Ute Tribe Air Program, Bureau of Land Management (BLM) Utah State and Vernal Field Offices, EPA ORD contractor Jacobs Technology Inc. (Jacobs) and its subcontractor team, and participating Uinta Basin ONG operators. The Measurement Technology Group of EPA’s Office of Air Quality Planning and Standards is advising on methods aspects for this project. Component manufacturers, API, and other organizations have commented on the planning process. This field study is primarily funded by an EPA ORD Regional Applied Research Effort (RARE) internal project grant with EPA R8 and through the ORD Air Climate and Energy (ACE) Program, Task EM 1.2.

This applied research effort includes experimental measurement approaches and is conducted on a defined-scope, best-effort basis. This project is not part of any enforcement or compliance activity or other EPA program. The cooperating Uinta Basin ONG operators participating in the study will supply in-kind resources in the form of information, personnel, and site access and shall remain anonymous for reporting purposes. The ONG operator participants may review and comment on this QAPP and draft publications generated by the study. No confidential business information will be recorded or maintained as part of this study. Information gathered will be controlled and anonymized on a best-effort basis by the core EPA study team (EPA ORD, EPA R8, and Jacobs). Site-specific information gathered, such as digital photographs, OGI videos, and PC-related process and production information, will be fully available to the ONG operator from which it was obtained but will not be shared with other participating ONG operators. General site characteristics, pertinent production and process information, specific examples of PC system configurations, photographs, OGI videos, emissions measurements, etc., will be reported in an anonymized fashion and may be reviewed by participating ONG operators as part of the publication development process. Information regarding the makes and models of PC systems will be reported and specific site and emissions information (ONG operator anonymous) may be reviewed with PC manufacturers as part of data analysis and the publication development process to ensure the best available information is obtained.

This project will be conducted under EPA ORD Quality Assurance Category B – Measurement Study. The data and information gathered in this project are intended for research purposes only. The quality assurance (QA) category for this project is not appropriate for enforcement or compliance activities. Information gathered will be constrained to PC systems and associated fugitive emissions (e.g., tubing or valve actuator diaphragm/gasket leaks that could be mistaken for PC emissions). As with any EPA field activity, if a potentially hazardous or environmentally significant condition (e.g., a gathering pipeline leak) is observed during the field study, EPA and Jacobs have the responsibility to immediately report this to both the company and appropriate authorities.

1.2 Description and Purpose of This QAPP

This document is an EPA ORD field research QAPP. The purpose of this QAPP is to describe details of a limited-scope field study (currently for up to 20 deployment days), to be conducted in the Uinta Basin, Utah, in cooperation with ONG operators, that seeks to improve information on well pad PC emissions and measurement methods. A single field team will conduct measurements on well pads in a sequential fashion in cooperation with participating ONG operators. This QAPP describes field measurements and QA procedures for the study. Data analysis procedures are not detailed in this QAPP but will be fully documented in future publications. This document is limited to QA aspects of the project and does not cover site-specific safety planning for the field work.

In general, this QAPP outlines the procedures used by personnel conducting the monitoring project to ensure that the data collected and analyzed meets project requirements. As a planning and operating tool, the QAPP not only supports the quality of the project's findings, but documents the project's goals, methods of data collection, storage, and analysis for current participants and

for those who may wish to use the project's data over time. U.S. EPA-funded monitoring programs must have an EPA-approved QAPP before sample collection begins.

1.3 Project Objectives

The primary objective of this effort is to improve information on Uinta Basin ONG well pad PC emissions and measurement methods. A goal is to acquire PC emissions and activity data of sufficient quality and breadth to help inform Uinta Basin emission inventories.¹ The scientific approach to achieving this objective centers on observational field studies of PC emissions to be conducted in cooperation with ONG operators. The following secondary field study objectives are listed in order of importance:

1. Safely conduct on-site data-gathering activities and PC emission measurements on small to medium-size well pads in the Uinta Basin.
2. Understand and record information on well pad PCs and associated equipment and processes of sufficient detail to support the following:
 - Real-time survey classification of PC types based on expected emission frequency.
 - Post-assignment of PCs to classification schemes currently under development.
 - Accurate engineering-based emissions calculations.
3. Conduct quality-assured PC actuation frequency and emissions measurements.
4. Advance PC measurement methods and possibly conduct method comparisons.
5. Acquire limited speciated emissions measurements to support inventory development.
6. Demonstrate select research measurement methods to the extent possible.
7. Understand and document process-related effects on PC emissions where possible.²
8. Assess the maintenance states and repair potential of encountered PCs where possible.²

The degree to which certain secondary objectives can be achieved will depend in part on site and measurement selection decisions and will be discussed in reporting.

¹ Due to the limited-scope nature of this study, the statistical representativeness of the populations of well pads visited and PCs sampled in relation to the overall Uinta Basin ONG inventory is not yet known. The limitations of the acquired data set will be reported in publications along with the site selection decisions. The degree to which certain secondary objectives may be achieved depends in part on site selection and will be discussed in reporting.

² The use of some preselected sites will reduce emphasis on these secondary objectives as it is assumed that preselected sites will be well maintained and typically free of operational issues.

2.0 Project Organization and Responsibilities

2.1 Project Personnel

This work is being conducted by Jacobs for the Air Pollution Prevention and Control Division (APPCD) of EPA's National Risk Management Research Laboratory (NRMRL) under Research Laboratory Support (RLS) Contract EP-C-15-08, Work Assignment (WA) 1-037, "EPA Region 8 Well Pad Studies." In addition to Jacobs and its subcontractor personnel, EPA personnel will be present on-site and conduct limited data-acquisition and information-gathering activities described here. EPA personnel will be covered under a separate safety plan. In addition to the Jacobs/EPA field team, the roles of the ONG operator on-site personnel are described here. Data processing, publication development activities, and the roles of the broader study team, including UDAQ, Ute Tribe Air Program, and BLM Utah State and Vernal Field Offices, are not described in this field activity QAPP.

Project personnel for this effort will include multiple individuals from EPA, Jacobs, and ONG operators in primary and supporting roles. The primary project personnel from EPA and Jacobs are as follows:

Dr. Eben Thoma is the EPA ORD project lead and the WA contracting officer's representative (WACOR) for WA 1-037. He is responsible for communicating technical direction to the Jacobs work assignment leader (WAL). Dr. Thoma provides technical oversight for the project. Dr. Michael Stovern is the EPA R8 technical lead for the project. Dr. Stovern will coordinate activities involving EPA R8 personnel and manage OGI data collection for the field effort. EPA ORD NRMRL APPCD's quality assurance (QA) manager, Ms. Libby Nessley, will review and approve this QAPP and coordinate any requested audits through the EPA WACOR. Ms. Nessley will review and approve all project reports before they are cleared for publication to verify that the project was implemented as has been specified in this document.

Mr. Parik Deshmukh will serve as the Jacobs WAL. He will be responsible for preparing project deliverables and managing the WA. He will ensure the project meets scheduled milestones and stays within the budgetary constraints agreed upon by EPA. Mr. Deshmukh will be responsible for managing subcontracts related to this WA and with coordinating ONG operators for on-site work. Mr. Deshmukh will be responsible for training field personnel, executing the field work, and providing preliminary data reduction and QA information. Mr. Deshmukh is also responsible for drafting this document and assisting Ms. Giao Nguyen, the Jacobs health and safety officer, with the Jacobs health and safety plan (HASP) for this effort. Mr. Chris Winterrowd, Jacobs department manager, is the technical advisor to Mr. Deshmukh for this project. The Jacobs QA officer (QAO), Ms. Zora Drake-Richman, is responsible for reviewing and approving the QAPP. Ms. Drake-Richman will review and approve all project deliverables before they are submitted to EPA to verify that the project was implemented as has been specified in this document. At this time, no planned internal systems or performance audits are scheduled. However, Ms. Drake-Richman has the authority to perform random internal audits on a regular basis on EPA/RLS projects, as warranted by data quality issues or if requested by Dr. Thoma. Internal audits by Ms. Drake-Richman will be coordinated through the Jacobs WAL.

The ONG on-site operator representative (OR) provided to the team for that field test day will need to have sufficient knowledge of the sites to be visited. The ONG on-site OR will

accompany the team in the daily sampling activities, describe the PCs at each site, and indicate which controllers can be sampled safely without disrupting a process.

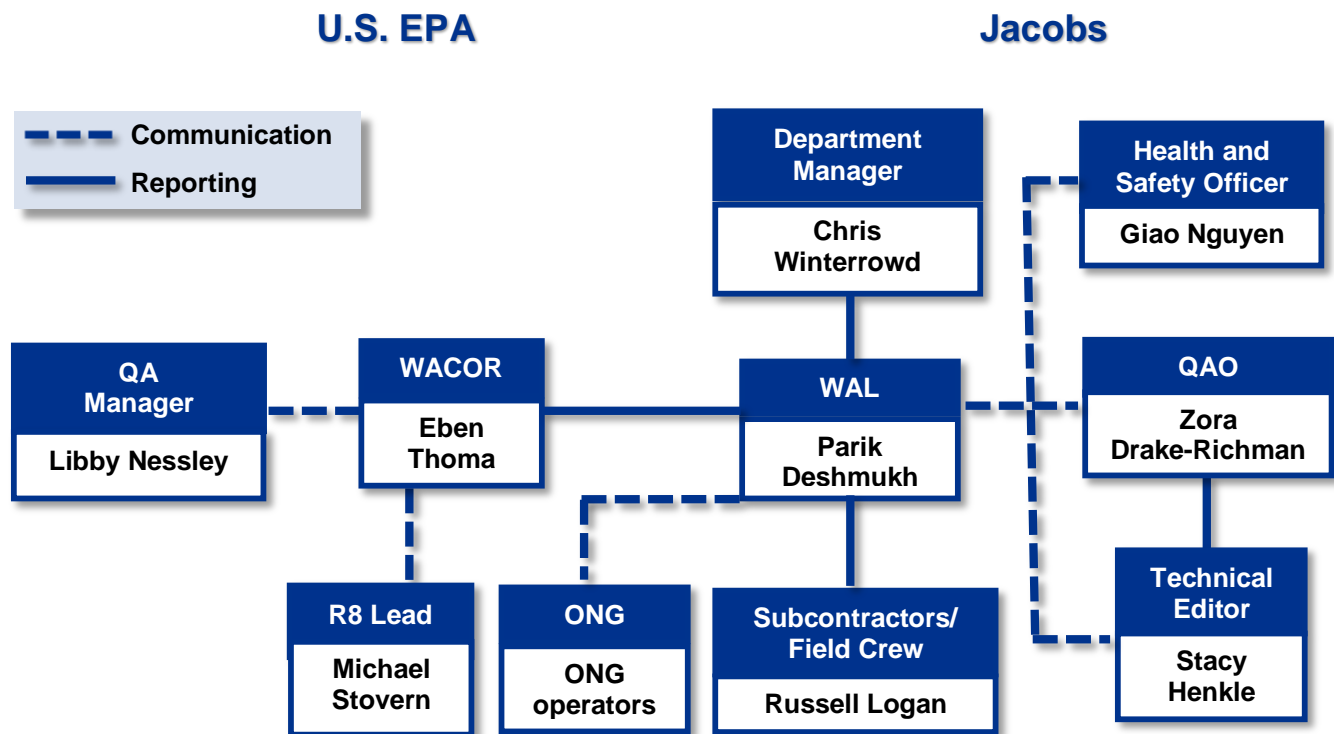


Figure 2-1. Organizational chart

2.2 Project Schedule

This field study aims to achieve 20 field deployment measurement days (not necessarily consecutive) and is planned to start in September 2016. The exact deployment dates are to be determined based on site access discussions with participating ONG operators. The exact number of field measurement days and the time scale for completion of field work will depend on budgetary and technical factors and on-site access and weather constraints.

3.0 Scientific Approach

This study seeks to build on existing research and complement information that is currently being produced by other groups (e.g., API PC standards subcommittee) and through other programs. The procedures used for this project are adapted in part from previous studies (Allen et al., 2013, 2014; OIPA, 2014; Prasino Group, 2013) with comments on previous approaches noted (Howard, 2015a,b; Howard et al., 2015).

3.1 Uinta Basin ONG Operators and Site Selection

Figure 3-1 shows the general locations of well sites and ONG operators in the study region. The different colored dots indicate the well pads operated by different ONG operators in the region. For the purpose of this study, “Uinta Basin ONG operators” refers to ONG operations in Uintah and Duchesne Counties, Utah. During the initial project planning phases, the study team contacted all known Utah ONG operators to discuss the proposed study. Two webinars were held in May and June 2016, and additional email and phone communications were subsequently conducted. As of the time of QAPP preparation, the participating ONG operator list has yet to be finalized. For this reason and because the participating sites and ONG operators will remain anonymous for reporting purposes, the specific site details are not included in the QAPP.

Site selection is an important aspect of any field research effort as these decisions can affect the strength of conclusions that can be logically drawn from a study. For this study, the specific measurement site locations, dates, and times are not detailed in this QAPP. Site selection decisions will be made by the project team including the participating ONG operators starting in early September 2016. These details will be determined in part by the final list of ONG operators agreeing to participate (the sites potentially available to the study), practical field sampling considerations (e.g., travel time), and project team determinations of best study focus (e.g., gas or oil well sites).

Site selection decisions and implications for this study will be analyzed and discussed in project reporting. Site selection will likely follow the guidelines described here. A subset of Uinta Basin ONG operators and their respective pools of candidate sites that meet final selection criteria will be identified based on study resources, the list of potentially participating ONG operators, and discussions of site type focus (e.g., old vs. new, gas vs. oil). The time frame for deployment will be worked out with individual ONG operators, and the sites belonging to that operator will be visited by the field team in a sequential fashion, typically over the course of several days, with the goal of surveying multiple sites per day.

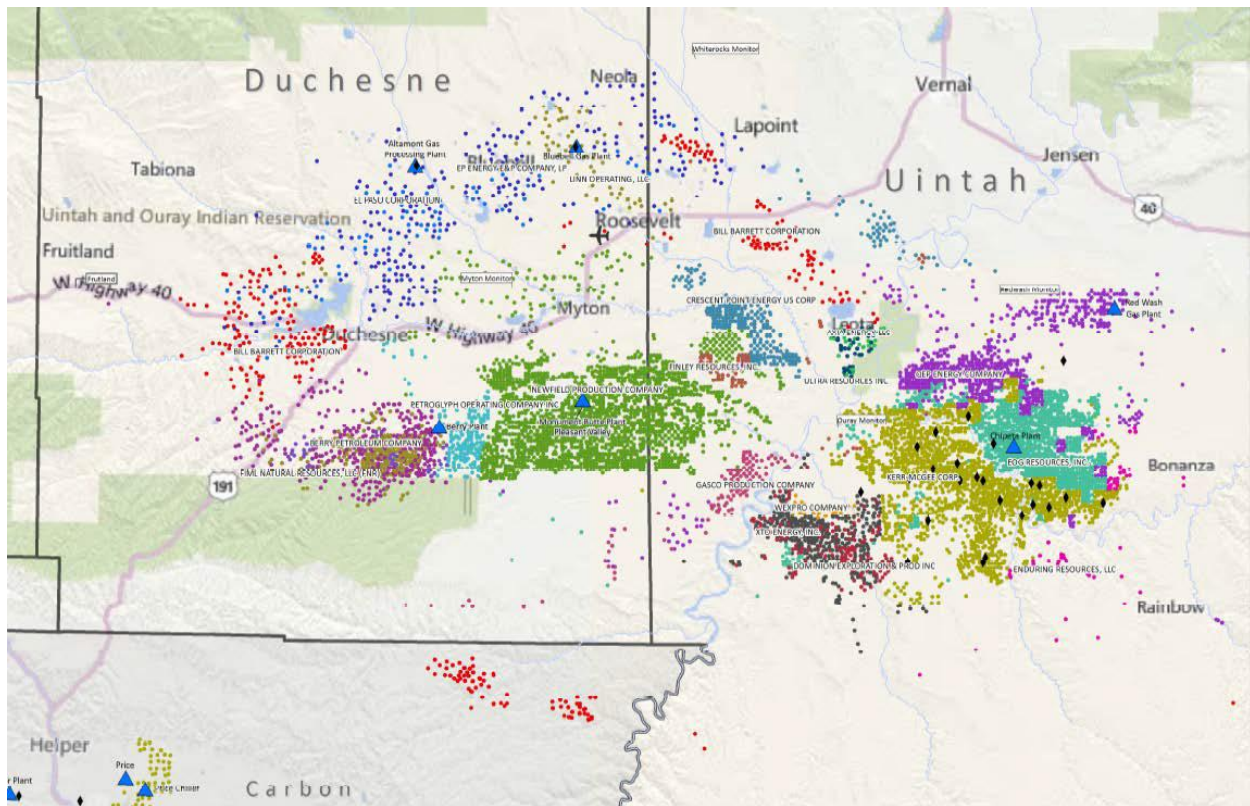


Figure 3-1. Locations of ONG sites and operators in the study region

The pool of potentially available sites for an ONG operator may be divided into “*daily selected*” and “*preselected*” categories. The former represents sites that are assumed not to have undergone any special preparation, information gathering, or PC maintenance other than normal company procedures and may be selected from the pool on a daily basis in a pseudo-random fashion during the measurement campaign. The daily selected site is not a completely random selection due to logistical considerations. The daily selected site will be selected randomly from a pool of potential sites in an agreed-upon geographic region within reasonable driving distance (e.g., < 1 h) to minimize field time spent on travel. Also, the ONG on-site operator representative (OR) provided to the team for that field test day will need to have sufficient knowledge of the sites visited, so this could further limit the available sites in the daily selection pool. If a second daily selected site is visited that day, it will likely be chosen from a group of proximate sites to minimize travel time. The procedures used for daily site selection (e.g., numbers of sites in the pool, selection process) will be discussed in reporting.

A preselected site is a site that is either collaboratively selected or selected solely by the ONG operator before the field team arrives. A preselected site may be visited by the ONG operator prior to primary field measurements for the purpose of gathering information on the PC systems, installing actuation counters, or perhaps performing special maintenance reviews or safety screening. Possible advantages of preselection include (1) assurance of site type representativeness, (2) superior knowledge of site components and processes, (3) logistical advantages regarding

travel time, (4) deployment setup advantages, (5) data collection advantages regarding PC actuation counting, and (6) improved statistical power by increasing the number of measurements that can be made during the study. Disadvantages of site preselection center on the assumption that observation of PC maintenance issues will be underrepresented compared to the daily site selection process. For the purposes of the QAPP, a mixture of daily selected and preselected sites is assumed.

3.2 Understanding Emissions from PC Systems

Understanding emissions from PC systems is complicated by both uncertainty in assignment of emissions and lack of standardized methods to measure all forms of PC emissions. As described in subsequent sections, part of the challenge is to fully understand the design of the PC system and its application so that the expected emission profile can be determined and its nominal operational state assessed. This is made difficult by the very large number of PC makes/models and application combinations, so knowledge transfer from the on-site OR is critical for success of the measurement survey. Another important aspect of the assessment is to understand which observed emissions are related to PC operation (or malfunction) and which are not (e.g., proximate fugitive leaks). Two examples of PC systems are shown in Figure 3-2, with additional discussion contained in many of the cited references.



Figure 3-2. Examples of well pad PCs: (a) separator PC and (b) thermostat PC on tank

3.3 Scientific Approach Overview

To achieve the study's primary and secondary objectives, the scientific approach for this study relies on information gathering of well pad PC systems and their process-specific applications, with field measurements of PC emissions and PC actuation data (where possible). This project will acquire information of sufficient detail to allow later assignment of the PC systems encountered into the best available categorization schemes (e.g., API PC standards currently under development). This project will use a simple, field survey-based PC system categorization scheme based on the expected temporal characteristics of the emission profile:

- PCs that are not capable of emitting NG to the atmosphere
- PCs that are not in operation due to seasonal or other reasons
- Intermittent PCs that are expected to actuate very infrequently (> every 1 day)
- Intermittent PCs that are expected to actuate infrequently (> every 15 min, but < 1 day)
- Intermittent PCs that are expected to actuate frequently (< every 15 min)
- Continuously emitting PCs
- Malfunctioning PC or associated equipment or process

Using this PC-type classification framework, the following specific information and data gathering will be executed as part of this project.

- PC system, PC application, and well pad process parameter data will be gathered using a system similar to that used by the Oklahoma Independent Petroleum Association (OIPA, 2014). Acquired information will include well pad site details, PC manufacturer, model number, actuator information, tubing length, and necessary PC-related process information. This basic PC system information will be augmented with other available information (e.g., date of installation, retrofit status, date of last maintenance) if known by the ONG operator. This information-gathering activity will improve knowledge of the types of PCs employed in the Uinta Basin (for the subset of well pad types surveyed). These data, for example, will provide AF information on the relative number of continuous and intermittent actuating PCs of various types in use. This information will allow PC emissions engineering calculations to be compared to PC emissions measurements. Additionally, this information will allow understanding of the designed PC system emission profile so that deviations from nominal (e.g., malfunctions) can be detected and the potential for in-field repairs assessed (where possible). See Appendix A: “Pneumatic Controller and Site Information-Gathering Procedures” for details of this activity as well as examples of the field log sheets for recording information.
- OGI will be used to (1) assist in determination of safe operations for the field team, (2) document specific aspects of PC operations and PC actuation frequency, (3) assist in determining if an emission is from the PC system or from a nearby fugitive emission source that is not part of the PC system, (4) assist in quality control (QC) aspects of the project such as ensuring actuation counters and flow measurement systems are properly installed, and (5) assist in documenting the nominal operational conditions of encountered PC systems. To support the OGI measurements, hand-held leak detection probes (HHPs), with sensitivity in parts per million (ppm), will be used to check for emissions from all parts of the PC system, and “Snoop” leak detection liquid (Swagelok) will be used to identify connection leaks in some cases. The exact procedures for OGI use are described in Appendix B: “Optical Gas Imaging Procedures.”

- Limited PC actuation counting will be attempted for this project using the approaches described in Appendix C: “PC Actuation Counting Procedures Using the SERN-5.” This information will improve PC-related AF data, especially for the infrequently actuating category of PC systems.
- PC system emission measurements will be conducted using one or more approaches. This information will improve PC-related EF data for the Uinta Basin. Measurements might include flow meter measurements (see Appendix D: “Operating Procedures for Flow Meter Measurements”) or determining the rate of gas leakage using the Bacharach Hi Flow[®] sampler (BHFS) (see Appendix E: “Operating Procedure for Augmented Bacharach Hi Flow Sampler Measurements”). As part of emissions measurements, a limited amount of evacuated canister sampling will be conducted to improve speciation data for Uinta inventories. These data will augment site-specific gas data provided by the ONG operators, which will be necessary for the emissions measurements. Procedures for canister sampling are given in Appendix F: “Evacuated Canister Analysis Procedures.”
- To the extent possible, measurement method development and method comparisons will be conducted and some research measurements will be attempted. The use of research measurements will be documented as an addendum to this QAPP.
- To the extent possible, malfunctioning PC systems will be identified and the in-field repair potential assessed, attempted, and documented.

3.4 Example Field Measurement Sequence

The following example site measurement sequence is provided to illustrate one possible survey mode. The current example is for a daily selected site, but as previously discussed, preselected sites are expected to play a large part in this study. For preselected sites, some of the PC system and process information collection activities may be accomplished prior to the on-site work and then confirmed by the on-site survey. Also, some preparation such as installation of actuation counters might have already been accomplished for preselected sites.

Step 1: The ONG operator agrees to provide site access and on-site support for 2–4 days during a specific calendar week, and a pool of potential sites in a geographic area is determined. It is important that the on-site OR provided by the ONG operator can explain details of the PC systems, can execute flow meter and actuation counter installation and manual PC actuation (when safe to do so), and is authorized to provide safety oversight for the work. Since some of the equipment used (e.g., OGI camera and digital camera) are not intrinsically safe, “hot work permits” will be required. The health and safety plans for this project will address hot work permit requirements. Some of the test procedures (e.g., installation of flow meters and PC actuation counters) will require higher level review with the ONG operator. This information will be part of operator-specific safety plans formulated by Jacobs and reviewed and agreed to by the ONG operator.

Step 2: On the day of measurement, a well pad is selected from the pool of potential sites by Jacobs (daily selected). Prior to arrival at the site (or designated meeting location), the Jacobs

field team will have already performed daily instrument time synchronizations and QA calibration procedures on all measurement equipment (as described in Section 5). These daily QC records will be shown to the OR on request. With the OR, the field team will review safety plans and perform safety checks including an area OGI site safety survey (Appendix B). The safe use limitations and required stand-off distances of non-intrinsically safe devices such as digital cameras and OGI cameras will be discussed and documented. The safety review will be documented on the form contained in Appendix A and initialed by the OR.

Step 3: A basic site layout drawing will be made by the Jacobs team lead indicating the position of major equipment at the site (Appendix A). All pneumatic devices on the well pad are identified in a walk-through with the OR. PCs are identified from the pneumatic device group and entered into a site layout and record form (Appendix A) using a unique ID. Detailed information on the PCs (make/model, depressurization method, service type) and their process function will be determined and recorded in direct consultation with the OR. Each PC will be photographed from multiple angles and file names logged on the checklist described in Appendix A, including the physical measurements needed for engineering calculation of emissions. Some necessary information, such as site gas composition, may be provided by the operator at another time. The information gathered will be as comprehensive as possible to provide the greatest opportunity for linking to other work in the future (e.g., developing API PC classification standards). Information gathered should include age and maintenance factors for the PCs if available. See Appendix A for further information.

Step 4: One or more OGI survey records (Appendix B) are produced for each PC with video file names and notes logged appropriately in the OGI section of the form in Appendix A. The video records will be recorded even if no OGI-visible emissions are present. The video records will be approximately 2 min in duration and will consist of an OGI color photo, followed by normal imaging mode video for approximately 1 min, and then high-sensitivity imaging video for approximately 1 min (all contained in the same video record). Step 4 has multiple purposes. One purpose is to document each PC in the “as encountered state” prior to any control loop shutdown for installation of PC actuation counters or flow meters. This is necessary because it has been suggested that shutting down the process to install flow meters can reset a malfunctioning PC state in some cases (Howard, 2015b). We assume here that a hypothetical malfunctioning state of an intermittent actuating PC manifests as near-continuous emissions from the PC that can be easily registered by a short-duration OGI survey. As discussed previously, we assume normal seepage emissions of an intermittent actuating PC system (when not actuating) are likely well below the detection sensitivity of the OGI camera, especially in normal imaging mode (Simpson, 2014).

As part of Step 4, HHPs with ppm sensitivity will be used to check for emissions on all parts of the PC system, and “Snoop” liquid (Swagelok) will be used in some cases. Attempts will be made to determine and video-document the origin of observed emissions from the PC system. For example, it may be determined that a tubing connection in the vicinity of the PC, and not the PC itself, is the emission source. This information will be appropriately noted in saved video files.

Step 5: Using information from Step 3, in coordination with the OR, each PC system will be assigned to one of the on-site survey categories listed below based on the best available understanding of the design and purpose of the PC system and the expected actuation frequency with intermittent throttling applications typically defaulting to group (f).

- (a) PCs that are not NG-driven, are recorded, but are not subject to measurements.
- (b) PCs that are associated with non-operating processes (seasonal or decommissioned). These will be recorded in steps (3) and (4) but are not subject to further measurements unless emissions are observed in Step 4.
- (c) Zero bleed (self-contained) PCs. These are PCs that should not emit to the atmosphere.
- (d) Intermittent PCs that are expected to actuate very infrequently ($>$ every 1 day).
- (e) Intermittent PCs that are expected to actuate infrequently ($>$ every 15 min, but $<$ 1 day).
- (f) Intermittent PCs that are expected to actuate frequently ($<$ 15 min).
- (g) Continuous PCs.
- (h) Potentially malfunctioning PC or process (established in subsequent steps).

See Appendix A for further information and the field log sheet.

Step 6: In coordination with the OR, compare expected behavior of the PC system established by make/model/application analysis (Step 5) with the OGI and HHP observations (Step 4) and log findings on the Appendix A form. This discussion might require additional OGI video observations and HHP tests (or Snoop liquid test) to help pinpoint the origin of emission to determine if it is related to the PC system. Depending on the PC group assigned in Step 5, observation of emissions during the OGI/HHP survey will mean different things and indicate different subsequent procedure steps. For group (g), OGI-observed emissions can confirm the continuous PC bin. If a group (c) through (f) PC is observed to be continuously emitting and a careful inspection confirms that the emission is not a nearby fugitive or tubing leak source, the PC could be misclassified—actually a continuous PC group (g) or a very frequently actuating PC in group (f)—or possibly assigned to group (h) as a malfunctioning PC or process.

Step 7 – PC Emissions Measurements 1: Prior to installation of any equipment that requires control loop shutdown, an initial series of emissions measurements will be made on select PC systems using the augmented BHFS protocol (Appendix E), with results recorded in the appropriate section of Appendix A.

If Step 4 (OGI/HHP survey) reveals no continuous emissions from PCs at the site, this step may be skipped as the continuous emissions will be assumed to be minimal with regard to malfunction and below the assessment capability of the BHFS.

If continuous emissions are observed in Step 4, the emissions will be measured using three replicates (minimum of one) using the augmented BHFS approach (if deemed safe to do so) and results logged on the form shown in Appendix A.

Step 8 – PC Emissions Measurements 2: Using information from previous steps, measurements will be made using a combination of installed flow meters (Appendix D) and augmented BHFS (Appendix E). For this project, BHFS measurements will be limited primarily to assessment of apparently continuous emissions, or for use in cases where installed flow meters are potentially problematic or unsafe.

In preparation for potential installed flow meter measurements, safety considerations and process impact for the proposed control loop shutdown, equipment installation, and reenergize step will be evaluated and only attempted if the OR approves the action.

Some PCs, such as safety devices, might trigger a well shut-in on loss of gas pressure (very high process impact), so these PCs (usually very infrequently actuating) will not be assessed with installed flow meters. In all cases, the potential process impact on downstream PCs will be deduced and noted if possible. If installation of the flow meter is not possible due to safety, configuration, or process concerns and continuous emissions are observed in Step 5, the augmented BHFS will be used to measure the emission if possible.

If feasible and if time allows, emission measurements will be attempted on all PCs in groups (d) through (h) at the site using the prioritization scheme described below. The default measurement time period will be 15 min to 1 h. For continuous emissions, the sampling time may be reduced to approximately 5 min or lower in some cases if the emission appears to be temporally stable. It is acknowledged that the following measurement prioritization ranking is biased toward higher emitting PCs.

- (1) If a suspected malfunctioning PC, in Group (h), is encountered, it will be a high priority for emissions measurement because the in-field repair secondary objective may be attempted (Step 10) and because this condition might disproportionately impact emissions.
- (2) If a PC appears to be a relatively significant emitter in Step 4 (e.g., continuous PC or heavily throttling (process-driven) intermittent PC), it will be a very high priority for emissions measurement since this type of PC can possess higher time-averaged emissions compared to infrequently actuating PCs, and natural actuation events will be easily logged in the base observation window of 15 min to 1 h. These may be PCs in Group (g) or group (f) with apparently very high actuation frequency (e.g., < 5 min).
- (3) Intermittent PCs that are observed to be relatively frequently acting, in Group (f) with cycle times less than 15 min, are a high priority for emissions measurement since this type of PC can possess higher time-averaged emissions compared to infrequently actuating PCs, and natural actuation events are possible to log in the base 15-min observation window. Another consideration is the expected actuation volume (if deemed high).
- (4) Intermittent PCs that are believed to be relatively infrequently acting, in Group (e) with cycle times of > 15 min but < 1 hour, for example, are a medium priority for emissions measurements. If the PC is judged to be a candidate for manual actuation and/or if expected actuation volume is deemed higher than normal, this will increase the priority of the measurements. If the PC is judged to be problematic for measurement by installed flow meters (e.g., instrumentation is potentially unsafe or would cause high process impact, coupling is technically problematic, manual actuations are judged to be potentially not representative), it will be a lower priority for measurement.
- (5) Intermittent PCs that are judged to be very infrequently actuating, in Group (d) and > 1 day, and/or are problematic for installed flow meters (e.g., instrumentation is potentially unsafe or would cause high process impact, coupling is technically

problematic, manual actuations are judged to be potentially not representative) will be the lower priority for measurement. If an infrequently actuating intermittent PC is not observed to be emitting in Step 4 and is very difficult to (or cannot be) instrumented with installed flow meters, it will be classified as a very low overall priority for emissions measurement since the degree to which the augmented BHFS procedure can assess these PCs is not well understood at this time.

- (6) Any PC system that cannot be measured safely with either installed flow meters or augmented BHFS will not be measured.

It is believed that emissions measurements can be conducted on some infrequently actuating intermittent PC systems using a manually triggered actuation. The ability to manually actuate and measure a PC emission depends on a number of factors including PC system design, monitoring fixture options, and safety and process considerations. Manual actuations of infrequently actuating PCs may be attempted on an experimental basis (upon approval by the OR) if the natural actuation event is not observed in the base time period of 15 min to 1 h. For these cases, a repeat 15-min observation may be used with a second manual actuation toward the end of the period. The manual actuation procedure will be detailed in field notes.

Step 9 – PC Actuation Counting: In coordination with the OR, the team will assess the feasibility of installing the PC actuation counters on the power gas tubing from the controller to the valve actuator for PCs in Groups (e), (d), and possibly (f) that do not show continuous emissions in the OGI survey, as per Appendix B. This step will be executed by the OR and will require proper control loop shutdown and restart and will be potentially coordinated with flow meter installations (Step 8). The selected PCs will be monitored for actuation events while measurements are being made on other PCs. The target sampling period of 2–3 hours or longer must be approved by the OR. It will be important to ensure that other measurement activities (such as installation of flow meters on other PCs) do not affect this monitoring activity.

PCs from group (f) might or might not be included in this PC actuation counting category. If the group (f) PC is obviously actuating with a high frequency (< 15 min) or is a near-continuous throttling application, it does not need to be monitored with an actuation counter since its temporal profile will be captured by the installed flow meter measurement. With a limited number of counters and a limited amount of time on-site, a prioritization scheme will be developed in coordination with the OR to ensure procedures are realistic and measurements remain on schedule. Manual actuation of these PCs (if possible) might be required to ensure proper setup, but these events could also be measured as part of Step 8.

Step 10: For PCs that are identified by the OGI/HHP survey to be potentially malfunctioning—possible assignment to group (h)—a complete record set will be acquired including emission measurements and OGI videos. It is likely that installed flow meter measurements will be used to assess group (h) candidates because the temporal resolution provided by the measurement can be a powerful diagnostic for later analysis. Upon completion of the measurement set on a potential group (h) PC, the OR (or PC manufacturer if on-site) may attempt an in-field corrective action if it is deemed feasible/safe. The details of the repair will be recorded. The installed flow meter will be left in place during the operation, and the PC will be reassessed by emission measurement and OGI after corrective action.

Step 11: Evacuated Canister Acquisition. As part of Step 8, typically one evacuated canister per site will be acquired during the PC emission measurements (Appendix F).

Step 12: Research measurements such as quantitative OGI and in-field speciation (e.g., using Precise[®] Tunable Filter Spectroscopy [TFST[™]] by MKS Instruments) might be conducted as resources and time allow. These measurements will be described in an addendum to this QAPP.

Step 13: Decommission site measurements and complete logs and chain of custody information.

Step 14: Back up data for each site visited at the end of the day.

4.0 Information, Measurement, and Analysis Procedures

4.1 Information-Gathering and Measurement Systems

This section details the primary information-gathering and measurement systems to be used in this study. This information is listed in Table 4-1 in the order used in the deployment sequence.

Table 4-1. Information-Gathering and Measurement Systems

No.	Instrument or Technique	Make/Model or Approach	Parameter Measured
1	PC, process, application and classification information	Information gathering using established procedures (Appendix A)	Systems information recorded
2	OGI mid-wave IR camera	GF320, FLIR, North Billerica, MA (Appendix B)	Safety survey and video files of emissions or documentation of no observable emissions
3	PC actuation counters	SERN-5 pneumatic counter, Control Equipment Inc., Wichita Falls, TX (Appendix C)	PC actuation events counted
4	Installed flow measurement devices	FT3 INLINE-0uP-SS-ST-E1-D0-MB-G3-G3, Fox Thermal Instruments, Marina, CA MW-10S Lpm-D-DB9M-MODBUS-485-X, Alicat Scientific, Inc., Tucson, AZ MW-100S Lpm-D-DB9M-MODBUS-485-X, Alicat Scientific, Inc., Tucson, AZ MW-500S Lpm-D-DB9M-MODBUS-485-X, Alicat Scientific, Inc., Tucson, AZ Custom four-channel, C1D2 cable, data acquisition panel for installed flow meters, Techstar Inc., Deer Park, TX (Appendix D)	Time-resolved whole-gas flow rates of PC emissions at 1 Hz data collection frequency
5	Augmented BHFS	BHFS, Bacharach Inc., New Kensington, PA (Appendix E)	Manually recorded whole-gas flow rates of continuous emissions with 100% exhaust BHFS concentration monitoring by flame ionization detector (FID)
5a	HHP: sensitive hydrocarbon (HC) leak measurement	PPM Gas Surveyor 500, Heath Consultants, Houston TX, or Gas Rover, Bascom-Turner Instruments, Norwood, MA	HC leak detection supporting OGI survey and HC concentration measurements at the exhaust of the BHFS as a QA check
5b	HHP: sensitive methane (CH ₄) and HC leak measurement	Detecto Pak-Infrared (DP-IR™), Heath Consultants, Houston, TX	CH ₄ with HC interference leak detection supporting OGI survey and concentration measurements at the exhaust of BHFS as a QA check

No.	Instrument or Technique	Make/Model or Approach	Parameter Measured
5c	HHP: FID	Thermo Scientific, TVA-1000B, Waltham, MA	HC leak detection supporting OGI survey and HC concentration measurements at the exhaust of the BHFS as a QA check
6	Subatmospheric canisters/ laboratory analysis	Silonite canisters, Entech Instruments, Simi Valley, CA / laboratory subcontractor analysis (Appendix F)	Compound speciation (limited application)

4.1.1 PC, Process, Application, and Classification Information

This section and associated appendices outline procedures to document the PC systems encountered in the field. The procedures used here build on those described by OIPA (2014) and other efforts. As previously discussed, one objective of the project is to obtain information of sufficient detail to allow later categorization according to separately developed PC classification standards and to allow comparisons with engineering calculations if possible. These PC system data-gathering procedures fit into the stepwise field survey approach described in Section 3.4. In addition to PC information, the procedure helps to identify the emission measurement priorities in potentially malfunctioning PC systems. These stepwise procedures are documented on the field log sheets shown in Appendix A. Preselected sites offer advantages for accurate characterization of PC system details since some work can be done beforehand and the work can be more complete and accurate. For daily selected sites, the ONG on-site OR must provide information support for these data-gathering activities, so knowledgeable personnel are required. Examples of information gathered on the field form in Appendix A include the following:

- Well pad information (ID, location, formation, layout)
- Gas, water, and condensate production information (can be provided at a later date)
- Gas composition information (can be provided at a later date)
- Basic description of PCs on the well pad (operating and non-operating processes)
- PC manufacturer information (make/model/year)
- Information on PC date of installation, maintenance, or retrofit status (if known)
- Digital photographs and OGI video of the PC systems
- Process function of each PC
- Process variables required for engineering calculations
- Physical measurements required for engineering calculations
- Collaborative estimation of PC actuation frequency (including on-site observation)
- Collaborative assignment to survey PC type category (based on actuation frequency)
- Collaborative assessment of PC system maintenance state (malfunctioning or nominal)

Jacobs will collect and summarize information gathered using field worksheets. It is envisioned that this information will be summarized in a separate database for each ONG operator that contains hyperlinks to specific photographs and OGI videos. This database will include PC emission measurement results in addition to engineering calculations where possible. The company-specific database will be shared only with the ONG site operator for review. If agreeable to the ONG operators, some select information might be shared with PC manufacturers for diagnostic purposes. As part of collaborative reporting, information from the individual ONG operator databases will be rolled up and anonymized for group discussion and publication.

4.1.2 Optical Gas Imaging and Hand-Held Leak Detection Probes

OGI is an emission survey tool that allows direct observation of normally invisible CH₄, HC, and other air pollutant emissions from a variety of sources. OGI systems work in a sub-region of the IR spectrum where molecules that make up the emission plume can absorb or emit energy (IR photons). The OGI camera looks at a scene and records a video image, similar to a standard video camera except OGI records IR photons emitted from objects in the background and by the gas itself. If an HC fugitive or vented gas emission is present, the molecules in the plume can net absorb IR radiation (or net emit if hotter than the scene), producing a visible contrast (detection) in the image. The OGI camera (Figure 4-1) used in this study is a FLIR model GF320 (FLIR Systems, Billerica, MA) operating in the 3.2 to 3.4 μm spectral region, which is appropriate for upstream oil and gas use.



Figure 4-1. FLIR GF320 OGI camera

The OGI camera (general operation procedures described in Appendix B) will be used in the following ways in this study: scanning of site for safety checks, assisting in identification of PC system types (Appendix A), identifying fugitive emissions not associated with the PC systems, and providing QA support of actuation counting emissions measurements (Appendices C–F), as well as supporting research measurements, if used. The OGI camera will be used in both hand-held survey mode with the camera operator scanning the site and components and relaying information to the study team and in tripod-mounted mode where the cameras is set to record a close-up of a component for some period of time to document some aspect of the measurement or observation. The various uses of OGI, operational modes, duration of videos, and the archiving of video are described in the appendices. Since OGI cameras are not intrinsically safe devices (potential ignition sources), strict safety precautions and appropriate stand-off distances must be used in close coordination with the site operator. The use of OGI, digital cameras, and installed

flow meters that will require special permissions and hot work permits will be described in the approved site safety plan for each ONG operator. The OGI camera is a high-value EPA-owned asset, and it is currently planned to be operated only by EPA personnel as part of the study. EPA personnel will transfer videos to the Jacobs WAL daily for backup.

To support OGI, hand-held HHPs with ppm sensitivity will be used to check all parts of the PC systems for sustained emissions. HHPs are further described in Section 4.1.5.

4.1.3 PC Actuation Counters

PC actuation counters are proposed to be used on a limited experimental basis to improve understanding of infrequently actuating PC systems. Actuation counting might not be used at all sites due to resource constraints and/or ONG operator use restrictions. Actuation counters will not be used on continuous PCs, frequently actuating on/off intermittent PCs, or near-continuous throttling applications since the PC emissions measurements should sufficiently acquire actuation data from these PC system types. Figure 4-2 shows a model SERN-5 pneumatic counter from Control Equipment Inc. (CEI; Wichita Falls, TX). These counters were developed originally for lease custody transfer units (commonly called barrel counters) but are believed to work robustly to register actuations for a variety of on/off intermittent PCs. The actuation counters will be installed on the power gas tubing from the controller to the valve actuator and are limited to 30 psi. These counters will not work well with throttling PCs since the frequent small pressure spikes will be inconsistently registered. A pre- and post-deployment test procedure was developed by the ORD NRMRL Quality Assurance Metrology (MET) Laboratory to characterize the range of operation (on the low end) and repeatability of the counter. This information, along with installation instructions, is included in Appendix C.



Figure 4-2. Model SERN-5 pneumatic counter (not fully installed)

4.1.4 PC Emissions Measurements by Flow Meters

One of the main objectives of the Uinta Basin Well Pad Pneumatic Controller Emissions Research Study is to conduct quality-assured PC emissions measurements. This section describes the use of installed flow meter measurements as part of the study. By using four flow meters with different ranges, emissions can potentially be measured over a wide range. Table 4-2 lists the equipment that will be used to conduct the emissions rate measurements. Figure 4-3 shows the flow meters used in the project.

The flow meter will be installed in line with the PC after the system has been depressurized. It is expected that on-site ORs will assist in this installation process. The flow meters can be used independently of each other or in series depending on the leak rate to be measured. All four flow meters will log data directly to a four-channel C1D2 data acquisition system (Techstar Inc., Deer Park, TX), which has the ability to log data from four different flow meters at 1 Hz. The flow meters will be equipped with Swagelok fittings and appropriate lengths of tubing to ensure their adaptability to different PC configurations. Two Excel spreadsheets will be used to reduce flow data. The Kimray spreadsheet is used to produce the engineering emission estimates from the PCs. The Alicat spreadsheet is used to correct the Alicat meter data for gas stream composition differences. Both spreadsheets, as well as further information on the operating procedures for the flow meters can be found in Appendix D: “Operating Procedures for Flow Meter Measurements.”

Table 4-2. Equipment Used for PC Emissions Flow Meter Measurements

Device	Manufacturer	Model	Range / Description
Calibration system mass flow controller (MFC)	Alicat Scientific, Inc., Tucson, AZ	MCR-100S Lpm-D-485-MODBUS-X / 5M, 5IN	0.5–100 slpm
Flow meter 1	Fox Thermal Instruments, Marina, CA	FT3 INLINE-0uP-SS-ST-E1-D0-MB-G3-G3,	0–24 (nom.) – 47 slpm 0–47 (nom.) – 235 slpm
Flow meter 2	Alicat Scientific, Inc., Tucson, AZ	MW-500S Lpm-D-DB9M-MODBUS-485-X/5M	2.5–500 slpm
Flow meter 3	Alicat Scientific, Inc., Tucson, AZ	MW-100S Lpm-D-DB9M-MODBUS-485-X/5M	0.5–100 slpm
Flow meter 4	Alicat Scientific, Inc., Tucson, AZ	MW-10S Lpm-D-DB9M-MODBUS-485-X	0.05–10 slpm
Data acquisition system for recording data	Techstar Inc., Deer Park, TX	Four-channel C1D2 DAQ for installed flow meters	1 Hz start/stop data acquisition panel



Figure 4-3. Fox Thermal flow meter FT3 (left) and Alicat flow meter (right)

4.1.5 PC Emissions Measurements by Augmented BHFS

Emissions measurements will also be conducted using a BHFS (Bacharach, Inc., New Kensington, PA) with an augmented QA protocol to quantify emission rates of continuously emitting pneumatic devices and any nearby fugitive emissions that might have an effect on flow meter-based PC emission measurements. Due to recent discussions regarding the validity of BHFS measurements (Howard et al., 2015), the use of a QA measurement device at the exhaust of the sampler will be an essential component of this study.

The BHFS (Figure 4-4) is a portable, intrinsically safe, battery-powered instrument that non-invasively measures the rate of gas emissions from a variety of sources. The system is designed for and calibrated to CH₄, but measures all combustible compounds (all HCs) in the sampled emission stream. With a properly operating instrument, the measured emission rate of a CH₄/mixed HC stream (as encountered in upstream ONG applications in wet gas areas) will deviate from actual due to both internal sensor response and flow rate effects. The instrument is packaged inside a backpack, thus leaving the operator's hands free. A component's leak rate is measured by sampling at a high flow rate (up to 10.5 scfm) so as to capture all the gas emitted from the component along with some amount of surrounding air. For the BHFS measurements, the instrument-determined emission rate is calculated using Equation 4-1:

$$\text{Emission (cfm)} = \frac{\text{Emission \%} - \text{Background \%}}{100} \times \text{Flow (cfm)} \quad (4-1)$$

where:

- Emission (cfm) = Flow rate of emission in cubic feet per minute
- Emission % = Volume percent of HC in the sample stream
- Background % = Volume percent of HC in the background sampling area
- Flow (cfm) = Flow rate of sample and background air in cubic feet per minute

The BHFS response is calibrated at 2.5% and 100% CH₄ before each day's trials. The augmented QA protocol refers to secondary measurements of the BHFS exhaust to confirm the leak rate (%) determinations are similar to those of Stovern et al. (2016).



Figure 4-4. Bacharach Hi Flow sampler (BHFS) with some attachments

The current choices for QA measuring systems are the TVA-1000B (Thermo Scientific Waltham, MA) for the low end and either a PPM Gas Surveyor 500 (Gas Measurement Instruments Ltd, Renfrew, Scotland) or a Gas Rover (Bascom-Turner Instruments Inc., Norwood, MA) as shown in Figure 4-5. Further information on the operating procedures for the flow meters can be found in Appendix E: “Operating Procedure for Augmented Bacharach Hi Flow Sampler Measurements.”



Figure 4-5. TVA-1000B (left), PPM Gas Surveyor 500 (middle), and Gas Rover (right)

4.1.6 Evacuated Canister Acquisition and Analysis

Evacuated canister samples will be collected on a limited basis as part of this PC emissions study. A target of at least one canister per site or site gas type will be attempted with additional samples being collected depending on the number of controllers at the site, number of emitting controllers, and several other factors. The acquisition of these subatmospheric canister samples will be conducted either at the exhaust of the BHFS or as part of the installed flow meter measurements. Samples will be collected in specially cleaned and evacuated 1.4-liter Silonite[®] canisters (part no. 29-MC1400SQT) manufactured by Entech Instruments (Simi Valley, CA).

Canisters will be sampled using a simple collection system consisting of stainless steel tubing, sintered filter, in-line vacuum gauge, and manually operated toggle valve that, when open, acquires a fast grab sample over a 20-second time period (typically reducing canister pressure from stated values of 25–28 in. Hg to 7–9 in. Hg). The 1.4-liter canister is connected to the collection system by a quick connect fitting. The sample is collected by inserting the collection system and canister into the exhaust stream of the BHFS. The initial and final vacuum values of the canister are recorded on the sample chain of custody (COC) form. If the vacuum is not between 25 and 28 in. Hg, sampling is aborted and a new canister is used. Sample ID, canister number, and final pressure of each sample are recorded on the COC form.

The evacuated canister grab samples of selected pneumatic devices will be analyzed for C₂–C₁₂ by EPA Method TO-14A (U.S. EPA, 1999) and for CH₄ using Modified EPA Method 18 (U.S. EPA, 2013). The TO-14A analysis is similar to the original photochemical assessment monitoring stations (PAMS) approach; however, all compounds are individually calibrated instead of reporting all compounds using a carbon response factor derived from a propane calibration curve.

The subcontractor selected for the canister sample analysis has worked with EPA to develop an approved approach to use EPA Method 18 to analyze fuel samples collected in canisters for HCs. The approved alternative is EPA ALT100 and is very similar to the American Society for Testing and Materials D1945 approach (ASTM, 2010).

The canister grab samples will also be analyzed for the compounds listed in Table 4-3 (PAMS compounds). For the PAMS compound analysis, the samples will be cryogenically concentrated and analyzed by gas chromatography/flame ionization detector (GC/FID). Further details about the canister acquisition and analysis are provided in Appendix F: “Evacuated Canister Analysis Procedures.”

Table 4-3. List of PAMS Target VOCs

Compound	Class
Acetylene	Olefin
Ethylene	Olefin
Ethane	Paraffin
Propylene	Olefin
Propane	Paraffin
Isobutane	Paraffin
1-Butene	Olefin
<i>n</i> -Butane	Paraffin
<i>trans</i> -2-Butene	Olefin
<i>cis</i> -2-Butene	Olefin
Isopentane	Paraffin
1-Pentene	Olefin
<i>n</i> -Pentane	Paraffin
Isoprene	Olefin
<i>trans</i> -2-Pentene	Olefin
Continued on next page	

Compound	Class
<i>cis</i> -2-Pentene	Olefin
2,2-Dimethylbutane	Paraffin
Cyclopentane	Paraffin
2,3-Dimethylbutane	Paraffin
2-Methylpentane	Paraffin
3-Methylpentane	Paraffin
2-Methyl-1-pentene	Olefin
<i>n</i> -Hexane	Paraffin
Methylcyclopentane	Paraffin
2,4-Dimethylpentane	Paraffin
Benzene	Aromatic
Cyclohexane	Paraffin
2-Methylhexane	Paraffin
2,3-Dimethylpentane	Paraffin
3-Methylhexane	Paraffin
2,2,4-Trimethylpentane	Paraffin
<i>n</i> -Heptane	Paraffin
Methylcyclohexane	Paraffin
2,3,4-Trimethylpentane	Paraffin
Toluene	Aromatic
2-Methylheptane	Paraffin
3-Methylheptane	Paraffin
<i>n</i> -Octane	Paraffin
Ethylbenzene	Aromatic
<i>m/p</i> -Xylene	Aromatic
Styrene	Aromatic
<i>o</i> -Xylene	Aromatic
<i>n</i> -Nonane	Paraffin
Isopropylbenzene	Aromatic
<i>n</i> -Propylbenzene	Aromatic
1,2,4-Trimethylbenzene	Aromatic
1,3,5-Trimethylbenzene	Aromatic
<i>o</i> -Ethyltoluene	Aromatic
<i>m</i> -Ethyltoluene	Aromatic
<i>p</i> -Ethyltoluene	Aromatic
<i>m</i> -Diethylbenzene	Aromatic
<i>p</i> -Diethylbenzene	Aromatic
1,2,3-Trimethylbenzene	Aromatic
<i>n</i> -Decane	Paraffin
<i>n</i> -Undecane	Paraffin
Total non-methane organic compounds	
Total speciated PAMS hydrocarbons	

4.1.7 Temperature and Pressure Measurement

Ambient temperature measurements will be conducted using a digital thermometer (Traceable Control Company, Webster, TX). Pressure measurements were made using an M1 Series digital manometer (Meriam Process Technology, Cleveland, OH). The temperature and pressure measurements will be conducted at each well pad site on arrival and recorded on the checklist shown in Appendix A.

The pressure sensor we used was a. We also need to correct the temperature instrument used to: Digital Thermometer by.

4.2 On-Site Procedures

Site-specific procedures to be followed will vary based on individual ONG companies, each company's health and safety procedures will be followed. An example of daily sampling procedures is given in section 3.4 of this QAPP.

4.3 Critical Measurements

The critical measurements for the field experiments are presented in Table 4-4.

Table 4-4. Critical Measurements

Measurement	Parameter	Technique	Cycle Time
Video record	Optically capture and quantify entire leak activity	OGI mid-wave IR camera	Variable
Liters per minute	Whole-gas emission rates	Installed flow meter	1 Hz
Leak rate (lpm) Leak rate (%)	Whole-gas emission rates	BHFS (Bacharach, Inc., New Kensington, PA)	0.3 Hz
Evacuated canister sample	Speciated HCs	Subatmospheric evacuated canister samples	N/A
Leak rate (%) or concentration value	CH ₄ emission rate at BHFS exhaust and leak identification in support of OGI survey	FID, TVA-1000B (Thermo Scientific Waltham, MA)	1 Hz
Leak rate (%) or concentration value	CH ₄ emission rate at BHFS exhaust and leak identification in support of OGI survey	PPM Gas Surveyor 500 (Gas Measurement Instruments Ltd, Renfrew, Scotland)	1 Hz
Leak rate (%) or concentration value	CH ₄ emission rate at BHFS exhaust and leak identification in support of OGI survey	Gas Rover, (Bascom-Turner Instruments Inc. Norwood, MA)	1 Hz
Counts	Number of times a PC actuates	Model SERN-5 PC (CEI, Wichita Falls, TX)	1 count per actuation

5.0 Quality Assurance and Quality Control

5.1 Data Quality Indicator Goals

Table 5-1 lists the data quality indicator (DQI) goals for the project.

Table 5-1. DQI Goals for the Project

Measurement Parameter	Analysis Method	Assessment	Accuracy	Precision
Flow rate	FT3 INLINE-0uP-SS-ST-E1-D0-MB-G3-G3, Fox Thermal Instruments, Marina, CA MW-100S Lpm-D-DB9M-MODBUS-485-X, Alicat Scientific, Inc., Tucson, AZ MW-500S Lpm-D-DB9M-MODBUS-485-X, Alicat Scientific, Inc., Tucson, AZ	50 lpm of CH ₄ gas delivered using a MET laboratory certified MFC. Gas allowed to flow for 1 min.	10% of expected flow rate or ± 2.5 lpm	$\pm 10\%$
	MW-10S Lpm-D-DB9M-MODBUS-485-X, Alicat Scientific, Inc., Tucson, AZ	5 lpm of CH ₄ gas delivered using a MET laboratory certified MFC. Gas allowed to flow for 1 min.	10% of expected flow rate or ± 0.25 lpm	$\pm 10\%$
HC leak rate	BHFS, Bacharach, Inc., New Kensington, PA	Multi-point calibration check prior to study using an Environics gas divider. Zero/span calibration setting prior to daily field deployment. Multi-point calibration check post-study using an Environics gas divider.	20% of set CH ₄ flow rates for multi-point checks. 10% of known CH ₄ cylinder concentration for single-point checks.	$\pm 20\%$
HC concentration measurement from leaking component or at BHFS exhaust	FID TVA-1000B, Thermo Scientific Waltham, MA	Multi-point calibration check prior to study using an Environics gas divider. Zero/span one-point verification check prior to daily field deployment. Multi-point calibration check post-study using an Environics gas divider.	20% of set CH ₄ flow rates for multi-point checks. 20% of known CH ₄ cylinder concentration for single-point checks.	$\pm 20\%$
Continued on next page				

Measurement Parameter	Analysis Method	Assessment	Accuracy	Precision
HC concentration measurement from leaking component or at BHFS exhaust	PPM Gas Surveyor 500, Gas Measurement Instruments Ltd, Renfrew, Scotland	Multi-point calibration check prior to study using an Environics gas divider. Zero/span one-point verification check prior to daily field deployment. Multi-point calibration check post-study using an Environics gas divider.	20% of set CH ₄ flow rates for multi-point checks. 20% of known CH ₄ cylinder concentration for single-point checks.	± 20%
HC concentration measurement from leaking component or at BHFS exhaust	Gas Rover, Bascom-Turner Instruments Inc., Norwood, MA	Multi-point calibration check prior to study using an Environics gas divider. Zero/span one-point verification check prior to daily field deployment. Multi-point calibration check post-study using an Environics gas divider.	20% of set CH ₄ flow rates for multi-point checks. 20% of known CH ₄ cylinder concentration for single-point checks.	± 20%

Additionally, the OGI camera DQI will be assessed by visualizing the emissions from the BHFS exhaust during the daily span procedure. Actuation counters will be evaluated using a Mensor APC-600 (automated pressure calibrator) containing a 0 to 100 psig pressure module (± 0.01 psi uncertainty), as shown in Figure 5-1. Actuation counters will first be evaluated to determine actuation pressure by slowly increasing pressure until the device triggers. The actuation counters will then be subjected to a series of 10 pressure pulses greater than their actuation pressure. Each pulse will be followed by a complete depressurization of the actuation counter. The actuation counters will be considered acceptable if their actuation pressure is below 5 psig and they count all 10 pulsed actuation cycles.



Figure 5-1. Mensor APC-600 with actuation counter attached.

5.1.1 Accuracy

Accuracy of measurement parameters is determined by comparing a measured value to a known standard, assessed in terms of percent bias using Equation 5-1:

$$\left[1 - \left(\frac{\text{Measurement}}{\text{Standard}} \right) \right] \times 100 = \% \text{ Bias} \quad (5-1)$$

Percent bias measurements are expected to fall within the tolerances shown in Table 5-1.

5.1.2 Precision

Precision is evaluated by making replicate measurements of the same parameter and assessing the variations of the results. Precision is assessed in terms of relative percent difference, or relative standard deviation. The replicate measurement points will be one specific parameter value within the measurement range of each instrument listed in Table 5-1, and replicate measurements are expected to fall within the tolerances shown in the table.

5.2 Assessment of DQI Goals

The QC checks used in the field to assess the DQI goals are provided in Table 5-2.

Table 5-2. Procedures Used to Assess QA Objectives

Measurement Parameter	Analysis Method	Assessment Method
Flow rate	FT3 flow meter, Fox Thermal Instruments, Marina, CA Alicat flow meters – 100 and 500 slpm, Alicat Scientific, Inc., Tucson, AZ	Multiple in-field single-point checks: 50 lpm of CH ₄ gas delivered using a factory-certified MFC. Gas allowed to flow for 1 min.
Flow rate	FT3 flow meter, Fox Thermal Instruments, Marina, CA Alicat flow meters – 10, 100, and 500 slpm, Alicat Scientific, Inc., Tucson, AZ	Multiple in-field point check: 5 lpm of CH ₄ gas delivered using a factory-certified MFC. Gas allowed to flow for 1 min.
HC leak rate	BHFS, Bacharach Inc., New Kensington, PA	Multi-point pre- and post-study calibration checks using an Environics gas divider. Zero/span calibration setting prior to daily field deployment.
HC concentration measurement from leaking component or at BHFS exhaust	FID TVA-1000B, Thermo Scientific Waltham, MA	Multi-point pre- and post-study calibration checks using an Environics gas divider. Zero calibration setting prior to daily field deployment. Cross-comparison to BHFS readings.
HC concentration measurement from leaking component or at BHFS exhaust	PPM Gas Surveyor 500, Gas Measurement Instruments Ltd, Renfrew, Scotland	Multi-point pre- and post-study calibration checks using an Environics gas divider. Cross-comparison to BHFS readings.
HC concentration measurement from leaking component or at BHFS exhaust	DP-IR, Heath Consultants, Houston, TX	Multi-point pre- and post-study calibration checks using an Environics gas divider. Cross-comparison to BHFS readings.
Optical capture and quantification of entire leak activity	OGI mid-wave IR camera, GF320, FLIR, North Billerica, MA	Visualizing emissions from the BHFS exhaust during the daily calibration procedure.
PC actuation counts	Model SERN-5 pneumatic counter, CEI, Wichita Falls, TX	Pre-deployment tests using a Mensor APC-600 (automated pressure calibrator). Field check by manual actuation of a PC with counter attached.

5.2.1 Flow Meter Assessment

The Fox Thermal FT3 flow meter along with three Alicat flow meters (10, 100, and 500 slpm) will be used in the study to determine the leak flow rates from the PCs. All flow meters used in this study will have received manufacturer's calibration certification within 3 months prior to conducting the study. Additionally, all flow meters will be checked by conducting pre-deployment

and daily flow checks. For the Fox Thermal FT3 flow meter and two of the Alicat flow meters (100 and 500 slpm), 50 lpm of CH₄ gas will be delivered using a factory-certified MFC. Gas will be allowed to flow for 1 min. For the 10 slpm Alicat meter, 5 lpm of CH₄ gas will be delivered using a factory-certified MFC. Gas will be allowed to flow for 1 min. The flow rate observed during these tests should be within 5% of the set flow rate.

Given a failure to meet this DQI, response actions will include, but are not limited to, (1) performing manufacturer-recommended maintenance, and (2) seeking technical support from the manufacturer.

5.2.2 *Bacharach Hi Flow Sampler and QA Measuring Instrument Assessment*

The BHFS will be used in this study with an augmented QA protocol to quantify emission rates of continuously emitting pneumatic devices and any nearby fugitive emissions that might affect flow meter-based PC emission measurements.

Proper operation of the BHFS will be assessed by conducting multi-point pre- and post-study calibration checks using an Environics gas divider and by checking zero/span calibration settings prior to daily field deployment. The BHFS response is calibrated at 2.5% and 100% CH₄ before each day's trials. The augmented QA protocol refers to secondary measurements of the BHFS exhaust to confirm the leak rate (%) determinations are similar to those of Stovern et al. (2016). The current choices for QA measuring systems are the TVA-1000B (Thermo Scientific Waltham, MA), a PPM Gas Surveyor 500 (Gas Measurement Instruments Ltd, Renfrew, Scotland) or a DP-IR, Heath Consultants, Houston, TX. The BHFS response will be tested by introducing gas to the instrument inlet using an Environics gas divider in steps of 1 lpm from 1–10 lpm. The BHFS responses will be recorded and are expected to be within 10% of the gas divider set value. The QA measuring instrument will be tested by sampling at the exhaust of the BHFS for each of 10 set points on the gas divider. The recorded values are expected to be within 10% of the gas divider set value. Table 5-3 shows example results of a multi-point check conducted on the BHFS with the QA measuring instrument used at the exhaust.

Table 5-3. Sample BHFS Calibration Check Test

Environics Set Value (lpm)	BHFS (lpm)	Leak Rate (%) Measured by BHFS	Leak Rate (lpm) Measured by BHFS	Leak Rate (%) Measured by QA Instrument
1	201.4	0.54	1.1	0.45
2	202.1	1.07	2.1	1.00
3	202.2	1.52	3.1	1.5
4	202.1	1.83	3.9	1.9
5	203.0	2.62	5.3	2.3
6	202.8	2.92	6.0	3.1
7	203.4	3.65	7.3	3.6
8	203.5	4.13	8.4	4.0
9	203.4	4.62	9.4	5.0
10	203.6	5.06	10.3	5.5

5.2.3 Optical Gas Imaging (OGI) Camera Assessment

The OGI camera will be verified qualitatively by visualizing and recording the emissions from the exhaust of the BHFS during the daily span procedures.

5.2.4 PC Actuation Counter Assessment

The PC actuation counters will be assessed by conducting pre-deployment tests using a Mensor APC-600 automated pressure calibrator. Actuation counters are first evaluated to determine actuation pressure by slowly increasing pressure until the device triggers. The actuation counters are then subjected to a series of 10 pressure pulses greater than their actuation pressure. Each pulse is followed by a complete depressurization of the actuation counter. The actuation counters are considered acceptable if their actuation pressure is below 5 psig and they count all 10 pulsed actuation cycles.

The PC actuation counters will also be field verified by manual actuation of a PC with the counter attached. This manual actuation will be carried out whenever possible and will be conducted with the assistance of the on-site ORs.

6.0 Data Reporting and Validation

6.1 Reporting Requirements

Reporting requirements for this project include the following:

- PC, process, application, and classification information
- Flow rates logged by the custom-designed flow meter data acquisition system
- BHFS data records
- Recorded data files from QA measurement instruments
- OGI camera videos
- PC actuation counts

6.2 Data-Related Deliverables

Jacobs personnel are ultimately responsible for all data acquisition deliverables for this project. Some data and information will be developed by the EPA project team members and some information will be provided by the participating ONG operators. Some information will be developed by subcontractors to Jacobs. Jacobs is responsible for compiling, backing up, and summarizing all project information including QA assessments for all information at all steps of the process. Data-related deliverables include the following:

- Documentation of safe operation procedures and site plan approvals
- Acquisition of field data and information (Appendices A through E)
- Backed up calibration data, field data, and QA information on a daily basis
- Field notebook pages providing information on experimental setup and execution
- Results of DQI assessments for precision and accuracy, as shown in Table 5-1
- Data reduction and summaries

Table 6-1 lists the data-related deliverables, format of each deliverable, and personnel responsible.

Table 6-1. Data-Related Deliverables

Deliverable	Custodian	Delivered to	Format
PC, process, and site Information (Appendix A)	Jacobs WAL	EPA WACOR	PDF of hard copy
Optical gas imaging videos (Appendix B)	EPA R8* or Jacobs WAL	EPA WACOR	Video files
PC actuation counting data (Appendix C)	Jacobs WAL	EPA WACOR	PDF of hard copy
Emission data by flow meter (Appendix D)	Jacobs WAL	EPA WACOR	Data acquisition files
Emission data by augmented BHFS (Appendix E)	Jacobs WAL	EPA WACOR	PDF of hard copy or logger files
Evacuated canister data (Appendix F)	Subcontractor/Jacobs WAL	EPA WACOR	Excel and PDF files
Notebook page copies	Jacobs WAL	EPA WACOR	PDF of hard copy
Results of DQI assessments	Jacobs WAL	EPA WACOR	MS Word file
*EPA is responsible for acquiring data when an EPA OGI camera is used and for giving it to the Jacobs WAL for incorporation into the data set.			

6.3 Data Reduction Deliverables

Personnel from Jacobs are responsible for all data reduction activities for this project.

6.4 Data Validation Deliverables

Jacobs personnel are responsible for all data validation activities for this project. An assessment of whether or not DQI goals were met will be performed and reported in a project summary document.

6.5 Data Storage Requirements

Jacobs is responsible for recording and archiving the project data presented in Table 6-1. At the end of each day that experiments are performed, the raw data files from the data acquisition/control computer will be backed up using a standard USB thumb drive. Log sheets will be copied, and two independent copies will be maintained. The data will be permanently backed up to the EPA network upon return from the field. Jacobs field notebook entries will be scanned to PDF files and saved to the EPA network after completion of the field experiments.

7.0 References

- Allen, David T., Vincent M. Torres, James Thomas, David W. Sullivan, Matthew Harrison, Al Hendler, Scott C. Herndon, Charles E. Kolb, Matthew P. Fraser, A. Daniel Hill, Brian K. Lamb, Jennifer Miskimins, Robert F. Sawyer, and John H. Seinfeld. (2013) "Measurements of methane emissions at natural gas production sites in the United States." *Proceedings of the National Academy of Sciences* 110(44): 17768–17773.
- 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. (2014). "Methane emissions from process equipment at natural gas production sites in the United States: Pneumatic controllers." *Environmental Science and Technology* 49(1): 633–640.
- American Society for Testing and Materials (ASTM). (2010). ASTM D1945-03, "Standard Test Method for Analysis of Natural Gas by Gas Chromatography" West Conshohocken, PA: ASTM International. www.astm.org, (last accessed December 13, 2016). doi:10.1520/D1945-03R10.
- Howard, Touché. (2015a). "University of Texas study underestimates national methane emissions at natural gas production sites due to instrument sensor failure." *Energy Science and Engineering* 3(5): 443–455.
- Howard, Touché. (2015b). Comment on "Methane emissions from process equipment at natural gas production sites in the United States: pneumatic controllers." *Environmental Science and Technology* 49(6): 3981–3982.
- Howard, Touché, Thomas W. Ferrara, and Amy Townsend-Small. (2015). "Sensor transition failure in the high flow sampler: implications for methane emission inventories of natural gas infrastructure." *Journal of the Air & Waste Management Association* 65(7): 856–862.
- Oklahoma Independent Petroleum Association (OIPA). (2014). "Pneumatic Controller Emissions from a Sample of 172 Production Facilities", http://www.oipa.com/page_images/1418911081.pdf, (last accessed December 13, 2016).
- Prasino Group. (2013). "Determining Bleed Rates for Pneumatic Devices in British Columbia." http://www2.gov.bc.ca/assets/gov/environment/climate-change/stakeholder-support/reporting-regulation/pneumatic-devices/prasino_pneumatic_ghg_ef_final_report.pdf, (last accessed December 13, 2016).
- Simpson, David. (2014). "Pneumatic Controllers in Upstream Oil and Gas." *Oil and Gas Facilities* 3(05): 83–96.
- Stovern, Michael, Adam P. Eisele, and Eben D. Thoma. (2016). "Assessment of Pneumatic Controller Emission Measurements Using a High Volume Sampler at Oil and Natural Gas Production Pads in Utah." Extended Abstract #92, Air and Waste Management Association Air Quality Measurement Methods and Technology Conference, Chapel Hill, NC, March 15–17.

-
- U.S. EPA. (1999). "Compendium Method TO-14A – Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using Specially Prepared Canisters with Subsequent Analysis by Gas Chromatography." <https://www3.epa.gov/ttnamti1/files/ambient/airtox/to-14ar.pdf> (last accessed December 13, 2016).
- U.S. EPA. (2013). "EPA Method 18 – Measurement of Gaseous Organic Compound Emissions by Gas Chromatography using EPA ALT100" <https://www3.epa.gov/ttn/emc/approalt/ALT100.pdf> (last accessed December 13, 2016).

Appendix A: Pneumatic Controller and Site Information-Gathering Procedures

Contract EP-C-15-008

December 2016

Prepared for

Air Pollution Prevention and Control Division
National Risk Management Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Contents

1.0	Scope and Applicability	3
2.0	Summary of Method	3
3.0	Definitions	4
4.0	Health and Safety Warnings	4
5.0	Personnel Qualifications	4
6.0	Equipment and Supplies	4
7.0	Forms	5
8.0	Data and Records Management	5
9.0	References	5

Figures

Figure 7-1.	Daily site information	6
Figure 7-2.	PC system OGI scan	7
Figure 7-3.	PC information form	8
Figure 7-4.	Form for recording test values	9

1.0 Scope and Applicability

- 1.1** This document describes the procedures for gathering pneumatic controller (PC) and site information at each site during the 2016 Uintah Basin (UB) Regional Applied Research Effort (RARE) field measurement activities.
- 1.2** This procedure applies to U.S. Environmental Protection Agency (EPA) and contractor personnel performing screening activities for the 2016 UB RARE project and contains direction developed solely to provide internal guidance to UB RARE associated personnel.

2.0 Summary of Method

To achieve the primary and secondary objectives described in the Uintah Basin quality assurance project plan (QAPP), the scientific approach for this study relies on information gathering of well pad pneumatic controller (PC) systems and their process-specific applications, with field measurements of PC emissions and PC actuation data (where possible). This project will acquire information of sufficient detail to allow later assignment of the PC systems encountered into the best available categorization schemes (e.g., American Petroleum Institute PC standards currently under development). This project will use a simple, field survey-based PC system categorization scheme based on the expected temporal characteristics of the emission profile, with the following categories:

- PCs that are not capable of emitting natural gas (NG) to the atmosphere
- PCs that are not in operation due to seasonal or other reasons
- Intermittent PCs that are expected to actuate very infrequently (> every 1 day)
- Intermittent PCs that are expected to actuate infrequently (> every 15 min, but < 1 day)
- Intermittent PCs that are expected to actuate frequently (< every 15 min)
- Continuously emitting PCs
- Malfunctioning PC or associated equipment or process

For the purposes of the UB RARE project, a FLIR GF320 infrared (IR) camera is used for three main purposes. First, the IR camera is used to conduct a visual site survey to identify any potential hazards to health and safety. Second, the IR camera is used to identify PCs that are emitting hydrocarbons and determine the frequency of actuation. Third, during the PC measurement phase, the IR camera continuously monitors measurements being conducted at PCs to ensure complete leak capture.

Using this PC-type classification framework, PC system, PC application, and well pad process parameter data will be gathered using a system similar to (OIPA, 2014). Acquired information will include well pad site details, PC manufacturer, model number, actuator information, tubing length, and necessary PC-related process information. This basic PC system information will be augmented with other available information (e.g., date of installation, retrofit status, date of last maintenance) if known by the ONG operator. This information-gathering activity will improve knowledge of the types of PCs employed in the Uintah Basin (for the subset of well pad types surveyed). These data, for example, will provide activity factor (AF) information on the relative number of continuous and intermittent actuating PCs of various types in use. This information will allow PC emissions engineering calculations to be compared to PC emissions measurements. Additionally, this information will allow understanding of the designed PC system emission profile so that deviations

from nominal (e.g., malfunctions) can be detected and the potential for in-field repairs assessed (where possible).

3.0 Definitions

AF	activity factor
IR	infrared
NG	natural gas
OGI	optical gas imaging
ONG	oil and natural gas
OR	operator representative
PC	pneumatic controller
QAPP	Quality Assurance Project Plan
RARE	Regional Applied Research Effort
UB	Uintah Basin

4.0 Health and Safety Warnings

- 4.1** All health and safety considerations outlined in the project health and safety plan must be kept in mind when recording the specific parameters required in this procedure. It is the responsibility of the user of this procedure to establish appropriate safety and health practices.
- 4.2** Minimize exposure to potential health hazards by use of protective clothing, eyewear, and gloves.
- 4.3** Always consult the ONG operator representative (OR) when gathering specific process parameter data.
- 4.4** Ensure the process loop is de-energized for some measurements. This process will require the assistance of the ONG OR.

5.0 Personnel Qualifications

- 5.1** UB RARE field personnel must only operate equipment for which they are trained and authorized to use. Personnel must be trained by qualified operators.
- 5.2** UB RARE field personnel must be sufficiently trained to identify specific PC and process parameters.

6.0 Equipment and Supplies

- Paper-based forms for noting PC system, PC application, and well pad process parameters
- Infrared thermal imaging camera, FLIR model GF320 (FLIR Gas Detection Systems, Boston, MA)

7.0 Forms

The form shown in Figure 7-1 is completed for each site visited. This form supplies information on the equipment and operations at the site, emission measurement instrument calibrations, safety checks, and ambient temperature.

Figure 7-2 shows the form for recording data from the optical gas imaging (IR) camera. optical gas imaging (OGI) data are used to assess safety of operations in an area (measure levels of flammable gas or explosion hazards), document PC operation (gas release), assess source(s) of natural gas emissions (PC or nearby source), check IR camera readings against PC actuation counters and flow measurement systems, and estimate PC gas emissions.

Figure 7-3 shows the form for recording the pneumatic controller specific information. This form provides data for PC classification and for performing engineering calculations.

Figure 7-4 shows the form used for noting actual test values including the BHFS readings, flow meter readings, GMI readings, and temperature and pressure values.

8.0 Data and Records Management

Information generated or obtained by UB RARE field personnel is organized and accounted for in accordance with established records management procedures. Jacobs will provide PDF copies of all field-generated hard-copy forms to the EPA WACOR on a daily basis. Online versions of the field-generated forms will then be filled out in Word or Excel format and copies will be retained by both the Jacobs work assignment leader and the EPA WA contracting officer's representative.

The files are named using the following format:

Date/Operator/Site/PC ID (YYMMDD/A/01/01)

9.0 References

Oklahoma Independent Petroleum Association (OIPA). (2014). "Pneumatic Controller Emissions from a Sample of 172 Production Facilities", http://www.oipa.com/page_images/1418911081.pdf, (last accessed December 13, 2016).

ONG On-site Rep:	Date/Arrival Time	pg. 1 of
Site Safety Check / OGI Scan:		
GPS Location:		
Company ID (A-Z):	Site ID (01-99):	
Oil site or Gas site:	Permitted site or Permit-exempt site:	
Site Located on Tribal land?	OOOO site?	
First production before year 2000?	Daily-selected or Preselected Site Type:	
Site Layout Drawing Number:		
Site Photos IDs:		
Number of Wells:		
Number of Separators:		
Number of Condensate/Oil Tanks:		
Number of Water Tanks:		
Number of Compressors:		
Number of Heater Treaters:		
Number of Dehydrators:		
Notes Field for Other Equipment:		
Notes Field for Equipment Not in Use:		
Gas Production Level:		
Condensate/Oil Production Level:		
Water Production Level:		
Site Gas Composition Information Operator:		
Gas Composition Canister ID:		
Number of pneumatic devices:		
Number of pneumatic controllers:		
Number of non-working pneumatic controllers:		
Notes:		ver. 9/16/16

Figure 7-1. Daily site information

Survey scan of PCs

*Reference Site Drawing File:

pg. 1 of

ONG On-site Rep:

Date/Arrival Time

Company ID (A-Z):

Site ID (01-99):

PC ID*: (01-99)	Description	OGI Scan	PC group (a-h)	Measure Rank / Notes

Figure 7-2. PC system OGI scan

Operator and Site ID (e.g.YYMMDDA01):	Date and Arrival Time
PC System ID (01-99):	
PC System Part of Operating Process?/desc.	
PC System Design Potentially NG Emitting/desc.	
PC System Services Single or Multiple Wells?	PC System Control or Safety Function?
PC System Sensed Variable: [Pressure, Diff. Pressure, Temperature, Level, Position, Unknown]	
PC System Basic Application: [Plunger Lift, Wellhead, Separator, Heater, Flare, Compressor, Dehydration, Sales, Tank, Other]	
Integrated or Pilot PC? [Integrated, Pilot, Unknown]	
PC and Actuator System Notes:	
PC Manufacturer and Model Family:	
PC Exact Model Number:	
PC Exact Serial Number:	
Actuator Manufacturer:	Actuator Model:
Actuator Volume (Post):	
Tubing length (Measured):	
Tubing OD (Measured):	
Tubing Volume (Calculated):	
Retrofit? [Y/N]	
Retrofit Description:	
Relays? [Y/N]	
Relay Description:	
PC Depressurization Primary: [Continuous (C), Intermittent (I), Unknown (U)]	
PC Service Type Primary: [On/Off (O), Throttling (T), Unknown (U)]	
PC Subtype: [No Vent (NV), On/Off Snap (OS), On/Off proportional (OP), Hybrid C-I (HP), Safety Shut-in (SS), Safety Pressure Relief (SP), Unknown (U)].	
Throttling / Proportional PC Valve Stem Travel % Estimate: (10, 20, 30, 40, 50, 60, 70, 80, 90, 100, unknown)	
PC and Actuator Photo IDs:	
PC Supply Pressure:	
OGI Video IDs:	
OGI Emissions Observed Low Sensitivity Mode: [Continuous (A1), Intermittent Low Sensitivity (B1), None (C1)]	
OGI Emissions Observed High Sensitivity Mode: [Continuous (A2), Intermittent Low Sensitivity (B2), None (C2)]	
OGI Emissions Strength: [1, 2, or 3 (high)]	Actuation frequency bin: [group (a) though (h)]
Installed flow meter on supply OK?	Installed flow meter on exhaust OK?
PC actuation counting possible/needed?	
Possible malfunction?	
Associated leak verification: #checked = #Number found = Label to meter form (L1, L2....) and detail	
Measurement priority calculation based on above (TBD)	

ver.9/16/16

Figure 7-3. PC information form

Operator and Site ID (e.g. YYMMDDA01):		Inst. Operators										ver: 10/12/16				Pg.	of					
PC or Source ID	MFC Flow if Used (LPM)	BHFS	ID	Time	Flow (ALPM)	Bkg (%)	Leak	(%)	Leak Rate (ALPM)	PPM - %lel - %Vol	GMI 1 - BHFS	GMI 2 - BHFS	A10	(SLPM)	A500	(SLPM)	Fox100	(SCFH)	T Probe	Temp	P Sensor	Pressure
			R8																			
Notes for above:																						
			R8																			
Notes for above:																						
			R8																			
Notes for above:																						
			R8																			
Notes for above:																						
			R8																			
Notes for above:																						
			R8																			
Notes for above:																						
			R8																			
Notes for above:																						

Figure 7-4. Form for recording test values

Appendix B: Optical Gas Imaging Procedures

Contract EP-C-15-008

December 2016

Prepared for

Air Pollution Prevention and Control Division
National Risk Management Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Contents

1.0	Scope and Applicability	3
2.0	Summary of Method	3
3.0	Definitions	3
4.0	Health and Safety Warnings	3
5.0	Cautions	4
6.0	Interferences	4
7.0	Personnel Qualifications	4
8.0	Equipment and Supplies.....	4
9.0	Procedure.....	5
10.0	Data and Records Management	10
11.0	Quality Control and Quality Assurance	10
12.0	References and Supporting Documentation	11

Figures

Figure 1. GF320 back of hand grip with Power, Menu Joystick, and Menu buttons.	6
Figure 2. GF320 top of hand grip with Auto/Manual/HSM, Focus/Zoom, and Save/Start-Stop Recording buttons	7
Figure 3. GF320 top of camera with Programmable button, Temperature Range, and Camera Dial.	7
Figure 4. GF320 front left side of camera with Manual Image Focus, Visible Image, and Laser buttons ...	8
Figure 5. GF320 back of camera with battery, battery release latch, battery compartment release, and camera SD card and data storage.	8

Tables

Table 1. GF320 Infrared Camera Buttons, Locations, and Functions	5
--	---

1.0 Scope and Applicability

- 1.1 The purpose of this procedure is to describe the use and operation of the FLIR GF320 infrared (IR) camera during the 2016 Uintah Basin (UB) Regional Applied Research Effort (RARE) field measurement activities. The FLIR GF320 is used to locate leaks of hydrocarbon vapors from nearly all potential sources, such as pneumatic controllers (PCs), valves, pumps, compressors, and tanks.
- 1.2 This procedure applies to U.S. Environmental Protection Agency (EPA) and contractor personnel performing screening activities using the GF320 for the 2016 UB RARE project and contains direction developed solely for internal guidance to personnel associated with the UB RARE project.
- 1.3 This procedure is a general guide. For more complete information on FLIR GF3xx series IR camera functionality, please consult the manufacturer's manual.

2.0 Summary of Method

The GF320 is designed to identify emissions of hydrocarbon gases using an IR detector. The detector has been designed to capture IR radiation emitted within a narrow IR spectral range corresponding to several hydrocarbon gases. The images of these hydrocarbon emissions, which appear as either black or white “smoke” depending on polarity settings and background, are displayed in a viewfinder in real time. Lower emission detection limits can often be obtained using the manual mode or high-sensitivity mode (HSM). The user should be familiar with these operating modes prior to use in the field.

For the purposes of the UB RARE project, the GF320 capabilities are implemented for three main purposes: (1) The IR camera is used to conduct a visual site survey to identify any potential hazards to health and safety. (2) The IR camera is used to identify PCs that are emitting hydrocarbons and determine the frequency of actuation. (3) During the PC measurement phase, the IR camera continuously monitors measurements being conducted at PCs to ensure complete leak capture.

This procedure was prepared by persons deemed technically competent by management based on their knowledge, skills, and abilities. The procedure has been validated in practice and reviewed in print by a subject matter expert.

3.0 Definitions

EPA	Environmental Protection Agency	RARE	Regional Applied Research Effort
HSM	high-sensitivity mode	SD	secure digital
IR	infrared	UB	Uinta Basin
PC	pneumatic controller		

4.0 Health and Safety Warnings

- 4.1 This document does not attempt to address all safety problems associated with the use of the IR camera. It is the responsibility of the user of this procedure to establish appropriate safety and health practices.
- 4.2 Always observe proper safety procedures when using the IR camera. The operator must be familiar with the safety aspects associated with the instrument's operation, as outlined in the instrument's operating manual.

- 4.3** The IR camera is not intrinsically safe and might require additional site-specific monitoring prior to operation. Refer to any pertinent site-specific health and safety plans for guidelines on safety precautions. These guidelines, however, should only be used to complement the judgment of an experienced professional.
- 4.4** Minimize exposure to potential health hazards by use of protective clothing, eyewear, and gloves.

5.0 Cautions

- 5.1** If the camera is not working properly and a reboot of the camera does not alleviate the problem, red-tag it and remove it from use.
- 5.2** Operate the camera only in appropriate environmental conditions. Temperatures above 50 °C (122 °F) can damage the camera.
- 5.3** Read the operational manual and fully understand all aspects of its use before attempting to operate the IR camera.
- 5.4** Avoid pointing the camera at strong energy sources, including the sun, as these could negatively affect the detector.

6.0 Interferences

- 6.1** For accurate measurements, allow the camera a 5-minute warm-up period before use.
- 6.2** Avoid pointing the camera at strong energy sources, including the sun, as these could negatively affect accuracy.

7.0 Personnel Qualifications

- 7.1** UB RARE field personnel must only operate equipment for which they are trained and authorized to use. Personnel must be trained by qualified operators.
- 7.2** Operators of the instrument must read the manufacturer's manual and this operating procedure, and demonstrate that they fully understand how to properly operate the instrument.

8.0 Equipment and Supplies

- Infrared camera (FLIR Systems model GF320)
- Infrared camera telephoto lens (FLIR Systems GF320 fixed lens; Standard 24° x 18°)
- FLIR Systems user's manual (FLIR GF3xx Series)
- Spare rechargeable lithium-ion batteries
- Laptop with secure digital (SD) storage

9.0 Procedure

9.1 Camera Startup

Table 1 provides a summary of IR camera operations. Users should refer to the GF320 IR camera operator's manual for additional information on keypad and button functions, level/gain control, and thermal image recording.

Table 1. GF320 Infrared Camera Buttons, Locations, and Functions

Button	Location	Function
S	Top of hand grip	Allows the user to save an image when in picture mode or start and stop the recording of video when in video mode.
A/M	Top of hand grip	Switches camera mode between Automatic -Level and Gain, Manual - Level and Gain, and High Sensitivity Mode (HSM).
FOCUS/ZOOM	Top of hand grip	Allows the user to focus the image when in video or picture mode and zoom in on an image that has been saved.
P	Top of camera	A programmable button that can be set to control the color palette, change zoom factor, invert polarity, or hide/show graphics.
Temperature Range	Top of camera	Allows the user to adjust the temperature range. Typical setting is 50–140 °F.
Menu	Back of hand grip	Allows the user to bring up the menu. Pressing menu a second time closes the menu or backtracks.
Menu Joystick	Back of hand grip	Allows the user to navigate menus. Pushing in selects menu option.
Power	Back of hand grip	Allows the user to turn the camera on and off.
Visible Image	Front left side of camera	Toggles the camera between visible imagery and IR imagery.
Laser	Front left side of camera	Allows the user to aim/identify. Holding down produces a laser dot for aiming/identifying.
Camera Dial	Back left side of camera	Used to switch between camera mode, video mode, file archive, program, and settings.

To operate the infrared camera:

1. Ensure that a fully charged battery has been inserted into the camera.
2. Turn the power on and allow 5 minutes for the camera to reach operating temperature. The message in the viewfinder will read “Cool down in progress” during this time.
3. After cool-down is complete, verify that the date and time settings are correct.
4. To set the date and time, turn the camera dial to settings, use the menu joystick to navigate to “set date and time,” and press joystick to change the date and time.
5. Remove the lens cap and select AUTO, MANUAL, or HSM mode by pressing the A/M button:
 - In AUTO mode, the camera sets the level and gain based on scene content, which can also be described as the temperature of the objects in the scene.
 - In MANUAL mode, the user adjusts the level and gain manually to optimize the image in the viewfinder. Adjusting level and gain is done by using the menu joystick (up/down adjusts level; left/right adjusts gain).

- In HSM mode, level and gain are set by the camera along with a higher image integration rate to allow imaging of smaller leaks.
6. Adjust the focus using the FOCUS/ZOOM button (or the black ring near the lens) to produce the clearest thermal image.
 7. Ensure the camera is functioning properly (operation verification) by viewing the presence of a hydrocarbon plume through the eyepiece. This can be accomplished by the use of a butane lighter or other hydrocarbon source. Document this verification in the field logbook.

The camera is now ready for thermal imaging.

Figures 1–5 show the control buttons for the Infrared Camera.

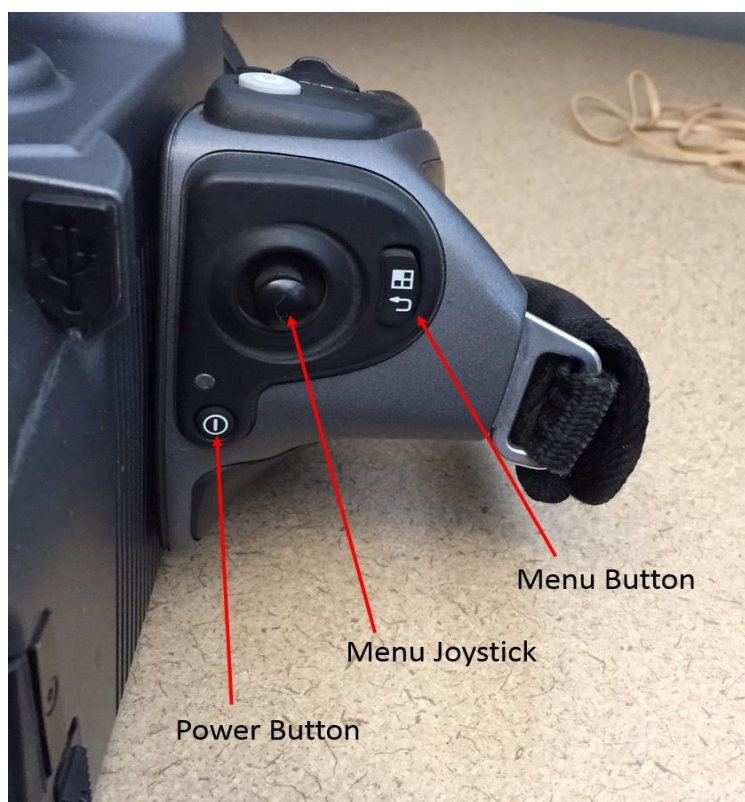


Figure 1. GF320 back of hand grip with Power, Menu Joystick, and Menu buttons.



Figure 2. GF320 top of hand grip with Auto/Manual/HSM, Focus/Zoom, and Save/Start-Stop Recording buttons.

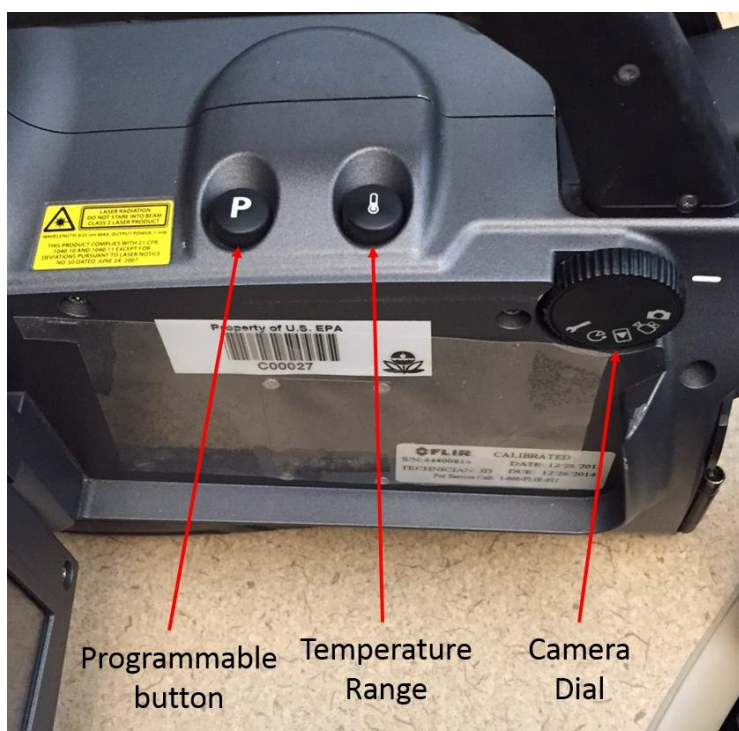


Figure 3. GF320 top of camera with Programmable button, Temperature Range, and Camera Dial.

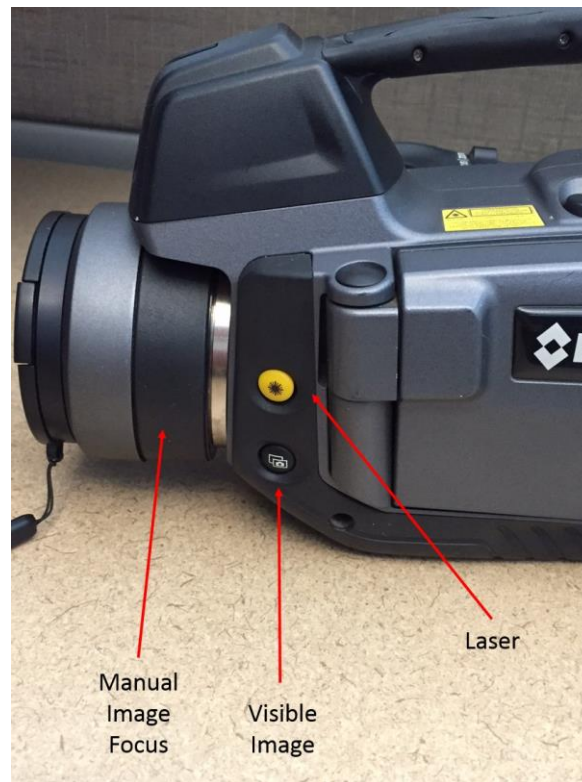


Figure 4. GF320 front left side of camera with Manual Image Focus, Visible Image, and Laser buttons.

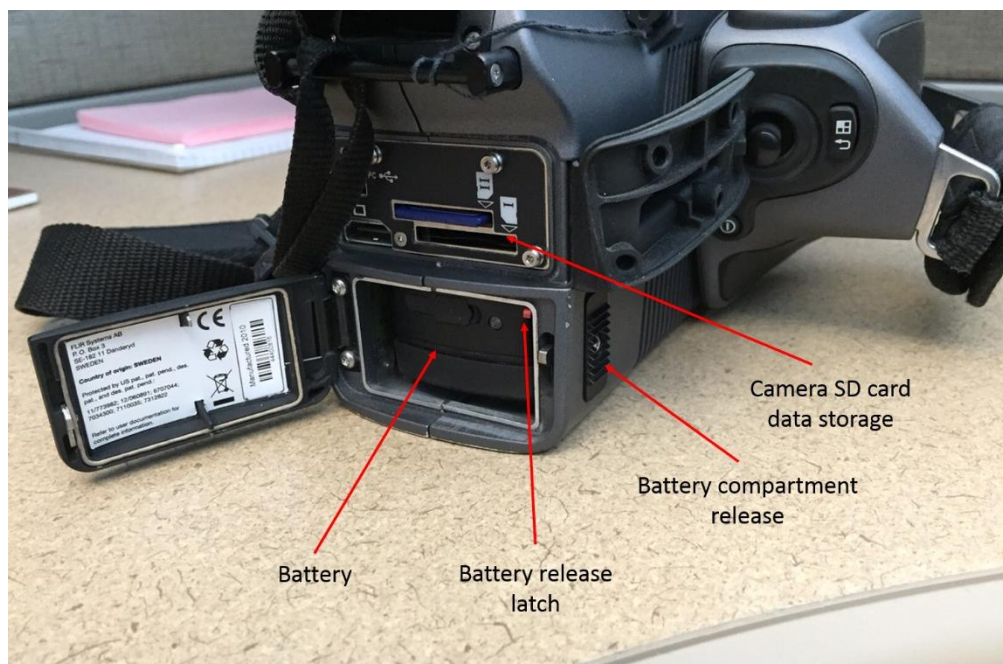


Figure 5. GF320 back of camera with battery, battery release latch, battery compartment release, and camera SD card and data storage.

9.2 Safety Site Survey

1. Upon entrance to a project facility, use the GF320 to identify any substantial hydrocarbon vapor plumes that might pose significant danger to health and safety by scanning the wellhead(s), multiphase separator(s), storage tank vessel(s), and closed vent system from a distance of at least 20 meters.
2. Once the safety site survey is completed and no hazardous conditions are identified, enter the required data on the form shown in Figure 7-1 in Appendix A of this QAPP and proceed to the survey of facility operations.
3. Project personnel can approach the facility process units to conduct the PC emissions identification procedure. No video recordings are necessary for the site safety survey procedure, as the IR camera is only used in a safety screening capacity during this survey.

9.3 PC Emissions Identification

Upon completion of the safety site survey procedure, screen the facility for hydrocarbon emitting PCs using the IR camera. Start the PC emissions identification at the wellhead and follow the process stream all the way to the control device as follows:

1. At each process unit (i.e., wellhead, separator, and storage vessel), thoroughly inspect the entire unit to identify all PCs.
2. When a PC is observed to be actuating (releasing hydrocarbon emissions), record a short (< 1 minute) video of the actuating PC. Record all associated data from this and subsequent steps on the data-entry form (Figure 7-2 in Appendix A of this QAPP).
3. For each actuating PC, document the video file number, PC identifying information, and the type of emissions stream (i.e., intermittent or continuous) on the form shown in Figure 7-1 in Appendix A.
4. Continue the identification process until the entire facility has been inspected with the camera and all actuating PCs have been documented.
5. Following identification of actuating PCs, a 10-minute continuous IR video will be recorded for each intermittent PC to determine actuation frequency. To monitor actuation frequency, set up the IR camera on a tripod with an unobstructed view of the PC.
6. Document the video file number and specific PC identifying information in the field logbook for each actuation frequency monitoring video.
7. At the end of the workday, remove the video files from the IR camera SD card and store the files on a secure data storage device (e.g., EPA laptop).

9.4 Measurement Leak Capture

During the PC measurement field campaign, the IR camera is used to verify leak capture of PC emissions being directly sampled using the augmented Bacharach Hi Flow instrument as follows:

1. Set up the IR camera on a tripod with a clear line of sight to the PC measurement setup to identify any excess emissions not being collected by the Hi Flow sampler.
2. At the beginning of the Hi Flow sampling, record a video confirming leak capture to verify that all emissions from the PC are being collected by the Hi Flow sampler.
3. Document the video file number and specific PC identifying information in the field logbook.
4. At the completion of the workday, remove the video files from the IR camera SD card and stores the files on a secure data storage device (e.g., EPA laptop).

9.5 Camera Battery Replacement

1. Open the battery compartment, located at the back of the camera by using the battery door release located just to the right of the battery compartment.
2. Press down on the battery release hatch (the small red lever located in the top right corner of the battery compartment).
3. Remove the old battery.
4. Insert a new battery with contacts up, facing towards the camera body.
5. Close the battery compartment door.

10.0 Data and Records Management

Information generated or obtained by UB RARE field personnel must be organized and accounted for in accordance with established records management procedures. Information concerning the field use of the IR cameras must be recorded in a bound logbook or equivalent electronic method, as described in the procedure sections. Data recorded in the field project logbooks shall include, but are not limited to, the following:

- IR camera serial number
- Project name
- Facility name
- Facility location
- Camera operator name
- Date and time
- Recorded video file number
- Description of recorded video
- Weather conditions
- Remarks

For each site visited, site description data are recorded on the form shown in Figure 7-1 of Appendix A. For each PC for which emissions are monitored, the data are recorded on the form shown in Figure 7-2 of Appendix A. These forms are scanned into electronic files at the end of each day's field work. Appendix A provides guidance on file names, organization and file storage, and backup.

11.0 Quality Control and Quality Assurance

Important factors in establishing quality requirements include the sensitivity and specificity of the detection system used. Quality requirements include ensuring that equipment is ready for use as follows:

- Operating instructions and/or manuals from the manufacturer are available for each piece of equipment.
- Equipment used for field activities must be handled, transported, shipped, stored, and operated in a manner that prevents damage and deterioration. Equipment must be handled, maintained, and operated in accordance with the manufacturer's operating instructions.

Field personnel are responsible for maintaining a central, comprehensive list of all field equipment subject to this procedure. The equipment inventory list for each instrument or piece of equipment must include the following:

- The description/identity of the equipment (e.g., IR camera, IR camera lens)
- Manufacturer's or vendor's name
- Equipment serial number or other manufacturer identification number
- The manufacturer's instructions or a reference to their location
- Record of damage, malfunctions, modifications, and/or repairs to the equipment

Any problems or abnormalities observed during use of the instrument must be recorded in the field notebook. If the instrument does not appear to be operating properly, red-tag it and remove it from service. Record pertinent information in the project logbook, including date, time, video file number and description, location, and camera operator name.

Another quality check performed at each PC emissions test site is the qualitative correlation of IR camera readings (strength: 1, 2, or 3 [highest]; frequency: continuous or intermittent) with the more sensitive hand-held probe measurements, as described in the main body of the QAPP, Section 4.1.5. OGI scans are also correlated with actuation counter data, as described in QAPP Section 4.1.3. This correlation is done at each PC emission measurement site and is recorded in the field notebook.

12.0 References and Supporting Documentation

NEICPROC/11-005. FLIR GasFindIR GF320 Infrared Cameras. 1-23-2012.

FLIR GF3xx Series User's Manual, Publ. No. T559157, Revision a506, December 21, 2010.

FLIR Systems, <http://www.flir.com> (last accessed December 13, 2016). Users can view training videos and download manuals from FLIR Systems.

Bacharach Inc., <https://www.mybacharach.com/> (last accessed December 13, 2016).

Appendix C: PC Actuation Counting Procedures Using the SERN-5

Contract EP-C-15-008

December 2016

Prepared for

Air Pollution Prevention and Control Division
National Risk Management Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Contents

1.0	Scope and Applicability	3
2.0	Summary of Method	3
3.0	Definitions	4
4.0	Health and Safety Warnings	4
5.0	Cautions	5
6.0	Interferences	5
7.0	Personnel Qualifications	5
8.0	Equipment and Supplies	5
9.0	Operation Procedures	6
10.0	Data and Records Management	7
11.0	Quality Control and Quality Assurance	7

Figures

Figure 1. Model SERN -5 pneumatic counter (not fully installed)	3
---	---

1.0 Scope and Applicability

- 1.1 The purpose of this procedure is to describe the installation, operation, and pre- and post-deployment quality control checks for the model SERN-5 pneumatic counter from Control Equipment Inc. (CEI; Wichita Falls, TX). The SERN-5 will be used on an experimental (limited) basis to count actuation events from a subset of pneumatic controllers (PCs) as part of the Uinta Basin (UB) Well Pad Pneumatic Controller Emissions Research Study. Note that other forms of PC actuation counting will be performed as part of the research study (e.g., installed flow meter observations, discussed in Appendix D of the project quality assurance project plan [QAPP]) and are not described here.
- 1.2 This procedure applies to U.S. Environmental Protection Agency (EPA) and contractor personnel performing screening activities using PC actuation counting for the 2016 UB RARE project and contains direction developed solely to provide internal guidance to UB RARE associated personnel.

2.0 Summary of Method

The SERN-5 was originally developed for a specific oil field custody-transfer application and is commonly called a “barrel counter.” It is a simple mechanical, diaphragm-based device that is designed to count discrete gas pressure pulses in an approximate range of 5 psig to 30 psig. Each pressure pulse corresponds to one increment on the counter. The purpose of the device for this project is to allow longer-term monitoring of intermittent PC actuation events. Figure 1 shows a SERN-5 partially installed on the actuation side of a PC. The SERN-5 is easily reset to zero with a mechanical knob. Little information is available on the use of the SERN-5 for general well pad PC actuation monitoring, but it is known to have limitations on certain types of PCs. This procedure is intended as a general field guide and may be altered based on improved information on the use of this device in initial field trials.



Figure 1. Model SERN-5 pneumatic counter (not fully installed)

As described in the QAPP for this effort, the main objective of this research study is the measurement of natural gas (NG) emissions from well pad PCs. One form of measurement will be installed PC actuation counting described in this operating procedure. SERN-5 units are tested in the EPA Metrology Laboratory before deployment to the field, installed in the field onto PC valves to count the number of actuations (described in Section 9.0), and then tested again after the field study to ensure continuing operation.

3.0 Definitions

EPA	U.S. Environmental Protection Agency
HASP	health and safety plan
IR	infrared
Jacobs	Jacobs Technology Inc.
NG	natural gas
OGI	optical gas imaging
ONG	oil and natural gas
OR	operator representative
PC	pneumatic controller
psig	pound(s) per square inch gauge
QA	quality assurance
QAPP	quality assurance project plan
UB	Uinta Basin

4.0 Health and Safety Warnings

- 4.1** Please consult the operator-specific site health and safety plan (HASP) for further information on safety procedures.
- 4.2** The procedures described here will only be conducted on PC systems on which the procedures are judged to be safe and to have negligible process impact. The decision on what PC systems are candidates for PC actuation counting is up to the oil and natural gas (ONG) operator representative (OR), a technical employee of the host site who will accompany and assist the Jacobs Technology Inc. (Jacobs) team in safe execution of these measurements.
- 4.3** Proper personal protective equipment (safety shoes, gloves, flame-resistant clothing) is required.
- 4.4** Proper confirmation of leak-free connections is required.
- 4.5** Removal of ignition sources is required.
- 4.6** Personal safety monitors are required.
- 4.7** Proper safety equipment such as first aid kits and fire extinguisher must be carried.

5.0 Cautions

- 5.1** The OR is responsible for control loop shutdown and restart, as well as installation and removal of the SERN-5.
- 5.2** A “hot work” permit is likely required for this activity.

6.0 Interferences

- 6.1** The counter has a maximum operating pressure of 30 psig. Exceeding 30 psig can potentially rupture the internal diaphragm.
- 6.2** The counter is designed to work in snap applications where the valve actuator goes from fully closed to fully open and then back to fully closed. If the counter is used in a throttle application, a false reading will be recorded. The counter senses each time a pressure change is made to the actuator. In throttle mode, most controllers output changes slightly during operation. A count might or might not be received each time the pressure changes in throttle application. Hence these actuation counters are not recommended for throttle use.

7.0 Personnel Qualifications

- 7.1** The ONG OR must be qualified to assist in the installation of the SERN-5 and knowledgeable of the well pad processes and PC types. The OR has safety responsibility oversight for the effort and will make all final decisions with regard to potentially installed flow meters and SERN-5 units. As an example, some PCs, such as safety devices, can trigger a well shut-in on loss of gas pressure (very high process impact), so these PCs (usually very infrequently actuating) will not be assessed with installed flow meters or the SERN-5. The OR must be knowledgeable of potential process impacts and safety considerations for control loop shutdowns.
- 7.2** Jacobs SERN-5 operators must have safety training and be trained and practiced in the use of this equipment. The proper qualification of Jacobs personnel will be determined by the Jacobs work assignment leader. Instrument operators must read the manufacturer’s manual and this operating procedure and demonstrate that they fully understand how to properly conduct measurements, calibration procedures, and data recording/backup.

8.0 Equipment and Supplies

- SERN-5 actuation counters
- Installation fittings
- Installation tools (might also be supplied by the OR)
- Digital cameras to document installation
- OGI camera for emissions and leaks diagnostics
- TVA-1000B (Thermo Scientific, Waltham, MA) hydrocarbon measurement instrument for emissions and leaks diagnostics
- Snoop liquid connect leak diagnostics
- Safety equipment listed in operator/site specific HASP

9.0 Operation Procedures

9.1 PC Selection Procedures for Actuation Counting

A PC is a candidate for installation of the SERN-5 actuation counting device if it meets *all* the following criteria:

- 9.1.1** Actuation counting provides value. Some PCs obviously frequently actuate and the temporal profile of these PCs can be established with other observations or measurement procedures described in the project QAPP. Some PCs are known to be very infrequently actuating (e.g., a safety shut-in device), and installation of a PC actuation counter for short-duration (hours to days) observation provides no value. Some PCs actuate on time scales, such as fractions of an hour, hourly, or potentially several times a day, for which observation and documentation of the events over hours or days would provide value to the study. This type of PC is a potential candidate for actuation counting.
- 9.1.2** Some PCs are not candidates for actuation counting because installation of the actuation counter is very difficult or could cause serious process or safety issues. If the OR determines a PC control loop can be shut down, the SERN-5 readily installed, and the PC control loop restarted with little process impact or safety risk, this PC is a candidate for actuation counting.
- 9.1.3** Some PCs are used in throttling or proportional applications or are continuously emitting and the pressure change profile may not robustly trigger the SERN-5. These types of applications are not good candidates for PC actuation counting. On the other hand, if a PC application is of the on/off snap action variety (especially full-valve actuation), it could be a good candidate for actuation counting if other criteria are met.
- 9.1.4** The PC control loop operates in the 8–30 psig range.
- 9.1.5** The PC is operating normally (not malfunctioning).

9.2 Installation and Operation

- 9.2.1** Pre- and post-testing of the SERN-5 units will be conducted by the EPA Metrology Laboratory to ensure that the devices are functional and able to count events and to establish their approximate count pressure threshold.
- 9.2.2** In the field, a PC will be selected for monitoring with the SERN-5. Optical gas imaging (OGI) and other assessment procedures described in the project QAPP will be conducted prior to installation of the SERN-5. This will be done to establish the operational state of the PC system and its candidacy for actuation monitoring.
- 9.2.3** The following procedure will be used to count actuation events on selected PCs:
 1. The site host (the ONG on-site OR) will de-energize and lock out the PC control loop, making it safe to install the SERN-5.
 2. The SERN-5 will be set to zero counts.
 3. The OR will install the SERN-5 close to the actuator being monitored using a short nipple and a tee (ideally, directly attached to the actuator being monitored), as shown in Figure 1. The counter should be positioned so it can be easily read.

4. The OR will complete the connection in the PC control loop and re-energize the supply gas, making sure to set it at the proper pressure. The actuation counter will be observed during the control loop restart to see if a count is registered. If so, this count will be removed from the final tally.
5. Leak detection procedures (OGI and Snoop leak detection solution) will be conducted to ensure proper installation.
6. A manual actuation of the PC will be attempted (if possible) to verify a single count. If this is not possible, an attempt will be made to correlate a natural actuation (audible or OGI signal) with an actuation count or other process information to confirm the counter is working. If this confirmation can be obtained, it will be recorded in the field notebook. If the count cannot be confirmed, this will be noted. If the unit fails to respond or registers multiple counts during the confirmation step, the unit will be removed and replaced after safe shutdown of the control loop by the OR. If it is deemed that the PC is not suitable for actuation counting after the initial attempt, the counting trial will be terminated and notes recorded in the field notebook.
7. After some agreed upon amount of time (hours to days), the actuation counts and total installation time will be recorded and the OR will prepare to remove the SERN-5. A manual actuation may be attempted (or natural actuation observed) to ensure the device is still counting prior to removal (notes recorded). As the control loop is de-energized, the actuation counter will be observed to see if a count is registered. This count will be removed from the final tally.
8. The device will be safely removed (after de-energizing the control loop) and the PC system returned to the original state.
9. The SERN-5 counter will be tested by the EPA Metrology Laboratory after its return from the field. A counter can be used in multiple trials.

10.0 Data and Records Management

All counts recorded by the actuation counters will be manually noted in the field notebook on an hourly, daily, or weekly basis depending on the length of the observation period for which the actuation counter is installed in the process loop. How long an actuation counter will be installed in any process loop will be determined after consulting the ONG OR.

11.0 Quality Control and Quality Assurance

- 1.1 Field personnel are responsible for maintaining a central, comprehensive list of all field equipment subject to this procedure. The equipment inventory list for each instrument or piece of equipment must include the following:
 - Description/identity of the equipment (e.g., infrared [IR] camera, IR camera lens).
 - Manufacturer or vendor name.
 - Equipment's serial number or other manufacturer identification number.
 - The manufacturer's instructions or a reference to their location.
 - Record of damage, malfunction, modification, and/or repair of the equipment.

- 11.2** Any problems or abnormalities observed during use of the instrument must be recorded in the field notebook. If the instrument does not appear to be operating properly, red-tag it and remove it from service. Record pertinent information in the project logbook, including date; time; video file number, description, and location; and camera operator name.
- 11.3** The pre- and post-field deployment testing done in the EPA Metrology Laboratory constitute one type of QA check. The Metrology Laboratory tests on each SERN-5 ensure that the devices are functional, able to count events (pulsed 10 times), and establish their approximate count pressure threshold. These data are recorded in Metrology Laboratory records and associated with each SERN-5 through its serial number. These data are also entered into the project electronic files for easy reference in the field.
- 11.4** A second type of QA check is the qualitative correlation of OGI scans with PC valve actuations. This information is recorded in the field notebook.

Appendix D: Operating Procedures for Flow Meter Measurements

Contract EP-C-15-008

December 2016

Prepared for

Air Pollution Prevention and Control Division
National Risk Management Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

JACOBS®

Contents

1.0	Scope and Applicability	3
2.0	Summary of Method	3
3.0	Definitions	3
4.0	Health and Safety Warnings	4
5.0	Cautions	4
6.0	Interferences	4
7.0	Personnel Qualifications	5
8.0	Equipment and Supplies.....	5
9.0	Operation Procedures	6
10.0	Data and Records Management	7
11.0	Quality Control and Quality Assurance	8
12.0	References and Supporting Documentation	9

Tables

Table 1.	Major Equipment Used for This Procedure	6
----------	---	---

1.0 Scope and Applicability

- 1.1** The purpose of this procedure is to describe the installation, operation, daily calibration, and data backup procedures for installed flow meter measurements as part of the Uinta Basin Well Pad Pneumatic Controller Emissions Research Study.
- 1.2** This procedure is intended as a general field guide. For additional information on the operation of the flow meters and mass flow controllers (MFCs) described here, please consult the product manuals.

2.0 Summary of Method

As described in the quality assurance project plan (QAPP) for this effort, measurements of natural gas (NG) emissions from pneumatic controllers (PCs) is the subject of the study. One form of measurement will be installed flow meters described in this operating procedure. The following summarizes the procedure:

- Daily calibration tests will be conducted on the flow meters at the start of each field measurement day. The daily calibration test procedure is described in sections 9.1 and 9.2.
- To conduct the installed flow meter measurement on a selected and approved PC, the OR will shut down the PC control loop (shut off/depressurize) and will disconnect a mutually agreed upon tubing connection (typically a 0.5-in. Swagelok fitting).
- The Jacobs meter run will then be installed.
- The control loop will be repressurized to the previous setting. Jacobs and the OR will verify and record the integrity of the connections and the process settings (primarily supply pressure).
- Jacobs will then conduct the flow measurement (typically 15 minutes in duration) and log the data in the field notebook. The OR will then shut down the control loop, remove the meter runs, and bring the system back to normal operation.

3.0 Definitions

DAS	data acquisition system
EPA	Environmental Protection Agency
HASP	health and safety plan
Hz	hertz
in.	inch(es)
IR	infrared
Jacobs	Jacobs Technology, Inc.
lpm	liter(s) per minute
min	minute(s)
ms	millisecond(s)
NG	natural gas
ONG	oil and natural gas
OGI	optical gas imaging
OR	operator representative
PC	pneumatic controller

QAPP	quality assurance project plan
slpm	standard liter(s) per minute
TVA	Toxic Vapor Analyzer

4.0 Health and Safety Warnings

- 4.1** Please consult the operator-specific site health and safety plan (HASP) for further information on safety procedures.
- 4.2** The procedures described here will only be conducted on PC systems on which the procedures are judged to be safe and to have negligible process impact. The decision on what PC systems are candidates for installed flow meter measurements is up to the oil and natural gas (ONG) operator representative (OR), a technical employee of the host site who will accompany and assist the Jacobs Technology Inc. (Jacobs) team in safe execution of these measurements.
- 4.3** This procedure uses compressed gas cylinders containing 100% methane gas. Proper personal protective equipment (e.g., safety shoes, gloves) and lift procedures are required when handling compressed gas cylinders.
- 4.4** Proper procedures for handling and venting flammable gases are required.
- 4.5** Proper confirmation of leak-free connections is required.
- 4.6** Removal of ignition sources is required.
- 4.7** Personal safety monitors are required.
- 4.8** Proper grounding of equipment is required.
- 4.9** Proper safety equipment such as first aid kits and fire extinguisher must be carried.

5.0 Cautions

- 5.1** Operate field equipment only in appropriate environmental conditions (temperature ranges indicated in the manuals). This equipment cannot be operated in the rain. Use a sun shield to keep direct sunlight off the equipment when possible in hot temperatures.
- 5.2** Daily calibration checks (described in sections 9.1 and 9.2) are required to ensure that the meters have not been damaged or internally corrupted through use in upstream ONG environments without pre-filters. Failure of daily calibration checks necessitates corrective action.

6.0 Interferences

- 6.1** The accuracy of installed flow meter measurements is affected by the operational range of the meter. The proper meter range must be used for all measurements. If it is determined during a real-time observation of the measurement that a different meter range is required, the OR will be notified and the new meter will be installed according to standard installation procedures.
- 6.2** The accuracy of installed flow meter measurements is affected by variations in NG composition. Best available information on gas composition must be obtained.

- 6.3** The accuracy of installed flow meter measurements is affected by connection leaks. The installed meter run must be verified to be leak-free using Snoop liquid.
- 6.4** The interpretation of the installed flow meter measurements is affected by the degree to which a positive attribution to the PC actuation can be obtained. Secondary fugitive leaks (not part of the meter run) or other issues such as gaskets or diaphragm leaks on the valve actuator will be recorded by some configurations of the installed flow meters. These emissions must be separately identified to the extent possible.

7.0 Personnel Qualifications

- 7.1** The ONG OR must be qualified to assist with installation of the installed flow meters and knowledgeable of the well pad processes and PC types. The OR has safety responsibility oversight for the effort and makes all final decisions with regard to potential installed flow meter measurements. As an example, some PCs, such as safety devices, can trigger a well shut-in on loss of gas pressure (very high process impact), so these PCs (usually very infrequently actuating) will not be assessed with installed flow meters. The OR must be knowledgeable of potential process impacts and safety considerations for control loop shutdowns.
- 7.2** Jacobs flow meter operators must have safety training and be trained and practiced in the use of this equipment. The proper qualification of Jacobs personnel will be determined by the Jacobs work assignment leader. Instrument operators must read the manufacturer's manual and this operating procedure and demonstrate that they fully understand how to properly conduct measurements, calibration procedures, and data recording/backup.

8.0 Equipment and Supplies

- Flow meters and data acquisition system
- Class 1 Div 2 cabling
- Flow meter calibration check system
- Calibration gases and two-stage regulators
- Meter runs, connection tubing, spare fittings
- Power supply
- Field tables to support meters
- Laptop computer and data storage media
- Digital cameras to document measurement configurations
- OGI camera for emissions and leak diagnostics
- TVA hydrocarbon monitor for emissions and leak diagnostics
- Snoop liquid connect leak diagnostics
- Safety equipment listed in operator/site-specific HASP

Table 1. Major Equipment Used for This Procedure

Device	Manufacturer	Model	Range / Description
Calibration system mass flow controller	Alicat Scientific, Inc., Tucson, AZ	MCR-100S Lpm-D-485-MODBUS-X / 5M, 5IN	0.5–100 slpm
Flow meter 1	Fox Thermal Instruments, Marina, CA	FT3 INLINE-0uP-SS-ST-E1-D0-MB-G3-G3,	0–24 (nom.) – 47 slpm 0–47 (nom.) – 235 slpm
Flow meter 2	Alicat Scientific, Inc., Tucson, AZ	MW-500S Lpm-D-DB9M-MODBUS-485-X/5M	2.5–500 slpm
Flow meter 3	Alicat Scientific, Inc., Tucson, AZ	MW-100S Lpm-D-DB9M-MODBUS-485-X/5M	0.5–100 slpm
Flow meter 4	Alicat Scientific, Inc., Tucson, AZ	MW-10S Lpm-D-DB9M-MODBUS-485-X	0.05–10 slpm
Data acquisition system for recording data	Techstar Inc., Deer Park, TX	Four-channel C1D2 DAQ for installed flow meters	1 Hz start/stop data acquisition panel

9.0 Operation Procedures

9.1 Daily Calibration Procedure Setup

Daily calibrations will be performed prior to making flow measurements on the gas valves. There is concern that the mass flow meters might be damaged by particulate or heavy organic matter present in the gas stream used to control the valves. A calibration check will ensure the meter was not damaged during previous measurements. The 10 lpm mass flow meter will be checked separately from the other larger mass flow meters. The three larger mass flow meters will be setup in series and the mass flow controller will be connected upstream of the three large controllers. A cylinder of pure methane will be used as the check gas.

9.2 Daily Calibration Check Operation

- 9.2.1** To check the calibration of the three large mass flow meters, the mass flow controller will be set to deliver 50 lpm of methane gas. The gas will be allowed to flow for 1 min. For a valid check, the gas flow measurements from the mass flow meters should be within 5% of the expected flowrate or ± 2.5 lpm.
- 9.2.2** To check the calibration of the 10 lpm mass flow meter, the mass flow controller will be set to deliver 5 lpm of methane gas. The gas will be allowed to flow for 1 min. For a valid check, the gas flow measurements from the mass flow meter should be within 5% of the expected flowrate or ± 0.25 lpm.
- 9.2.3** If time permits, the FLIR and OGI systems can be spot-checked during the calibration checks for the flow meters. These checks are recorded in the field notebook.

9.3 PC Measurement Setup

After the mass flow meters have been plumbed to the PC gas valve to be tested, the meters will be wired to the data acquisition system (DAS). The data acquisition system has been designed to log the flows for the four mass flow meters. Data from the DAS will be downloaded and backed up using a standard USB thumb drive. The internal clock on the DAS will be checked daily and adjusted to within 5 seconds of the local cell phone service time.

9.4 PC Measurement Operation

The DAS for the mass flow meters is operated through a Yokogawa (Sugarland, TX) Smartdac+ GP 20 portable paperless recorder. The mass flow meter DAS can log data at 100 ms or 10 Hz. This is a standalone DAS with an internal memory unit to store the data. The data collection is started using a touchscreen start/stop key on the DAS.

10.0 Data and Records Management

Data from the mass flow meter calibrations will be logged in a laboratory notebook. The DAS system has internal memory for storing the flow rates from the mass flow meters. This data will be transferred using a USB thumb drive to the field team leader's computer at the end of the workday. Data reduction is accomplished using the spreadsheets shown in Figures 1 and 2.

Alicat Viscosity Correction Table


Gases included: Methane (CH₄), Ethane (C₂H₆), Propane (C₃H₈), i-Butane(i-C₄H₁₀), Nitrogen (N₂), Carbon Dioxide (CO₂), Oxygen (O₂), Hydrogen Sulfide (H₂S)


	Inputs	Normalized percentages	Outputs	
% Methane	79.35735	0.794086102	Mix viscosity	103.737
% Ethane	10.66191	0.106688018	Correction factor	1.067695
% Propane	5.142666	0.051459876	% off from CH ₄	6.770%
% Isobutane	4.466217	0.04469102		
% Nitrogen	0.1365	0.001365882		
% Carbon Dioxide	0.1708	0.001709103		
% Oxygen	0	0		
% Hydrogen Sulfide	0	0		
Total %	99.93545	100		

(Multiply Alicat readings when set to pure methane by the correction factor for meter reading while flowing the mix input [specified in the table to the left], when the meter is set to measure 100% methane.

NOTE: All the butanes, pentanes, octanes, etc., were lumped into isobutane for approximation purposes.

Figure 1. Example Alicat viscosity correction spreadsheet

	A	B	C	D	E	F	G	H	I	J
1										
2		<div>  <div> <div>Actuator Vent Calculator</div> <div> Calculations assume actuation from fully closed to fully opened and back Calculations assume venting to 14.7psia </div> </div> </div>								
3										
4										
5										
6										
7										
8										
9	Valve Size	1								
10	Section	E1								
11										
12	Tubing I.D.	0.277	inches							
13	Tubing Length	2.8	feet							
14	Actuations per hour	10								
15	Temperature	60	°F							
16	Supply Pressure	30.0	PSIG							
17										
18		0.56	SCFH							
19	Vented Gas	13.51	SCFD							
20										
21	*not for use with throttling application									
22										



Actuator Volume (in ³)			
Valve Size	E1	E2	E3
1	30	1.1	-
2	110	9	6
3	225	31	22
4	243	73	27
5 (6, 8, 10 for E1)	650	244	40

Figure 2. Example actuator vent calculator spreadsheet

11.0 Quality Control and Quality Assurance

11.1 The sensitivity and specificity of the detection system are important factors in establishing quality requirements. Quality requirements include ensuring that equipment is ready for use as follows:

- Operating instructions and/or manuals from the manufacturer are available for each piece of equipment.
- Equipment used for field activities is handled, transported, shipped, stored, and operated in a manner that prevents damage and deterioration. Equipment must be handled, maintained, and operated in accordance with the manufacturer's operating instructions.

11.2 Field personnel are responsible for maintaining a central, comprehensive list of all field equipment subject to this procedure. The equipment inventory list for each instrument or piece of equipment must include the following:

- Description/identity of the equipment (e.g., Fox Thermal FT3, Alicat 10 lpm).
- Manufacturer or vendor name.
- Equipment's serial number or other manufacturer identification number.
- The manufacturer's instructions or a reference to their location.
- Record of damages, malfunctions, modifications, and/or repairs to the equipment.

- 11.3** During field operations, the main QC checks are the calibration checks performed prior to daily use of the flow meters, described in Section 9.2. All flow meters are checked at several flow rates, using mass flow controllers, in the RTP Metrology Laboratory prior to and after field deployment. These data are associated with flow meter serial numbers as part of the project records.
- 11.4** Any problems or abnormalities observed during use of the instrument must be recorded in the field notebook. If the instrument does not appear to be operating properly, red-tag it and remove it from service. Record pertinent information in the project logbook.

12.0 References and Supporting Documentation

- Alicat Scientific, <http://www.alicat.com/products/mass-flow-meters-and-controllers/low-pressure-drop-mass-flow-meters-controllers/> (last accessed December 13, 2016).
- Fox Thermal, <https://foxthermalinstruments.com/products/ft3.php> (last accessed December 13, 2016).
- Yokogawa GP20, <https://www.yokogawa.com/us/solutions/products-platforms/data-acquisition/portable-data-acquisition/> (last accessed December 13, 2016).

Appendix E:

Operating Procedure for Augmented Bacharach Hi Flow Sampler Measurements

Contract EP-C-15-008

December 2016

Prepared for

Air Pollution Prevention and Control Division
National Risk Management Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Contents

1.0	Scope and Applicability	3
2.0	Summary of Method	3
3.0	Definitions	3
4.0	Health and Safety Warnings	4
5.0	Cautions	5
6.0	Interferences	5
7.0	Personnel Qualifications	6
8.0	Equipment and Supplies	6
9.0	Instrument Setup Procedure	8
10.0	Data and Records Management	12
11.0	Quality Control and Quality Assurance	12
12.0	References and Supporting Documentation	13

Figures

Figure 1.	BHFS	7
Figure 2.	BHFS sampling attachments	7
Figure 3.	BHFS Control Unit with pushbutton options	8
Figure 4.	BHFS top panel and connections.....	9

Tables

Table 1.	BHFS Control Unit Buttons	8
Table 2.	Expanded Mode Main Options	10

1.0 Scope and Applicability

- 1.1 The purpose of this procedure is to describe the use and operation of the augmented Bacharach Hi Flow[®] sampler (BHFS) during the 2016 Uinta Basin (UB) Regional Applied Research Effort (RARE) field measurement activities. The instrument is used to determine the rate of gas leakage around various components of oil and natural gas (ONG) facilities, and will be applied to measure emissions from natural gas (NG)–driven pneumatic controllers (PCs) at selected well pad operations.
- 1.2 This procedure applies to U.S. Environmental Protection Agency (EPA) and contractor personnel performing screening activities using the augmented BHFS for the 2016 UB RARE project and contains direction developed solely to provide internal guidance to UB RARE associated personnel.
- 1.3 This procedure is a general guide. For more complete information on the BHFS functionality and maintenance, please consult the manufacturer's manual.

2.0 Summary of Method

- 2.1 The BHFS is designed to use a high flow rate, of up to 10.5 standard cubic feet per minute (scfm) at full battery charge, to capture both the gas leaking from a component and a portion of the surrounding air to determine the component's leak rate.
- 2.2 The main unit of the instrument, which consists of a high-flow blower and gas manifold, is packaged inside a backpack and is controlled by a hand-held control unit (CU), which is attached to the main unit with a 6-foot coiled cord. A gas sample is drawn into the main unit using a flexible 1.5-inch hose and various attachments for complete capture. The sample is passed through an orifice restrictor to measure pressure differential and calculate sample flow rate. A portion of the sample is directed to a combustibles sensor channel to measure methane (CH₄) concentration, while a second combustibles sensor channel measures background CH₄ away from the leak. A second blower exhausts the gas sample to the atmosphere.
- 2.3 Calculation of the gas leak rate is achieved from accurate flow rate measurement, sample stream CH₄ concentration, and background CH₄ concentration, with all values displayed on the CU.
- 2.4 For the purposes of the UB RARE project, the BHFS capabilities will be implemented to measure the rate of gas emissions from continuously emitting PCs. The BHFS will measure all combustible compounds in the sample stream, but as the instrument is calibrated for CH₄, the measured emissions rate will deviate from the actual emissions rate due to internal sensor response and flow rate effects. In addition, the BHFS capabilities will be used to measure any fugitive emissions in the vicinity of a PC.

3.0 Definitions

BHFS	Bacharach Hi Flow [®] sampler
cfm	cubic feet per minute
CH ₄	methane
CU	control unit

EPA	Environmental Protection Agency
HASP	health and safety plan
ID	identification
in.	inch(es)
lpm	liter(s) per minute
NiMh	nickel metal hydride
NG	natural gas
ONG	oil and natural gas
PC	pneumatic controller
ppm	part(s) per million
QA	quality assurance
QC	quality control
RARE	Regional Applied Research Effort
scfm	standard cubic feet per minute
UB	Uinta Basin

4.0 Health and Safety Warnings

- 4.1 This document does not attempt to address all the safety issues associated with the use of the BHFS. It is the responsibility of the user of this procedure to establish appropriate safety and health practices.
- 4.2 Always observe proper safety procedures when using the BHFS. The operator must be familiar with the safety aspects associated with the instrument's operation, as outlined in the instrument's operating manual.
- 4.3 The BHFS is designed to be intrinsically safe for use in hazardous locations Class I, Division 1, Groups A, B, C, and D, in North America.
- 4.4 The instrument is packaged inside a backpack, leaving the user's hands free for additional safety. The unit also has two magnets and a neck strap accessory to facilitate viewing of the CU while in operation.
- 4.5 The BHFS is not to be used in any application that is beyond its intended purpose or beyond the scope of its specifications. It is not for use as a safety device for the personal protection of the user. Failure to follow this warning can result in personal injury or damage to the equipment.
- 4.6 The BHFS must be grounded while conducting a leak test. Failure to ground the unit introduces the possibility of a static discharge.
- 4.7 The BHFS was developed for use on NG streams with high CH₄ content. Additional precautions and considerations might be required when using the instrument in NG streams of mixed composition, as these locations might contain lower CH₄ percentages in the overall mixture.
- 4.8 The instrument uses an intrinsically safe nickel metal hydride (NiMh) rechargeable battery pack. Connecting or disconnecting the battery back in an unsafe atmosphere presents an explosion hazard and must not be performed.

- 4.9** Refer to any pertinent site-specific health and safety plan (HASP) for guidelines on safety precautions. These guidelines, however, should only be used to complement the judgment of an experienced professional.
- 4.10** Minimize exposure to potential health hazards by use of protective clothing, eyewear, and gloves.

5.0 Cautions

- 5.1** Read the operational manuals and fully understand all aspects before attempting to operate the instrument.
- 5.2** Operate field equipment only in appropriate environmental conditions. This instrument should be operated between 0 and 50 °C (32 and 122 °F) and stored between –40 and 60 °C (–40 and 140 °F). Temperatures above 60 °C (140 °F) can damage the instrument.
- 5.3** Avoid sampling leaded gasoline vapors or gases or vapors that contain silicones or sulfur compounds. Tetraethyl lead, silicones, and sulfur compounds can form contaminating compounds on the sensor element (poison the sensor), with resulting loss in sensitivity.
- 5.4** Always purge the instrument with clean air after testing to remove combustibles from the sensor chambers. Purging the instrument prolongs sensor life.
- 5.5** Removing the instrument cover can result in electrostatic discharge and destroy sensitive electronic components. Prior to removing the cover, connect to a reliable ground point using a wrist strap, ground all equipment with ground straps, and handle components on a grounded anti-static work surface. Do not wear clothing that generates static electricity during movement or handle static-generating objects. Maintain the work area humidity between 40% and 50%.

6.0 Interferences

- 6.1** The BHFS was developed for use on NG streams with high CH₄ content. Use of a response correction factor is recommended when sampling at alternate locations where less CH₄ as a percentage of the overall mixture is present.
- 6.2** Calibrate the instrument every 30 days, or more frequently depending on use or the amount of gas sampled, to ensure its accuracy.
- 6.3** Turn the instrument on in clean air. Turning the instrument on in air contaminated with combustible gas will cause false readings to occur.
- 6.4** The instrument does not measure absolute pressure and therefore does not compensate for the effects of altitude.
- 6.5** Choose an attachment that will ensure the complete capture of the gas leak.
- 6.6** Attachments can have the effect of concentrating the leak. Ensure that enough air is present when first sampling to support catalytic mode (from 0 to 5% CH₄ concentration by volume) of the instrument. Flooding the sensor with high concentrations of CH₄ at startup can result in erroneously low readings and prevent transition to thermal conductivity mode.
- 6.7** For either the Manual Two-Stage Mode or the Automatic Two-Stage Mode, a test is only considered valid when the difference between measurements 1 and 2 is < 10%.

7.0 Personnel Qualifications

- 7.1** UB RARE field personnel must only operate equipment for which they are trained and authorized to perform. Personnel must be trained by qualified operators.
- 7.2** Operators of the instrument must read the manufacturer's manual and this operating procedure and demonstrate that they fully understand how to properly operate the instrument.
- 7.3** Personnel should have sufficient background in physical science and understand the hazards associated with NG.

8.0 Equipment and Supplies

- BHFS unit (see illustrations of this instrument and associated equipment in Figures 1 and 2)
- Backpack
- 6-foot, 1.5-inch hose assembly
- 2 NiMh rechargeable battery packs
- Battery charger with power supply
- Control unit with LCD and four-button keypad
- Flange strap attachments (34, 80, and 137 in.)
- Capture bag attachment (36 x 36 in.)
- Beveled nozzle attachments (6.5 and 24 in.)
- Bag nozzle
- Bellows tool
- Claw tool
- 2.5% CH₄ in air, P/N 0051-1121
- 100% CH₄, P/N00 55-0060

Figures 1 and 2 show the BHFS unit and associated sampling attachments.



Figure 1. BHFS



Figure 2. BHFS sampling attachments

9.0 Instrument Setup Procedure

9.1 Instrument Calibration

The instrument is calibrated daily prior to the collection of any gas leak measurements. The BHFS CU buttons (Table 1 and Figure 3) are used during the calibration process.

Table 1. BHFS Control Unit Buttons

Button	Function
I/O ↵	The Enter button turns the instrument on or selects highlighted display option
^	The Up Arrow button scrolls up through display options
v	The Down Arrow button scrolls down through display options
ESC	The Escape button cancels warm-up, leak rate test, or calibration, or exits to previous display

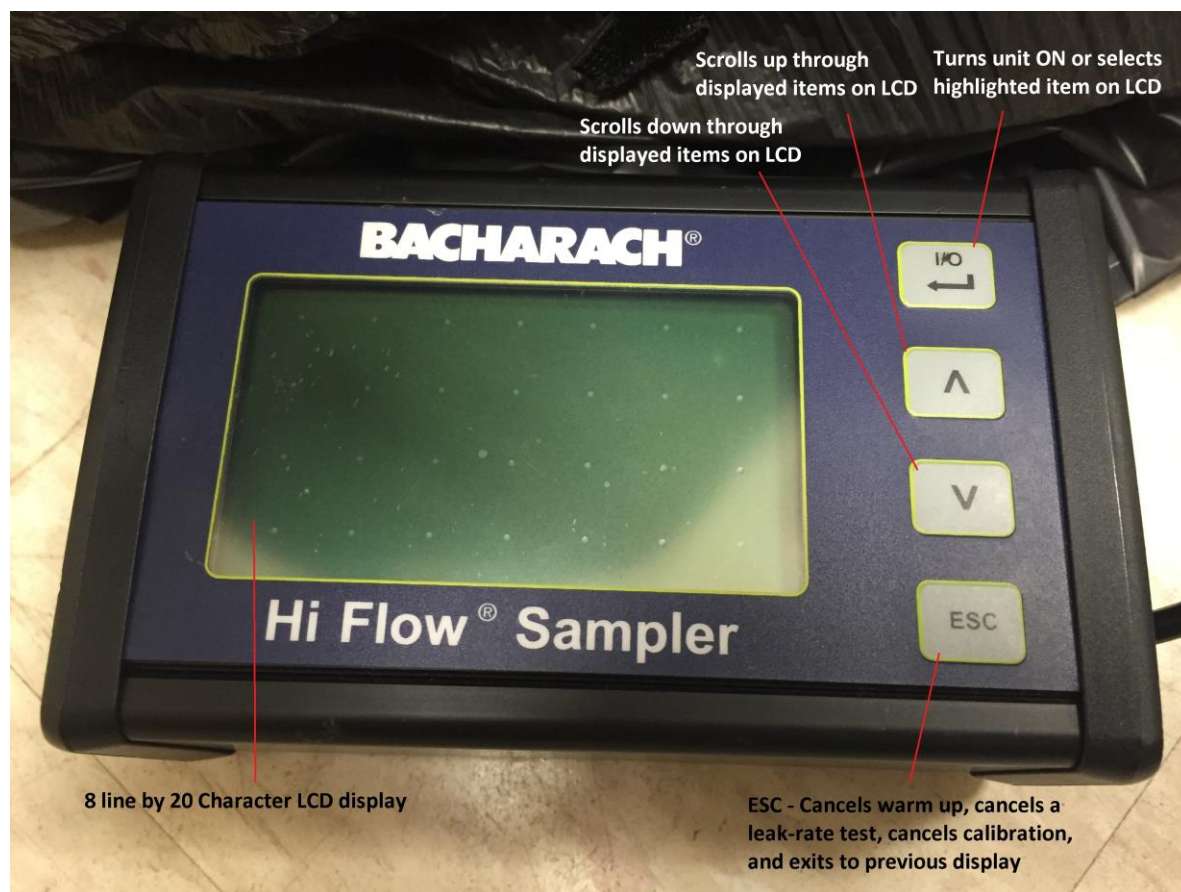


Figure 3. BHFS Control Unit with pushbutton options

9.1.1 Check Calibration

A calibration check is run prior to calibration because the calibration check requires less time and less gas compared to a complete calibration run. Section 11.2 describes additional quality assurance (QA)/quality control (QC) procedures followed during the study.

1. Ensure that the calibration equipment is not connected to the Gas or Background inlet port and that the instrument is located in a clear air environment.
2. Turn the instrument on and wait for the warm-up period to complete.
3. Connect the 2.5% CH₄ cylinder from the calibration equipment to the Background inlet port.
4. Select “Menu” from the main screen followed by “Calibration,” and then “Verify Calibration” to begin the calibration verification process. The gas-sampling pump motors will start. After several minutes, the display will indicate a stabilized “Back %” concentration that should match the calibration gas cylinder value. (The BHFS has a built-in calibration check. The instrument displays the result of the calibration check by indicating whether the check is within limits. If the system calibration is not within the acceptable range of the instrument, the calibration process is repeated.)
5. Disconnect the hose from the Background inlet port and connect it to the Gas inlet port. After several minutes, the display will indicate a stabilized “Leak %” concentration that should match the calibration gas cylinder value.
6. Disconnect the hose from the Gas port, and allow the pumps to run until both the Back and Leak readings display zero percent.
7. Press the ESC key three times to return to the main screen. If gas is still present in either sensor chamber when ESC is pressed, the instrument will automatically begin to purge the sensors until all gas is removed from the instrument. Figure 4 shows the top of the BHFS unit with the various gas inlets.

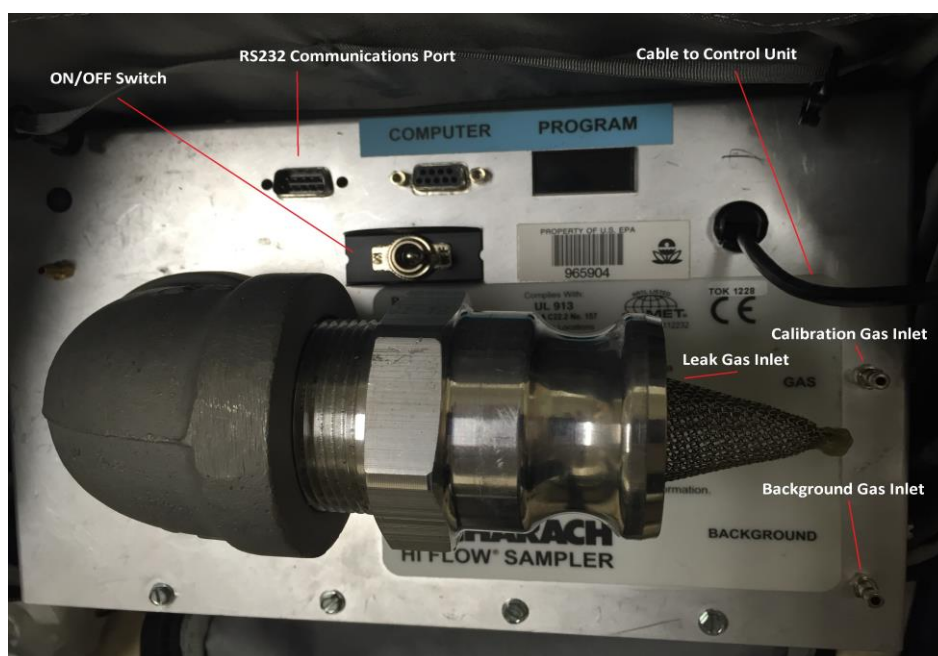


Figure 4. BHFS top panel and connections

9.1.2 Gas Calibration


1. Ensure that the calibration equipment is not connected to the Gas or Background inlet port and that the instrument is located in a clean air environment.
2. Turn the instrument on and wait for the warm-up period to complete.
3. Select “Menu” from the main screen, followed by “Calibration,” and then “Calibrate Sensors” to display the Sensor Calibration screen.
4. Highlight the sensor to be calibrated along with its gas level using the Arrow (↵) keys.
5. Connect the appropriate calibration gas to the instrument’s Gas or Background inlet port. Press the I/O (↵) key to start the calibration process. The gas-sampling pump motors will start and the Calibration screen will appear.
6. Adjust the “Appl(%)” reading, if necessary, using the ↵ keys to match the calibration gas cylinder value.
7. After the gas reading stabilizes, press the I/O ↵ key to calibrate the actual gas reading to the applied reading. The message “Calibration Passed!” will be displayed to indicate successful calibration.
8. Disconnect the hose from the Gas or Background port, and wait until the measured gas reading falls to zero percent.
9. Press the ESC key to return to the Calibration Menu screen.
10. Repeat this procedure as necessary to calibrate both sensors at 2.5% and 100% CH₄ (two different gas cylinders).

9.2 Instrument Startup






Users should refer to the BHFS operator’s manual for additional information on CU buttons, functions, and options and how to properly connect attachments. The operator’s manual contains additional information on submenu options available by selecting the Menu option in either Basic mode or Expanded mode (see Table 2).

Table 2. Expanded Mode Main Options

Option	Function
Date and Time	Date (mm/dd/yy) and time (12-hour format) display
Btry(V)	Battery voltage
#1-#2(%)	The difference (%) between the first and second test measurements
Flow(lpm)	Sample flow rate in liters per minute (lpm) or cubic feet per minute (cfm)
Back(%)	Measured background level in parts per million (ppm) or percent by volume
Leak(%)	Measured gas leak concentration at current sample flow rate in parts per million (ppm) or percent-by-volume
Leak(lpm)	Calculated leak rate in liters per minute (lpm) or cubic feet per minute (cfm)
Speed(Lo← →Hi)	Blower speed indicator
Save	Save all current measurement parameters
Start/Stop	Start and stop a test
Continued on next page	

Option	Function
Menu	Display the first of several submenus
	Battery status
[0001]	Current test identification (ID) number
(A) or (M)	Automatic or Manual mode
S or --1 or --2	Standby, Measurement #1 (maximum flow rate), or Measurement #2 (reduced flow rate)
Message Line	Displays various status or error messages during operation
Calibration	Allows the user to perform, view, or erase calibration verification, dates, and values
Set Flow Units	Set flow rate display in liters per minute (lpm) or cubic feet per minute (cfm)
Select Language	Set display language to English or Russian
Menu Mode	Set display to Basic Mode or Expanded Mode
Operating Mode	Set operating mode to Automatic Mode or Manual Mode
Access Records	Send, view, or erase saved records
Access Test IDs	Create, edit, send, or erase Test IDs

The following steps are used for operation of the BHFS:

1. Ensure that the instrument is located in an area containing clean air and is free of combustible gases or vapors.
2. Turn the power on by flipping the On/Off switch. An initial banner screen is displayed for 3 seconds that displays the instrument name, software version, and software create time. After 3 seconds, the sensors will automatically zero to ambient conditions.
3. After calibration, either the Basic Mode or Expanded Mode main screen is displayed. Select the Expanded Mode by selecting “Menu” and then “Menu Mode.” Highlight “Expanded Menu” and press the I/O  button. Press ESC to return to the main screen.
4. Ensure operating units are in cubic feet per minute. Select “Set Flow Units” and highlight “cfm (cu.ft./min.)”. Press the I/O  button. Press ESC to return to the main screen.
5. Ensure the instrument is operating in Manual 1-Stage Mode. Select “Operating Mode” and highlight “Manual 1-Stage”. Press the I/O  button. Press ESC to return to the main screen. “(M)” is now displayed at the bottom of the screen.
6. Create a Test ID by selecting “Access Test IDs” and highlighting “Edit Test IDs.” Select the last Test ID number that can be displayed. The next number after the displayed number will be the next test ID. Use the \wedge/\vee and I/O  keys to select and enter the desired Test ID. After all characters are selected, press and hold the I/O  button to move the cursor to the end of the screen. When the “Edit Test IDs” display appears, press ESC twice to return to the main screen.

9.3 Leak Rate Measurements

1. Ensure that the instrument is operating in Manual 1-Stage Mode.
2. Select an attachment that will completely capture the chosen gas leak. Connect the attachment to the end of the main sampling hose. When attaching the flange strap or capture bag, a click will be heard when the main sampling hose has been successfully connected.

3. When using the capture bag attachment, use the draw strings to partially close the end of the bag, allowing air to replace the volume of gas and air removed during the test.
4. Place the background gas sampling hose inlet opposite the leak source to prevent leaks from contributing to background measurement.
5. Select “Start” from the main screen to initiate sampling.
6. The message “Access new test ID” is displayed to prompt the selection of a new or different Test ID. Select “No” to return the display to the main screen and begin measurement with the current Test ID. To select an alternate Test ID, select “Yes” to define a Test ID with the Access Records menu.
7. Begin measuring until a stable leak measurement (leak rate that does not vary over 10 seconds of measurement time) is achieved. If desired, use the “Speed” function to manually control the flow rate by pressing the I/O \leftarrow key to lower the flow rate. Adjustments to the flow rate are indicated by the speed bar moving to the left.
8. Select “Stop” to complete the measurement.

10.0 Data and Records Management

Information generated or obtained by UB RARE field personnel must be organized and accounted for in accordance with records management procedures. Information concerning the field use of the BHFS must be recorded in a bound logbook or equivalent electronic method, as described in the procedure sections. Data recorded in the field project logbooks shall include, but are not limited to, the following:

- BHFS serial number
- Project name
- Facility name
- Facility location
- BHFS operator name
- Measurement date and time
- Recorded Test ID
- Attachment used
- Measured leak concentration and calculated leak rate
- Weather conditions
- Remarks

11.0 Quality Control and Quality Assurance

11.1 General Quality Considerations

11.1.1 Sensitivity and specificity of the detection system are important factors in establishing quality requirements. Quality requirements must include ensuring that equipment is ready for use as follows:

- Operating instructions and/or manuals from the manufacturer are available for each piece of equipment.

- Equipment used for field activities is handled, transported, shipped, stored, and operated in a manner that prevents damage and deterioration. Equipment must be handled, maintained, and operated in accordance with the manufacturer's operating instructions.
- The instrument must be calibrated daily, prior to collecting measurements, to ensure consistency and comparison of data across multiple sites.

11.1.2 Field personnel are responsible for maintaining a central, comprehensive list of all field equipment subject to this procedure. The equipment inventory list for each instrument or piece of equipment must include the following:

- Description/identity of the equipment (Bacharach Hi Flow® sampler, attachments used, etc.).
- Manufacturer or vendor name.
- Equipment's serial number or other manufacturer ID number.
- The manufacturer's instructions or a reference to their location.
- Record of damages, malfunctions, modifications, and/or repairs to the equipment.

11.1.3 Any problems or abnormalities observed during use of the instrument must be recorded in the field notebook. If the instrument does not appear to be operating properly, red-tag it and remove it from service. Record pertinent information in the project logbook, including date, time, test ID, location, and instrument operator name.

11.2 Specific Quality Checks

11.2.1 The correct operation of the BHFS will be assessed by conducting pre- and post-study multi-point calibration checks using an Environics gas divider in steps of 1 lpm from 1 lpm to 10 lpm, with acceptable responses within 10% of the gas divider set value. Zero/span calibration settings will also be checked prior to daily field deployment. The BHFS response is calibrated at 2.5% and 100% CH₄ before each day's trials (described in Section 9.1).

11.2.2 Due to recent discussions regarding the validity of BHFS measurements (Howard et al., 2015), the use of a QA measurement device at the exhaust of the BHFS will be an essential component of this study. The augmented QA protocol refers to secondary measurements of the BHFS exhaust to confirm the leak rate (%) determinations are similar to those of Stovern et al. (2016). The current choices for QA measuring systems are the TVA-1000B (Thermo Scientific Waltham, MA, USA) for the low end and either a PPM Gas Surveyor 500 (Gas Measurement Instruments Ltd, Renfrew, Scotland) or a Detecto Pak-Infrared (DP-IR Heath Consultants, Houston, TX, USA) for higher concentrations.

12.0 References and Supporting Documentation

Bacharach Inc., <https://www.mybacharach.com/> (last accessed December 13, 2016).

Bacharach HI FLOW® Sampler for Natural Gas Leak Rate Measurement Instruction 0055-9017
Operation and Maintenance Manual, Revision 7, July 2015

- Howard, Touché. (2015a). "University of Texas study underestimates national methane emissions at natural gas production sites due to instrument sensor failure." *Energy Science and Engineering* 3(5): 443–455.
- Howard, Touché. (2015b). Comment on "Methane emissions from process equipment at natural gas production sites in the United States: pneumatic controllers." *Environmental Science and Technology* 49(6): 3981–3982.
- Howard, Touché, Thomas W. Ferrara, and Amy Townsend-Small. (2015). "Sensor transition failure in the high flow sampler: implications for methane emission inventories of natural gas infrastructure." *Journal of the Air & Waste Management Association* 65(7): 856–862.
- Stovern, Michael, Adam P. Eisele, and Eben D. Thoma. (2016). "Assessment of Pneumatic Controller Emission Measurements Using a High Volume Sampler at Oil and Natural Gas Production Pads in Utah." Extended Abstract #92, Air and Waste Management Association Air Quality Measurement Methods and Technology Conference, Chapel Hill, NC, March 15–17.

Appendix F:

Evacuated Canister Analysis Procedures

Prepared for

Air Pollution Prevention and Control Division
National Risk Management Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Prepared by

Enthalpy Analytical, Inc.

Appendix Fa:
GC/FID Analysis of Hydrocarbons
Using Method TO-14A

SOP-ENT 115 Rev. 2.0

Prepared by Enthalpy Analytical, Inc.

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE**Enthalpy Analytical, Inc.**
Standard Operating Procedure**GC/FID Analysis of Hydrocarbons using Method TO-14A**

Enthalpy SOP #	ENT115	Revision #	2.0
Author	David M. Berkowitz	Date Written	December 6, 2011
Revised by	T. Denese Daniels	Date Revised	January 20, 2014

Pages 11

Laboratory Director/designee Approval:  Approval Date: 3/28/14Quality Assurance Coordinator/designee Review:  Review Date: 3/28/14Effective Date: April 11, 2014**1.0 Scope and Application:**

This document describes the procedures for sample preparation, analysis, and QC of volatile organic hydrocarbon analytes in ambient air samples. Air samples are collected in 3L, 6L or 1.4L canisters at pressures above or below atmospheric pressure. The analytes that may be determined using this SOP are listed in Appendix A: Table 1.

2.0 Summary of Method:

The samples are analyzed using a cryogenic concentrator and a gas chromatograph equipped with a flame ionization detector. Sample analysis begins by employing a three stage sample concentration technique using a series of cryogenically cooled traps. The sample is desorbed and refocused at the head of the analytical column for enhanced chromatographic resolution.

It is the responsibility of the qualified analytical staff of Enthalpy Analytical, Inc. to follow the procedures set forth in this SOP.

3.0 Definitions:

- 3.1 ppbv – Part per billion by volume
- 3.2 Batch – A batch consists of group of up to 20 samples over analyzed over a 24 hour period.
- 3.3 Laboratory Control Sample (LCS) – An analysis of the ICV or a second preparation of the calibration standard analyzed at a concentration that falls within the range of the initial calibration.
- 3.4 Initial Calibration Verification (ICV) – The analysis of a standard prepared from a second source of lot used to verify the initial calibration; also referred to as Second Source Standard.
- 3.5 Continuing Calibration Verification (CCV) – The analysis of a mid-level calibration standard used to verify the instrument meets calibration acceptance criteria.

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE

- 3.6 Order Acknowledgement Form (OAF) – A form generated by the Sales staff, detailing the analytical services that the customer requires for the particular project along with the cost. This document includes information about sample receipt and condition, the samples to be tested, the analyses to be performed, the target compounds and the date the report is due to the customer.
- 3.7 Qualified analytical staff – Those individuals who have documented demonstration of proficiency with the method.

4.0 Safety:

Appropriate personal protective equipment should be worn including a lab coat, gloves and safety glasses during standard preparation and sample analysis.

5.0 Equipment and Supplies:

- 5.1 Gas Chromatograph (GC) – Agilent 5890, 6890N, or 7890 series or equivalent equipped with a Flame Ionization Detector (FID).
- 5.2 GC Column – Restek® Rtx-1, or equivalent, 60 m, 0.32 mm, 1.0 um film thickness fused silica capillary column coated with 100% dimethyl polysiloxane.
- 5.3 Concentrator – Entech 7100A Preconcentrator, or equivalent; the Entech utilizes a three-stage concentration to eliminate water vapor, methane and CO₂.
- 5.4 Entech 4600A Dynamic diluter equipped with 5L/min and 50cc/min mass flow controllers for standard preparation.
- 5.5 Data system – Agilent ChemStation, or equivalent, for data acquisition. This system is capable of continuous acquisition and storage of chromatographic data obtained throughout the run.

6.0 Reagents and Standards:

- 6.1 Calibration standards – Certified 1ppm stock calibration gas cylinders containing 57 ozone precursor hydrocarbons are purchased. Working gas standards are prepared using the stock calibration gas in 6L canisters using the Entech Dynamic Diluter System.
 - 6.1.1 A clean 6L canister is evacuated to <50mtorr and humidified with approximately 50μL of DI water for preparation of the TO-14A standard. The certified cylinder is attached to the clean canister and the standard is introduced into the canister. Stock calibration gas is typically diluted to working standard concentrations of 20ppbv and 1ppbv. Standards should not be pressurized in excess of 20psi.
 - 6.1.2 The canisters of working standards are allowed to sit for a minimum of 4 hours (overnight if time permits). This provides necessary time for a layer of water to form on the surface of the canister displacing VOCs from the surface and forcing them back into the gas phase.

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE

6.1.3 These working standards are analyzed at various load volumes to create an initial calibration curve.

6.2 Initial Calibration Verification Standard (Second Source Standard) Cylinder(s) – a certified calibration gas containing all target analytes.

6.3 Zero-air or Nitrogen (N₂) – Hydrocarbon free air (or high purity Nitrogen may be substituted, if sufficiently clean air is not available) is used for standards prep, blanks and sample dilution.

7.0 Sample Preservation, Storage, and Handling:

7.1 Samples are stored in the ambient canister sample storage area, prior to, and after analysis.

7.2 VOCs are stable for at least 30 days after collection into canisters.

8.0 Calibration:

8.1 Initial Calibration:

8.1.1 Analyze an initial calibration consisting of a minimum of 3 concentration levels. One of the calibration levels must be the same as the daily continuing calibration. (See Appendix B: Tables 2 and 3 for typical GC and pre-concentrator operating conditions.)

8.1.2 One canister containing target analytes is prepared. This canister is diluted and analyzed at various concentrations to build the initial calibration. Analyzing a 500mL aliquot of the working standard canister is an undiluted analysis. Analysis of a 100mL aliquot of the working standard is a 5-fold dilution.

8.1.3 Enter the concentration of each level in ppbv, into the calibration table when new standards are prepared. The Relative Standard Deviation (RSD) of the response factors of all analytes must be <30%. If the RSD is >30% the instrument must be recalibrated. The average response factor for each analyte is used to quantify sample results.

8.2 Initial Calibration Verification (ICV)

8.2.1 Analyze an ICV standard (second source standard) after the acceptable analysis of an initial calibration. The ICV standard should be prepared using different mass flow controller settings on the dynamic diluter than those used to prepare the initial calibration standard. The ICV should contain all of the analytes of interest at concentrations within the calibration range.

8.2.2 The results of the analysis of the ICV should be within 30% of its tag values. If this criterion is not met, analyze (or prepare and analyze) a fresh standard. If the standard continues to fail, correct any problems and analyze a new initial calibration.

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE

8.3 GC Retention Time Window Determinations:

- 8.3.1 Retention time windows must be determined for every 72 hours of continuous operation.
- 8.3.2 Three injections of reference materials containing all of the analytes of interest are injected for retention time window determination.
- 8.3.3 Calculate the standard deviation of the three absolute retention times for each single component standard. The retention window is defined as the mean plus or minus three times the standard deviation of the individual retention times for each standard. In those cases where the standard deviation for a particular standard is zero, the laboratory must substitute the standard deviation of a closely-eluting, similar analyte to develop a valid retention time window.
- 8.3.4 Retention time windows must be reestablished for each GC column whenever a new column is installed or when major instrument maintenance is performed.

8.4 Daily/Continuing Calibration Verification (CCV):

- 8.4.1 Analyze a mid-level calibration standard at the beginning and end of the analytical sequence.
- 8.4.2 The RPD of each response factor from the mean response factor of the initial calibration curve must be <30% for continued use of the mean response factors. If the RPD is >30%, recalibration is required.

8.5 After initial or continuing calibration acceptance criteria have been met, analyze a LCS. See Section 10.3 for LCS analysis and acceptance criteria.

8.6 Following a passing LCS, a humidified blank must be analyzed to ensure the analytical system is not contaminated. See blank acceptance criteria in section 10.2

9.0 Procedure:

9.1 Canister Cleaning: See SOP ENT089 for canister cleaning procedures.

- 9.1.1 All 6L sample canisters used for low level TO-14A analysis are cleaned to 0.2ppbv and tagged as TO-14A clean. Cleanliness is verified through the GC analysis of the cleaned canister.
- 9.1.2 All sample canisters should undergo a 24 hour leak check in which the pressure over a 24 hour period should not vary more than 13.8 kPa (± 2 psig or 103 mmHg). If time constraints do not allow for a 24 hour leak check, a 12 hour leak check in which the pressure should not vary more than 6.9kPa (± 1 psig or 51 mmHg) may be performed. The canister leak check information is recorded in the Canister Leak Check binder.
- 9.1.3 All sample canisters are stored pressurized after they have been determined to be leak free and at the appropriate cleanliness. Before sampling, the canisters are evacuated to less than 50mtorr and the temperature and pressure are

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE

recorded on the Canister Pressurization Form or in the Sample Manager database.

9.2 Sample Preparation:

- 9.2.1 The pressure of each canister is checked prior to analysis using a calibrated pressure gauge and the reading is recorded in mmHg. Check the OAF to determine the analysis required and to determine the appropriate gas for pressurizing canisters. Check the requested MDL to determine the level of pressurization needed to minimize canister dilution values.
- 9.2.2 If the canister pressure is below atmospheric pressure, pressurize the canister using N2 or zero air, unless fixed gas (ASTM D-1946) analysis is also required for that canister. For samples requiring both Method TO-14A and ASTM D-1946 analyses, pressurize the canisters with helium only. Record the type of gas used to pressurize the canister as well and the final pressure in mmHg. (Canisters are usually pressurized to approximately 700mmHg for an approximate 2-fold dilution of the sample.)
- 9.2.3 The Entech concentrator is equipped with a vacuum pump that will allow samples received at ambient pressure to be analyzed without additional pressurization if a lower detection limit is required.
- 9.2.4 Initial and final canister pressures, temperature, and barometric pressure are recorded on Canister Pressurization forms. Additional information to be recorded on the Canister Pressurization form is customer name, project number, customer sample ID, canister number, weather station number and expiration date, transducer or pressure gauge number and expiration date, gas used to pressurize samples, analysts initials and the date samples are pressurized.

9.3 Sample Analysis:

- 9.3.1 Samples are analyzed in the same manner as calibration standards. If the sample is to be analyzed with no instrument dilution factor a 500mL aliquot of the sample is analyzed. If the sample is expected to be high level, then a smaller sample volume may be analyzed.
- 9.3.2 The concentration of target analytes in the sample analysis should fall within the established instrument calibration range. If a target analyte concentration exceeds the calibration range, reanalyze the sample at a dilution to bring the concentration of the analyte(s) within calibration range. When more than one analyte concentration exceeds the instrument's calibration range, dilute the sample based on the highest analyte concentration.

9.4 Interferences:

- 9.4.1 Contamination may occur in the sampling system if canisters are not properly cleaned before use. Additionally, all other sampling equipment (e.g., pump and flow controllers) should be thoroughly cleaned to ensure that the filling apparatus will not contaminate samples.

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE

- 9.4.2 Very volatile analytes, such as the C₂ and C₃ hydrocarbons can display peak broadening and co-elution with other species if the analytes are not delivered to the GC column in a small volume of carrier gas. Refocusing of the sample after collection on the primary trap, either on a separate focusing trap or at the head of the gas chromatographic column mitigates this problem.
- 9.4.3 Interferences in canister samples may result from improper use or from contamination of: (1) the canisters due to poor manufacturing practices, (2) the canister cleaning apparatus, and (3) the sampling or analytical system. Attention to the following details will help to minimize the possibility of contamination of canisters. Canisters should be stored in a contaminant-free location and should be capped tightly during shipment to prevent leakage and minimize any compromise of the sample.
- 9.4.4 Impurities in the calibration dilution gas (if applicable) and carrier gas, organic analytes out-gassing from the system components ahead of the trap, and solvent vapors in the laboratory account for the majority of the contamination problems. The analytical system must be demonstrated to be free from contamination under the conditions of the analysis by running humidified zero air or N₂ blanks. **The use of non-chromatographic grade stainless steel tubing, non-PTFE thread sealants, or flow controllers with Buna-N rubber components must be avoided.**
- 9.4.5 Significant contamination of the analytical equipment can occur whenever samples containing high VOC concentrations are analyzed. This in turn can result in carryover contamination in subsequent analyses. Whenever a high concentration sample is encountered, if possible, it should be followed by an analysis of a humid zero air or N₂ blank to check for carryover contamination. Otherwise, closely examine the sample analysis following the high concentration sample for the presence of carryover. If carryover is suspected, reanalyze the affected sample.
- 9.5 Once the samples have been analyzed, process each sample using the data analysis software. Use the established GC Retention Time Windows to identify target analytes based on retention time.
- 9.6 Record all information associated with instrument maintenance, instrument calibration, and sample analysis in the applicable instrument log.

10.0 Quality Control

10.1 System blank:

- 10.1.1 Prior to initial or continuing calibration, a nitrogen blank may be analyzed to verify the analytical system is free of contaminants.
- 10.1.2 No target compounds should be detected in the system blank at concentrations greater than 0.2 ppbv. If the system is contaminated, analyze another system blank.

10.2 Humidified Method Blank:



- 10.2.1 Analyze the humidified canister method blank once per 24 hour analytical sequence, prior to sample analysis but after an acceptable initial or continuing calibration.
- 10.2.2 Prepare the humidified method blank in a clean canister only used for method blank analysis.
- 10.2.3 Analyze the method blank in the same manner as the calibration standards.
- 10.2.4 The concentration in the method blank must not exceed 0.2 ppbv for any target analyte.
- 10.3 Laboratory Control Sample (LCS):
 - 10.3.1 The LCS is an analysis of the ICV standard at a concentration that falls within the initial calibration range.
 - 10.3.2 Analyze the LCS with each analytical batch.
 - 10.3.3 The LCS recovery values should be 70% to 130% for all target analytes. If the LCS fails, reanalyze. If the LCS continues to fail, check for problems with the instrument or standards; recalibrate if necessary.
- 10.4 Laboratory Duplicate:
 - 10.4.1 Analyze one field sample in duplicate per sample batch.
 - 10.4.2 The results of the duplicate analysis should be within 25%D for target concentrations above the limit of quantification (LOQ).
 - 10.4.3 A lab duplicate analyzed at a dilution different from the initial analysis is acceptable for 1.4L canisters with limited sample volume for analysis.

11.0 Data Analysis and Calculations:

- 11.1 Target analyte concentrations that exceed the instrument's calibration range are flagged with an "E", denoting an estimated concentration.
- 11.2 Report the undiluted (or least diluted) analysis and the diluted analysis that brings the highest concentrated target analyte within the calibration range.
- 11.3 Report only the target analytes that exceeded the calibration range in the undiluted (or least diluted) analysis from the diluted analysis.
- 11.4 Conc. as sampled in ppbv = Conc as analyzed * Canister pressurization Factor * Analytical Dilution Factor.
- 11.5 Calculate the Percent Difference (%D) between the initial sample analysis and the duplicate sample analysis for all analytes greater than the LOQ:

$$\left(\frac{Conc_{mit} - Conc_{dup}}{Avg(Conc_{mit} + Conc_{dup})} \right) * 100$$

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE

Where:

Conc_{init} = Concentration of initial analysis

Conc_{dup} = Concentration of duplicate analysis

- 11.6 If the canister is pressurized prior to analysis, a canister pressurization factor is calculated and included in the calculation for “as sampled” analyte concentrations. The following formula is used to calculate canister pressurization factors:

$$\frac{\frac{GPF + PbarF}{TempF + 460}}{\frac{GPI + PbarI}{TempI + 460}} - \frac{\frac{GPP + PbarP}{TempP + 460}}{\frac{GPI + PbarI}{TempI + 460}}$$

Where:

GPF = Final Gauge Pressure, mmHg

PbarF = Final Barometric Pressure, mmHg

TempF = Final Temperature, degrees F

GPI = Initial Gauge Pressure, mmHg

PbarI = Initial Barometric Pressure, mmHg

TempI = Initial Temperature, degrees F

GPP = Pretest Gauge Pressure, mmHg

PbarP = Pretest Barometric Pressure, mmHg

TempP = Pretest Temperature, degrees F

12.0 Method Performance:

Method performance is demonstrated through MDL studies and demonstrations of capability performed by the analyst. Follow procedures detailed in SOP ENT027, to determine MDL. Follow the procedures detailed in SOP ENT005, for performing demonstrations of capability.

13.0 Pollution Prevention and Waste Management:

Sample canisters are purged and vented into a laboratory fume hood or a closed system manifold.

14.0 References:

EPA Method TO-14A – EPA/625/R-96/010b, January, 1999.

15.0 Tables, Diagrams, and Flow Charts:

15.1 Appendix A: Table 1 – Target Volatile Organic Analytes

15.2 Appendix B: Table 2 – Gas Chromatographic Conditions

15.3 Appendix B: Table 3 – Entech 7100 Sample Pre-concentrator Conditions

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE

Revision History:			
Revision #	Date	Author	
2.0	1/20/14	Denese Daniels	Update Chromatographic & Preconcentrator conditions & various updates
1.0	9/3/13	Denese Daniels	periodic review and update
0.0	12/6/11	D. M. Berkowitz	New document

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE

Appendix A

Table 1

Target Volatile Organic Analytes	
Ethene (Ethylene)	3-Methylhexane
Ethyne (Acetylene)	2,2,4-Trimethylpentane (Isooctane)
Ethane	n-Heptane
Propylene	Methylcyclohexane
Propane	2,3,4-Trimethylpentane
2-Methylpropane (Isobutane)	Toluene
1-Butene	2-Methylheptane
n-Butane	3-Methylheptane
trans-2-Butene	n-Octane
cis-2-Butene	Ethylbenzene
2-Methylbutane (Isopentane)	m&p-Xylene
1-Pentene	Styrene
n-Pentane	o-Xylene
2-Methyl-1,3-butadiene (Isoprene)	n-Nonane
trans-2-Pentene	Isopropylbenzene
cis-2-Pentene	n-Propylbenzene
2,2-Dimethylbutane	1-Ethyl-3-methylbenzene
Cyclopentane	1-Ethyl-4-methylbenzene
2,3-Dimethylbutane	1,3,5-Trimethylbenzene
2-Methylpentane	1-Ethyl-2-methylbenzene
3-Methylpentane	1,2,4-Trimethylbenzene
1-Hexene*	n-Decane
n-Hexane	1,2,3-Trimethylbenzene
Methylcyclopentane	m-Diethylbenzene
2,4-Dimethylpentane	p-Diethylbenzene
Benzene	n-Undecane
Cyclohexane	n-Dodecane
2-Methylhexane	
2,3-Dimethylpentane	

Appendix Fb:
EPA Method 18 Bag and
EPA ALT-100 Canister Analysis

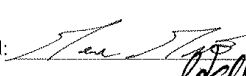
SOP-ENT 150 Rev. 7.0

Prepared by Enthalpy Analytical, Inc.

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE**Enthalpy Analytical, Inc.
Standard Operating Procedure****EPA Method 18 Bag and EPA ALT-100 Canister Analysis**

Enthalpy SOP #	ENT150	Revision #	7.0
Author	P.G. Zemek	Date Written	March 31, 2000
Revised by	Clint Thrasher	Date Revised	September 24, 2014

Pages 6

Laboratory Director/designee Approval:  Approval Date: 12-8-2014Quality Assurance Coordinator/designee Review:  Review Date: 12-9-2014Effective Date: 12-23-2014**1.0 Scope and Application:**

This document describes the Gas Chromatography (GC) analysis of gas samples collected in flexible bags from stationary sources using the procedures set forth in EPA Method 18. A varied list of gaseous organic compounds is analyzed. Specific compounds of interest are identified on the Order Acknowledgement Form (OAF) for the individual project.

This document also describes the GC analysis of gas samples collected in rigid canisters from stationary sources using the procedures set forth in EPA Method 18 including the allowances set forth in EPA Method ALT-100, Approval of Canister Sampling with Methods 18 Flares. For EPA Method ALT-100, the procedures herein and those in SOP ENT165 are used to analyze flare gas collected in canisters. The compounds of interest are listed in Appendix A.

It is the responsibility of the employee who performs these methods to follow the procedures set forth in this SOP.

2.0 Summary of Method:

For bag analysis, source gas is collected in triplicate by the stack tester in separate flexible bags. For canister analysis, source gas is collected in separate rigid canisters. The bags/canisters are delivered to the lab and analyzed as soon as possible. One sample bag from each location (or as specified by the client) is spiked with a known concentration of target compound(s), held for the appropriate time and analyzed. The recovery efficiency values are calculated and used to adjust the sample concentrations for each sampling location.

Spiking of samples collected in rigid canisters is not required per EPA Method ALT-100.

3.0 Definitions:

3.1 The Limit of Quantitation (LOQ) – The concentration of the lowest calibration standard (typically, 5 ppm) used in the initial calibration. A lower concentration standard may be analyzed, if the client requires a lower LOQ.

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE

- 3.2 Instrument Detection Limit (IDL) – The lowest concentration of a compound that can be detected by the instrument that has a peak area greater than 3 times signal-to-noise. An IDL is determined at least annually. The compounds analyzed will vary based on the desired compound list.

4.0 Safety:

All samples should be considered hazardous material, and should be handled in an appropriate manner. Any sample that poses a specific health hazard to Enthalpy Analytical, Inc. (Enthalpy) personnel must be pre-approved. All personnel who will come in contact with such sample(s) must be notified of appropriate safety measures to be taken. The client must also provide any information, i.e., a material safety data sheet (MSDS), which would enable Enthalpy to take the required safety precautions.

5.0 Equipment and Supplies:

- 5.1 An HP or Agilent series 5890, 6890, 7890, or equivalent gas chromatograph in good working order
- 5.2 GC column, verified as appropriate for method
- 5.3 Gas dilution system
- 5.4 Gas-tight syringes
- 5.5 Bags with an appropriate valve or septa in good condition
- 5.6 Stream selection valve (Valco 16 port), mass flow controller(s), and Teflon diaphragm pump for automation, if desired

6.0 Reagents and Standards:

Unexpired, certified cylinders containing calibration gas corresponding to the analytes of interest.

7.0 Sample Preservation, Storage, and Handling:

- 7.1 Bag samples are analyzed as soon as possible after delivery to the laboratory, typically within 48 hours of receipt. Sample bags are stored at ambient temperature away from direct light.
- 7.2 Canister samples are also analyzed as soon possible after receipt. Sample canisters are stored at ambient temperature.

8.0 Calibration:

- 8.1 Initial calibration (Pre-test):
 - 8.1.1 A minimum of three calibration standard concentration levels must be analyzed in triplicate, and a curve developed that brackets the sample concentrations. Calibration gases may contain more than one compound. If sample concentrations exceed the highest calibration point, the range of the calibration must be expanded to include the level of the samples or the samples must be diluted to within the calibration range.

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE

- 8.1.2 The calibration gases used should be certified by the manufacturer to a minimum of 2% accuracy (1% is preferred). Dilution systems are an option when using with high concentration cylinders. Such dilution systems must be calibrated. Refer to SOP ENT065 dilution system calibration procedures.
- 8.1.3 There is no requirement for the linearity of the calibration curve in the reference method. However, in-house QA requirements are that the average concentration of the triplicate injections of the calibration standards must not differ from the actual theoretical standard concentration by more than 10%, when calculated using the equation of the line for the calibration curve. (Accuracy of prepared audit samples must be within 10% of the theoretical value.)
- 8.1.4 The peak areas of each injection for each compound must not differ by more than 5% from their mean. If they do not agree, continue to inject until three consecutive injections meet the 5% criteria. If the 5% precision requirement is difficult to achieve, instrument maintenance should be performed or the analytical technique modified.
- 8.1.5 The retention time for the compound in each of the triplicate injections should not differ by more than 1%.
- 8.2 Continuing Calibration (Post-test)
 - 8.2.1 A mid-level calibration standard (Concal) should be analyzed every 24 hours or every ten samples (whichever is more frequent) in an analytical sequence and at the end of the sequence. The area responses for the analysis of the Concal must meet the criteria in section 8.1.4.
 - 8.2.2 Compare the average response factor for the three post-test injections to the corresponding pre-test calibration standard response factor. If the pre-test response factor deviates by less than 5% from the mean of the pre and post-test response factors, the pre-test calibration curve is used to quantitate the samples.
 - 8.2.3 If the average response factor of the post-test differs by more than 5% from the average pre-test response factors, analyze the remaining calibration points and develop a new calibration curve averaging all the pre and post calibration levels. The averaged calibration curve is used to quantitate the samples.
 - 8.2.4 The results for all calibration standards shall meet within 10% of the tag value of the standard when processed against the curve.

9.0 Procedure

9.1 Sample analysis:

- 9.1.1 When analyzing canister samples, the canister must be pressurized in order for analysis to commence. Record the environmental conditions (ambient temperature and pressure) and canister pressure, prior to and after canister pressurization in the canister pressurization form (TankDilution.xls) saved in the electronic job folder. Enter the pressurization data into the applicable tab

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE

in the SampleManager database. If the sample canisters are received under sufficient positive pressure such that no further pressurization is necessary, record the temperature and pressure information, prior to analysis.

- 9.1.2 Connect the bag(s) or can(s) to the gas valve with a piece of Teflon or stainless steel tubing. Analyze each sample in triplicate. The analyses must meet the criteria in section 8.1.4 and 8.1.5.
 - 9.1.3 If testing is for the purpose of complying with New Source Performance Standards (NSPS) or Hazardous Organic National Emission Standards for Hazardous Air Pollutants (HON) requirements, "Identify" all unknown peaks greater than 5% of the total chromatographic material using a GC/MS, or produce an estimation of possible compounds by their retention times compared to other known compounds, with confirmation by further GC analysis.
 - 9.1.4 After the bag sample analysis is complete, choose a bag from each location/source (or as designated by the client) to perform spike and recovery testing. (See section 10.2). After the spiked bag has been analyzed, the volume of the bag before spiking and amount of each spike gas added to the bag must be taken into account to calculate a spike recovery. (See section 9.2).
- Note: If the bag volume will be determined by the technique in section 9.2.2.2 and the volume of the bag appears to be greater than or equal to the volume of the canister (20 L), reduce the volume of the gas in the bag before spiking it by opening the valve and applying pressure. This will improve the accuracy the measurement of the total volume spiked.
- 9.1.5 If the volume of the bag, measured after reanalysis, is significantly lower than the volume measured before spiking and the recovery value is low, repeat the test using another bag.
 - 9.1.6 Measure the baseline concentration before spiking the second bag as it may have changed since the original analysis. Baseline analysis should follow all guidelines in section 8.1.4.

9.2 Determination of the Volume of the Bag for Spike Recovery Calculations:

- 9.2.1 The volume of the bag must be considered in order to calculate the correct amount of high concentration gas or liquid stock used for spiking. Before spiking, determine the volume of the bag to be spiked by measurement using the WVD. See SOP ENT151 for instructions on using the WVD. The WVD should be used, as obtaining volumes in this manner is non-destructive to the sample.
- 9.2.2 If the WVD technique is not appropriate for the bag, the analyst has the option of making an educated guess as to the volume of the bag before spiking it. After the spiked bag has been analyzed, the volume of the bag before spiking must be determined for calculating the spike recovery values. Either of the following two evacuation techniques may be used to determine the volume of the spiked sample bag:

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE

9.2.2.1 Dry gas meter bag evacuation:

- 9.2.2.1.1 Connect the bag to the inlet of a calibrated dry gas meter using a three-way valve. The common leg of the three-way valve shall be attached to the dry gas meter. One of the legs is attached to the bag. The third is open to ambient air. Connect a pump to the outlet of the dry gas meter.

Note: The three-way valve is used because the majority of the error associated with the dry gas meter occurs at the start and stop of the meter. By using this “running start” technique, the error is greatly reduced.

- 9.2.2.1.2 Start the pump with the three-way valve turned to ambient air. Set the flow rate to approximately 2 liters per minute. Observe the dial of the dry gas meter. As the needle passes the zero mark on the gauge, rotate the three-way valve towards the bag. Record the initial dry gas meter volume at the time the valve was rotated.

- 9.2.2.1.3 Allow the bag to evacuate completely. Record the final dry gas meter reading when the bag is empty. Record the ambient temperature and the barometric pressure. Correct the metered volume to 68 °F and 29.92 inches Hg.

9.2.2.2 For some high concentration samples, the dry gas meter may become contaminated by passing the sample through it. In those instances, use an evacuated 20 L steel canister to determine the volume of the bag as follows.

- 9.2.2.2.1 Record the initial vacuum in mmHg of the evacuated canister. Record the temperature of the canister and the barometric pressure.
- 9.2.2.2.2 Connect the bag to the canister inlet. Slowly open the valve and allow the vacuum in the canister to draw the sample into the canister.
- 9.2.2.2.3 When the bag is empty, close the valve and disconnect the bag. Record the final vacuum, temperature and pressure.
- 9.2.2.2.4 If the bag to be evacuated appears to have a gas volume greater than or equal to the volume of the canister used for evacuation, reduce the volume of the bag
- 9.2.2.2.5 The volume of the bag is determined using the formula in section 11.3.

9.2.2.3 For the procedures in sections 9.2.1, 9.2.2.1, and 9.2.2.2, after the spiked bag has been analyzed, and spike recovery values have been

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE

calculated, the spike sticker is either copied or removed from the bag and taped into the logbook following the procedures in SOP ENT011.

9.2.2.4 The spike recovery values are calculated and reported using either the SampleManager reporting database or the Bag Spike and Recovery spreadsheets located on the server at Enthdc02\Data\Sheets-Validated\Lab Use.

9.3 Documentation:

All sequence information shall be printed from the chromatography software and taped into the instrument logbook. Temperatures, pressures, and volumes shall be recorded in the instrument logbook for entry in Sample Manager or into a spreadsheet for recovery tests.

10.0 Quality Control:

10.1 Analyze any Stationary Source Audit Samples (SSAS), if received, before analyzing field samples. The compound recovery for the SSAS must be within 10% of the expected value.

10.2 Recovery Study for Bag Sampling.

10.2.1 After an acceptable analysis, a bag sample from each sampling location is chosen and checked for integrity before spiking.

10.2.2 The chosen bag sample is spiked with a known mixture of all of the target compounds. The theoretical concentration, in ppm, of each spiked compound in the bag, using an estimate of the bag volume, should be 40 to 60 percent of the average concentration measured in the three bag samples.

10.2.3 If a target compound was not detected in the bag samples, the method states the bag will be spiked at 5 times the limit of detection. Often that level is lower than the LOQ. In that circumstance the spike concentration should be 1.5 to 4 times the LOQ for that compound.

10.2.4 All spiking information (time, temperature, barometric pressure, volume of spikes, ID of spike material) is to be placed on a sticker generated using the Word documents, "bag spike label Evac" or "bag spike label WVD". Both are saved at ENTHDC02\Data\Documents\Sheets – NOT VALIDATED.

10.2.5 The spiked bag is then held for a time period equal to or greater than the elapsed time between the sample collection and the sample analysis. If multiple sample bags are to be associated with the same spiked sample, the longest elapsed time of the sample group is used as the required hold time.

10.2.6 Analyze each spiked sample in triplicate. The analyses must meet the criteria in section 8.1.4 and 8.1.5. The average fraction recovery value (R) is determined for each compound.

10.2.7 For the bag sampling technique to be considered valid for a compound, the recovery value must meet 70 to 130%. If the recovery value does not meet this criterion for a target compound (and no errors were found in the collection,

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE

spiking, and/or analysis of the bag samples) the sampling technique should be considered unacceptable for that compound and an alternate technique should be evaluated for acceptance.

- 10.2.8 Report the spike recovery value in the test report. Unless otherwise directed by the client, use the applicable, acceptable, spike recovery value to correct all field sample results.

11.0 Data Analysis and Calculations

- 11.1 The average fraction recovery value (R) of each spiked target compound is calculated using the following equation:

$$R = \frac{t - u}{s}$$

Where:

- t = measured average concentration (ppm) of spiked target compound and source sample (analysis results after bag spiking)
- u = source sample average concentration (ppm) of target compound in the bag (analysis results before bag spiking)
- s = theoretical concentration (ppm) of spiked target compound in the bag; determination of the bag volume will be required per one of the techniques in section 9.2.2

- 11.2 All results with the calculated R-value for that compound are reported using the following equation:

$$\text{Reported Result} = \frac{\text{Measured Concentration (ppm)}}{R}$$

- 11.3 Calculate the volume of gas in a canister using the following equation:

$$Vol = \frac{Vol_c \times (Pab_f - Pab_i) \times 760 \times 17.64 \times Pbar}{T + 460}$$

Where:

- Vol_c = volume of the canister as determined by water capacity or as certified by vendor
- Pab_f = pressure absolute mmHg after evacuating bag
- Pab_i = pressure absolute mmHg before evacuating bag
- Pbar = barometric pressure inHg
- T = temperature, °F

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE

12.0 Method Performance

Method performance is evaluated through the analysis of detection limit studies, analysts' demonstration of capability and audit sample analyses. Follow the procedures detailed in SOP ENT027 to determine detection limits. Follow the procedures in SOP ENT005 for analysis of demonstrations of capability.

13.0 Pollution Prevention and Waste Management

Sample bags are evacuated in a fume hood. Canisters are evacuated and vented to the atmosphere through a canister cleaning apparatus.

14.0 References

- 14.1 EPA Method 18, Measurement of Gaseous Organic Compound Emissions by Gas Chromatography, 40 CFR Part 60, Appendix A, promulgated as of 2/25/2000.
- 14.2 EPA Method ALT-100, Approval of Canister Sampling with Method 18 for Flares, 6/2013. <http://www.epa.gov/ttn/emc/approalt/ALT100.pdf>

15.0 Tables, Diagrams, and Flow Charts

Appendix A: EPA Method ALT-100 Compound List

Revision History:			
Revision #:	Date:	Author:	Comments:
7.0	September 24, 2014	C. Thrasher	changed title; added analysis of canister samples
6.0	June 3, 2014	K. Maturo	2014 Internal audit finding methods review
5.0	July 10, 2011	B. Evans	Review/revise as corrective action for Finding #3 for the TCEQ 2009 Desk Assessment.
4.0	April 20, 2010	S. Thorne Gregory/ D. Berkowitz	
3.0	December 9-13, 2006	M. Schapira	
2.0	November 1-30, 2006	M. Schapira	
1.0	September 4, 2003		

ORIGINAL
IF NOT RED, DESTROY THIS COPY AFTER USE

Appendix A

EPA Method ALT-100 Compounds	
methane	ethylbenzene
ethane	xylene
propane	propylene
butane	ethylene
pentane	hydrogen
hexane	oxygen
heptane	nitrogen
benzene	carbon monoxide
toluene	carbon dioxide