METEC Controlled Test Protocol:
Continuous Monitoring Emission Detection And Quantification

Revision 1.0

September 22, 2020

1 Purpose:

This testing will assess the performance of continuous monitoring (CM) systems which perform leak detection and quantification (LDAQ) under Single-Blind controlled release testing over a range of environmental conditions and emission rates. Testing will evaluate system-level performance measures including Probability of Detection and Detection Time. Additional metrics including accuracy and precision of localization and quantification estimates will be evaluated if applicable. Due to the dependence of methods on weather conditions, testing will require an extended period, typically months, with active emission and non-emissions periods to (1) allow each Experimental Design Point to operate for an extended duration, typically hours, and (2) assess performance across a wide range of meteorological conditions.

2 Definitions

- Continuous Monitor (CM) – An Emission Detection System in which sensors are installed to autonomously monitor a facility without direct human supervision or intervention for an extended period of time. A Continuous Monitor may operate continuously or at specific intervals.

- Controlled Release (CR) – A type of experiment where emissions are intentionally created for the purpose of evaluating emission detection and/or quantification systems. During a Controlled Release, the emission rate and location are known to the Test Center within well understood accuracy.

- Detection – An alert provided by an Emission Detection System to the Facility operator that an Emission is present. An elevated gas concentration measurement alone does not constitute a Detection, but instead must be accompanied by analytics or further evaluation to attribute the elevated concentration to an Emission within the Facility. This attribution must be established with a high enough confidence to warrant providing a detection alert to the Facility operator.

- Detection Time (DT) – The time between when a Controlled Release was first emitted and when a Detection was first reported to the Test Center. See section 6.2.4.

- Emission – a release of gas to the ambient environment.

- Emission Detection System – A system comprised of one or more sensors and associated analytics capable of detecting emissions and attributing them, at minimum, to a facility. Emission Detection Systems may include analytics to categorize emissions as Fugitive or Vent, and/or to provide emission rate quantification estimates.
- Equipment Group – A set of Equipment Units in proximity of one another.
- Equipment Unit – An individual unit of equipment such as a wellhead, separator, or liquid storage tank.
- Experimental Design (a test matrix) – A set of Experimental Design Points defined to investigate correlation between variation in a dependent variable and variation of one or more independent variables.
- Experimental Design Point (an experiment) – A single combination of settings for the independent variables of a controlled release experiment. Independent variables include both the emission rate of the Controlled Release(s) and environmental conditions.
- Facility – A set of equipment with a common purpose and defined boundary which may be physical (such as a fenceline) or implied.
- False Negative (FN) – A Controlled Release which was not detected by a Performer. See section 6.1 for classification of Detections.
- False Negative Fraction (FNF) – The number of False Negative Controlled Releases relative to the total number of Controlled Releases. See section 6.2.3.
- False Positive (FP) – A Detection reported by a Performer that cannot be attributed to a Controlled Release. See section 6.1 for classification of Detections.
- False Positive Fraction (FPF) – The number of False Positive Detections relative to the total number of Detections. See section 6.2.2.
- Final Report – A report issued by the Test Center after the conclusion of testing. See section 8.
- Fugitive – An unintentional emission associated with a leak, upset condition, or malfunction. Examples include leaks, stuck valves, or excess emissions from normally venting components.
- Localization Accuracy (LA)– A measure of the distance between the location of an emission as estimated by a Performer and the location where a Controlled Release occurred. In this protocol location accuracy is 2D. Three localization accuracies may be calculated based on (1) an Equipment Unit, (2) a single latitude-longitude coordinate pair, or (3) a pair of coordinates indicating a bounding box reported by the Performer (see sections 6.2.6, 6.3.5 and 6.3.6 respectively).

- Localization Precision (LP) – A measure of the area to which an emission source is attributed by a Performer. Two Localization Precisions may be calculated based on (1) an Equipment Unit, or (2) a pair of coordinates indicating a bounding box reported by the Performer (see sections 6.2.5 and 6.3.8 respectively).
- Operational Factor (OF) – The fraction of time which a CM is operational. See section 6.2.7.
- Performer – A single participant in the testing under this protocol. The Performer includes the personnel and one Continuous Monitoring system.
- Probability of Detection (PD) – Fraction of Controlled Releases, over a set of Experimental Design Points, that the Performer reported as Detections. The Probability of Detection may vary across independent variables such as the emission rate and/or the meteorological conditions, resulting in a Probability of Detection curve or surface. See section 6.2.1.
- Quantification Accuracy (QA) – A measure of the difference between the emission rate estimated by a Performer and the metered emission rate of a Controlled Release. Quantification Accuracy may be represented as an absolute difference, or as a percentage difference relative to the metered emission rate (see sections 6.3.1 and 6.3.2 respectively).
- Quantification Precision (QP) – A measure of the difference between the upper and lower confidence limits reported by a Performer for an emission rate estimate (see sections 6.3.3 and 6.3.4 respectively).
- Single-Blind – An experimental procedure in which the Test Center knows the location, timing, and emission rate of all emissions, but Performers do not.
- Test Center – The location at which testing is performed under this protocol. The term 'Test Center' includes the physical facilities, the personnel performing the evaluation, and any supporting software or analysis.
- True Positive (TP) – A Detection reported by a Performer that can be attributed to a Controlled Release. See section 6.1 for classification of Detections.
- Vent – An intentional emission associated with a process. Examples include venting from gas pneumatics, compressor rod packing, tank vent emissions from uncontrolled tanks, and equipment blowdowns.

3 Variables and Subscripts

The variables listed in Table 1 are used in equations throughout the protocol:

Table 1: List of variables

Variable	Description
N	Total number across all experiments
n	Number during a single experiment or subset of all experiments
t	Time
FP	False Positive Detection(s)
FN	False Negative Detection(s)
PD	Probability of Detection
FPF	False Positive Fraction
FNF	False Negative Fraction
OF	Operational Factor
QA	Quantification Accuracy
QP	Quantification Precision
LA	Localization Accuracy
LP	Localization Precision
DT	Detection Time

The subscripts in Table 2 are used in equations throughout the protocol:

Table 2: List of subscripts

Subscript	Description
CR	Controlled Release(s)
RD	Reported Detection(s)
TP	True Positive Detection(s)
FP	False Positive Detection(s)
FN	False Negative Detection(s)
Unit	Equipment Unit Precision
Group	Equipment Group Precision
Facility	Facility Precision

4 System Types Covered by Testing

CM systems include many designs and configurations, but generally consist of (1) one or more gas sensor(s) of any type including auxiliary components such as retroreflectors installed at or near a Facility to monitor emissions, (2) auxiliary sensors (e.g. a meteorological station) installed at or near the Facility, (3) analytics which interpret sensor data (e.g. gas concentration readings) to make emission and/or leak detections, localization estimates and/or quantification estimates accounting for variations in background concentration levels or potential interference from nearby, off-Facility sources, and (4) a data management system to report detection, localization, and quantification data.

Regardless of configuration, any CM system is qualified to participate in testing under this protocol if all operational and reporting requirements described in section 5 are met by the system.

Note: *Systems tested under this protocol must implement appropriate analytics to report Detections, and are encouraged to report localization and quantification estimates. A CM system that produces concentration readings (e.g. ppm or ppm-m), or plume pictures or video, without the analytics to analyze those readings and report Detections, is not supported by this protocol.*

Testing under this protocol will operate for multiple weeks, 24 hours per day, 5-7 days per week. Therefore, a system where a sensor is not weatherproof, is moved around on a single Facility, is moved between facilities, or requires frequent attention by personnel other than routine maintenance and calibrations as discussed in section 5.2, is not suitable for testing under this protocol.[1]

5 Test Method

Testing consists of four activities – installation, maintenance, operation, and reporting.

5.1 Installation

Performers will schedule with Test Center for installation.

5.1.1 Location of System Components

The location of system components may be selected by the Performer to best represent their methodology when deploying at customer locations, subject to approval by the Test Center. The Test Center may provide recommended locations or infrastructure where available. A Test Center may articulate specific restrictions on deployment locations and requirements. Typically, selected locations must meet the following guidelines:

1) Installations shall not inhibit vehicle or foot traffic on roadways and walkways on or around the Test Center.

2) System components shall not introduce an undue safety hazard including but not limited to loose cabling, exposed wires, tripping hazards, unmarked guy cables, or unsecured overhead components.

3) System components shall comply with hazardous space/ATEX requirements of the Test Center.

4) When required, Performers shall attain permission to install components outside of the Test Center from the land owner or operator.

5.1.2 Power

Performers are encouraged to provide their own power for sensors or auxiliary equipment, ideally using the same power subsystems as would be used in a field deployment. The Test Center may provide access to power for use by Performer CM systems if available; locations where power is available may be restricted by the Test Center. Performers should work with the Test Center to determine a safe and

[1] Other protocols will address survey systems that move between facilities, and human operated sensors.

effective power plan including approval of any connections to Test Center infrastructure, mounting locations for PV panels, batteries, or other power equipment.

5.1.3 Data Communications

The Test Center may provide a wired network connection if available, or Performers may be required to provide their own data communications via wireless mechanisms. Performers are encouraged to use the same (or similar) communications methods as would be used in field deployments.

5.1.4 Meteorological Data

Systems must install their own meteorological station if local meteorology is required, subject to approval by the Test Center. Performers are encouraged to use the same meteorological system(s) as would be used in field deployment.

5.1.5 Installation Documentation

The configuration of the system under test shall be documented and reported to the Test Center. Documentation must be sufficient for a reviewer to fully identify the '*as tested*' revision and configuration of the CM system. At a minimum, documentation shall include:

1. Location (latitude, longitude, height) of system components including central instruments, meteorological station, retroreflectors, sensor nodes, or any other equipment installed at or near the Test Center.
2. Model number of each component in (1).
3. Power configuration of each component in (1)
4. Revision number of software installed in each component in (1) that includes performer-specific software components, revisions, or customizations.
5. Revision number of any software analytics installed offsite.
6. Confidence level at which emission detection data are reported.

Installation documentation should be considered public information, and Performers should not include proprietary information (e.g. algorithmic details, reasons for locating sensor in specific locations, performance data of sensors, etc.) as part of this documentation.

5.1.6 Installation Cautions

Performers should recognize results are applicable only to the CM system *as tested and documented.* Future reviewers of results will be interested in whether systems proposed for field deployment include the same density and quality of sensors (or other equipment) as were tested under the protocol. Deploying more sensors, higher cost-performance sensors, more extensive analytics, or more human intervention than would be typical in field deployments may render the results produced in these tests inapplicable to future field deployments, regulatory applications, or other uses of the test results.

5.1.7 Non-Compatible Systems

If multiple Performers installed at a Test Center are identified as incompatible due to data communications platforms, positioning of sensors, or other reasons the Test Center and Performers will work to resolve the issue on a case-by-case basis. The Test Center will not always be able to identify these issues in advance of installation. If a conflict cannot be resolved via discussion between impacted Performers and the Test Center, the decision of the Test Center is final.

5.2 Maintenance

Performers are expected to complete any maintenance required to keep the installed system operational for the duration of the test period. This includes but is not limited to required calibration, cleaning, component replacement, or unit replacement. Performers must notify the Test Center to schedule maintenance as needed. Performers will provide documentation of maintenance tasks performed and the total time onsite during each maintenance visit. Maintenance records will be included in the Final Report at the conclusion of testing.

Performers may train Test Center personnel to perform simple maintenance tasks such as power cycling or cleaning of external lenses. Tasks qualifying as “simple maintenance” will be at the discretion of the Test Center. Test Center personnel will not perform troubleshooting or additional maintenance of systems. Maintenance performed by Test Center personnel will be recorded and included in the Final Report.

Periods when the CM system is not operational must be reported to the Test Center using method described in section 5.4.2, and will be used to compute the Operational Factor.

Performers may adjust or modify their installations during maintenance visits. Modifications of the installed system during the test period must be documented by the Performer and reported to METEC including the date which the installation was modified and the full documentation of the new configuration as defined in section 5.1.5. System modifications will be included in the Final Report.

5.3 Operation

Performer staff will not be present at the Test Center during the operation period except to complete required maintenance as discussed in section 5.2. During the operation period:

1) The Test Center will perform Controlled Releases as outlined in section 7. For each Controlled Release, the Test Center will record the location, timing, gas composition, metered emission rate, and uncertainty (95% confidence limit) of the metered emission rate.

2) Performers will remotely monitor their sensors and complete any necessary back-end analytics to translate sensor readings into emission detection reports as described in section 5.4.

3) Performers will send emission detection reports to the Test Center. Emission detection reports must include the data fields outlined in section 5.4. Performers will also send reports

to the Test Center to indicate periods when their CM system is operational or non-operational.

4) The Test Center will record the time which Performer emission detection reports are received and store them for results analysis.

Due to the extensive nature of this test protocol, there may be periods when planned or unplanned conditions may disrupt the testing within the Facility boundary at the Test Center (Facility boundary defined in section 7.1). In these scenarios, the Test Center will inform Performers of the dates of disruptive testing, and will not consider Controlled Releases or Detections during the identified period in the analysis. The Test Center will make every reasonable effort to inform Performers in advance of a planned disruption, or, if unplanned, as quickly as possible after the disruption commences.

5.4 Reporting

This section outlines data which must be reported by the Performer to the Test Center during the experiments. Two categories of data, detection reports and online/offline reports, must be reported in order for the Test Center to complete the classification of detections (section 6.1), evaluate all primary metrics (section 6.2), and evaluate optional secondary metrics (section 6.3).

5.4.1 Detection Reports

Detection reports allow Performers to indicate when a new emission is detected, or to update a previously detected emission. Detection reports include estimates by the Performer for the timing, location, and quantification of each detected emission. Each detection report must be for a single emission and must contain, at minimum, all mandatory fields listed in Table 3. Optional fields listed in Table 3 may be included if the CM is capable of reporting these additional data. Performers that are capable of reporting optional data fields are encouraged to do so in order to support the evaluation of secondary metrics under the same series of experiments.

234 *Table 3: Detection report fields*

Field	Description	Acceptable Values	Mandatory or Optional
DetectionReportID	A unique ID assigned by the Performer to the individual detection report. *This number should be **incremented** for every detection report sent.* Duplicate numbers will be assumed to be multiple transmissions of the same report; only one (the first received) report will be logged. The increment amount between reports is arbitrary and need not be constant; report ID should never be decremented.	Positive Integer	Mandatory
DetectionReportDateTime	Date and time (Coordinated Universal Time, UTC) at which this detection report was generated in *yyyy/mm/dd hh:mm* format	Formatted Date & Time	Mandatory
EmissionStartDateTime	Estimated date and time (UTC) at which the emission source began to emit in *yyyy/mm/dd hh:mm* format	Formatted Date & Time	Mandatory
EmissionEndDateTime	Estimated date and time (UTC) at which the emission source stopped emitting in *yyyy/mm/dd hh:mm* format If the emission has not stopped yet this field may be omitted or reported as `NULL`	Formatted Date & Time	Optional
EmissionSourceID	A unique ID assigned by the Performer to the individual emission source the detection report refers to. Updates to *any* parameter for this detection should utilize the same *EmissionSourceID*	Positive Integer	Mandatory
Gas	The gas the CM system measured to perform a detection.	List provided by Test Center	Mandatory

Field	Description	Acceptable Values	Mandatory or Optional
EquipmentUnit	The Equipment Unit ID on which the emission was detected. An emission source attributed within the defined Facility but not attributed to an Equipment Unit should be reported as `OTHER`. An emission source detected by a CM but not attributed to the Facility may be reported as `OFF_FACILITY`.	List provided by Test Center	Mandatory
Latitude1	If a bounding box is reported, the southern-most latitude of the bounding box in decimal degrees. Otherwise, the estimated latitude of the emission source location in decimal degrees.	Maximum and minimum values provided by Test Center	Optional
Latitude2	If a bounding box is reported, the northern-most latitude of the bounding box, in decimal degrees. Otherwise this field may be omitted or reported as `NULL`.	Maximum and minimum values provided by Test Center	Optional
Longitude1	If a bounding box is reported, the eastern-most longitude of the bounding box, in decimal degrees. Otherwise, the estimated longitude of the emission source in decimal degrees.	Maximum and minimum values provided by Test Center	Optional
Longitude2	If a bounding box is reported, the western-most longitude of the bounding box, in decimal degrees. Otherwise this field may be omitted or reported as `NULL`.	Maximum and minimum values provided by Test Center	Optional
EmissionRate	Estimated emission rate of the source. The units of this field should be **grams per hour** of the gas specified in *Gas.*	Decimal number >0	Optional

Field	Description	Acceptable Values	Mandatory or Optional
EmissionRateUpper	Upper estimate of emission rate of the source. The units of this field should be **grams per hour** of the gas specified in *Gas.* If *EmissionRateUpper* is reported, *EmissionRateLower* must also be provided.	Decimal number >0	Optional
EmissionRateLower	Lower estimate of emission rate of the source. The units of this field should be **grams per hour** of the gas specified in *Gas.* If *EmissionRateLower* is reported, *EmissionRateUpper* must also be provided.	Decimal number ≥0	Optional
EmissionCategory	Emission category of the detection. Used only in the second experimental variation (see section 7.3.2).	`FUGITIVE` `VENT`	Optional

As a CM collects additional data to improve confidence in a quantification estimate or localization estimate, or to notify end of emission, additional detection reports may be provided referencing the same *EmissionSourceID*. Detection reports referencing the same *EmissionSourceID* will be grouped together in the metrics to match Detections to Controlled Releases. Detection reports providing updated information for a single field should provide a complete detection report including all other data fields, not just the field or subset the Performer wishes to update.

Localization estimates may be reported as a single set of coordinates, or as a bounding box defined by a maximum and minimum latitude and longitude.

5.4.2 Offline Reports

Offline reports allow Performers to indicate when a CM is not operating during the testing period. These reports will be used (1) to compute the fraction of time the system was operational relative to the total testing time, and (2) to limit the metrics to include only results from Controlled Release experiments performed while the system is online.

Each offline report must contain, at minimum, all mandatory fields listed in Table 4. Optional fields listed in Table 4 may be included.

Table 4: Offline report fields

Field	Description	Acceptable Values	Mandatory or Optional
OfflineReportID	A unique ID assigned by the Performer to the individual offline report. This number should be incremented for each and every offline report sent. Duplicate numbers will be assumed to be multiple transmissions of the same report; only one (the first received) report will be logged.	Integer	Mandatory
OfflineReportDateTime	Date and time (UTC) at which this offline report was generated in *yyyy/mm/dd hh:mm* format	Formatted Date & Time	Mandatory
OfflineDateTime	Date and time (UTC) at which the system went offline in *yyyy/mm/dd hh:mm* format	Formatted Date & Time	Mandatory
OnlineDateTime	Date and time (UTC) at which the system returned online in yyyy/mm/dd hh:mm format	Formatted Date & Time	Mandatory

OfflineReason	Reason why system went offline	`ROUTINE_MAINTENANCE`
		`ENVIRONMENTAL_CONDITIONS`
		`SYSTEM_FAULT`
		`COMMUNICATION_FAULT`
			Optional

5.4.3 Data Formatting and Responsibilities of the Test Center

The Test Center will establish, in advance of testing, how Detection Reports and Offline Reports shall be submitted by the Performer. The Test Center may provide data formatting requirements to the Performer to standardize the analysis performed by the Test Center. The Test Center must record the date and time which data were received from the Performer for inclusion in the analysis and Final Report. The time which emission detection reports are received by the Test Center will be used to evaluate the Detection Time metric (see 6.2.4). It is encouraged that the Test Center establish a "real-time" data reporting method to allow the Detection Time metric to estimate the elapsed time between

when an emission source starts and when a CM provides an alert to the operators identifying the emission on the Facility.

6 Performance Metrics

To evaluate performance metrics, detection reports and Controlled Releases will first be classified as True Positive or False Positive Detections. Results will then be used to evaluate primary and secondary metrics. Primary metrics will be evaluated for all CM systems under test; secondary metrics will be evaluated for systems that report optional data fields.

Caution: Performance metrics and the operational and environmental conditions during the experiment will be reported in the Final Report (see section 8). Performance metrics may only be applicable under the conditions tested and caution should be exercised in extrapolating test results to operational or environmental conditions not encountered during the testing period.

6.1 Classification of Detections

Detection reports which refer to the same *EmissionSourceID* will be grouped together as one "Detection" during the classification process. The order of the detection reports referring to the same *EmissionSourceID* will be determined using the *DetectionReportID* field; the 'first' report is the detection report with the smallest *DetectionReportID,* the 'last' detection report is the detection report with the largest *DetectionReportID*. **The data in the last detection report for each Detection will be used in the classification process.**

Prior to classification the following Controlled Releases and Detections will be removed from the classification process: (1) Controlled Releases which occur during experiments entirely within a period where the CM was reported offline by the Performer (see section 5.4.2), and (2) Detections where the EquipmentUnit is `OFF_FACILITY` in the last detection report. Controlled releases removed in this step will not be classified as False Negatives. Detections removed in this step will not be classified as True Positives or False Positives.

Note: Performers should note that the last detection report will be utilized for matching, and detections with a location `OFF_FACILITY` will be removed from the matching. This allows a CM to identify a possible emission as early as possible, but also to change the location to locate it outside the facility boundaries later, eliminating a possible False Positive Detection.

The Test Center will perform the classification using the following process for each experiment:

1. The list of Controlled Releases performed within the Facility boundary during the experiment will be sorted by Equipment Unit, then by emission rate in descending order.

2. The list of all Detections where *EmissionStartDateTime* is between the start time and end time of the experiment will be sorted by *EquipmentUnit*, then by *EmissionRate* (if reported) in descending order.

3. For each Controlled Release in (1), if a Detection in (2) is reported on the same Equipment Unit, the Detection and Controlled Release will be paired as a True Positive Detection and removed from further matching. True Positives matched in this step will be identified as correct unit Detections (see section 6.2.5).

4. The list of Controlled Releases and list of Detections remaining after (3) will be resorted by Equipment Group, then by emission rate in descending order.

5. For each Controlled Release in (4), if a Detection in (4) is reported on the same Equipment Group, the Detection and Controlled Release will be paired as a True Positive Detection and removed from further matching. True Positives matched in this step will be identified as correct group Detections (see section 6.2.5).

6. The list of Controlled Releases and list of Detections remaining after (5) will be resorted by Facility, then by emission rate in descending order.

7. For each Controlled Release in (6), if Detection in (6) is reported on the same Facility, the Detection and Controlled Release will be paired as a True Positive Detection and removed from further matching. Detections where EquipmentUnit = `OTHER` will be interpreted as on the Facility in this step. True Positives matched in this step will be identified as correct Facility Detections (see section 6.2.5).

8. Any Controlled Releases remaining after (7) will be identified as False Negative Detections.

9. Any Detections remaining after (7) will be identified as False Positive Detections.

This process will classify all Detections attributed to the Facility as either True Positive or False Positive, and all Controlled Releases occurring on the Facility as either True Positive or False Negative, and result in the three possible scenarios illustrated in Table 5 for each experiment when the CM is online. If the number on Controlled Releases, n_{CR}, is greater than the number of reported Detections, n_{RD}, then each reported Detection will be classified as True Positive and the remaining Controlled Releases will be classified as False Negative. If the number of Controlled Releases is equal to the number of reported Detections, then each reported Detection will be classified as True Positive and no Controlled Releases will be classified as False Negative. If the number of Controlled Releases is less than the number of reported Detections, then each Controlled Release will be classified as True Positive and the remaining Detections will be classified as False Positive.

Table 5: Detection classification outcomes for each experiment

Relationship between n_{CR} and n_{RD}	Number of True Positives, n_{TP}	Number of False Positives, n_{FP}	Number of False Negatives, n_{FN}
$n_{CR} > n_{RD}$	n_{RD}	0	$n_{CR} - n_{RD}$
$n_{CR} = n_{RD}$	n_{RD}	0	0
$n_{CR} < n_{RD}$	n_{CR}	$n_{RD} - n_{CR}$	0

6.2 Primary Metrics

The following performance metrics have been identified as primary metrics:

6.2.1 Probability of Detection

Probability of Detection (PD) will be calculated as a curve or surface. Detection data will be binned by conditions (environmental and controlled). For each set of conditions the PD will be calculated as the number of True Positive Detections divided by the sum of the number of True Positive Detections and False Negative Detections in the relevant conditions:

$$PD|_x = \frac{n_{TP}}{n_{TP} + n_{FN}}\Bigg|_x$$

Where x is the combination of conditions at which the PD is evaluated at.

PD results will be calculated for the following three cases unless otherwise agreed by the Performer and Test Center:

1) PD vs emission rate
2) PD vs average wind speed
3) PD vs emission rate and average wind speed

The Performer may request PD be calculated against an independent variable other than wind speed, if they believe the performance of their CM solution is more impacted by another, recorded and available variable. The Performer may also request only (1) to be calculated with (2) and (3) omitted, producing only a PD curve instead of a surface or series of curves. While the Final Report will contain only the requested PD curve/surface, all data will be released, and other parties may compute other PD curves/surfaces.

6.2.2 False Positive Fraction

The False Positive Fraction will be calculated for the set of all experiments as the number of False Positive Detections divided by the total number of reported Detections.

$$FPF = \frac{N_{FP}}{N_{RD}} = \frac{N_{FP}}{N_{FP} + N_{TP}}$$

The False Positive Fraction *does not* represent the rate at which a Performer reported a Detection when there were no emissions at the Facility.

6.2.3 False Negative Fraction

The False Negative Fraction will be calculated for the set of all experiments as the number of False Negatives divided by the total number of Controlled Releases.

$$FNF = \frac{N_{FN}}{N_{CR}}$$

The False Negative Fraction does not represent the rate at which controlled emissions were undetected by a Performer.

6.2.4 Detection Time

Detection Time will be calculated for each True Positive Detection as the time between the start of the Controlled Release and the time when the matched Detection was *received by the Test Center.* If the matched Detection includes multiple detection reports for the same *EmissionSourceID*, the Detection Time will consider the time which the first detection report was received.

6.2.5 Localization Precision (Equipment Unit)

For primary metrics, localization uses only the *EquipmentUnit* provided in the detection report to determine the precision of each True Positive. If the True Positive Detection includes multiple detection reports for the same *EmissionSourceID*, the Localization Accuracy will consider the *EquipmentUnit* of the last detection report received. Each True Positive Detection will be classified into one of three levels of precision, from most precise to least precise:

1) Correct unit: The *EquipmentUnit* was the Equipment Unit on which the Controlled Release occurred.

2) Correct group: The *EquipmentUnit* was in the Equipment Group where the Controlled Release occurred.

3) Correct Facility: The *EquipmentUnit* was within the facility boundary where the controlled release occurred.

6.2.6 Localization Accuracy (Equipment Unit)

Localization Accuracy will be calculated for the set of all experiments as the fraction of reported Detections at each level of precision.

1) Correct unit:

$$LA_{Unit} = \frac{N_{TP_{Unit}}}{N_{RD}} = \frac{N_{TP_{Unit}}}{N_{TP} + N_{FP}}$$

2) Correct group

$$LA_{Group} = \frac{N_{TP_{Group}} + N_{TP_{Unit}}}{N_{RD}} = \frac{N_{TP_{Group}} + N_{TP_{Unit}}}{N_{TP} + N_{FP}}$$

3) Correct Facility

$$LA_{Facility} = \frac{N_{TP_{Facility}} + N_{TP_{Group}} + N_{TP_{Unit}}}{N_{RD}} = \frac{N_{TP}}{N_{TP} + N_{FP}}$$

6.2.7 Operational Factor

Operational Factor will be calculated as the fraction of time the CM system is operational as reported by the Performer relative to the total deployment time.

$$OF = 1 - \frac{\sum t_{offline}}{t_{total}}$$

6.3 Secondary Metrics

Secondary metrics will only be evaluated when optional data fields necessary for their calculation are included in detection reports. The following performance metrics have been identified as secondary metrics:

6.3.1 Quantification Accuracy (Absolute)

Quantification Accuracy will be calculated for each True Positive Detection as the absolute difference (in g/hr) between the *EmissionRate* reported and the metered emission rate of the matched Controlled Release.

6.3.2 Quantification Accuracy (Relative)

Quantification Accuracy will also be calculated as a relative difference for each True Positive Detection as the absolute difference (in g/hr) between the *EmissionRate* reported and the metered emission rate of the Controlled Release normalized by the metered emission rate of the Controlled Release.

6.3.3 Quantification Precision (Absolute)

Quantification Precision will be calculated for each True Positive Detection as the absolute difference between *EmissionRateLower* and *EmissionRateUpper.*

6.3.4 Quantification Precision (Relative)

Quantification Precision will also be calculated for each True Positive Detection as the absolute difference between *EmissionRateLower* and *EmissionRateUpper* normalized *by the* metered emission rate of the matched Controlled Release.

6.3.5 Localization Accuracy (Single Coordinate)

Localization Accuracy will be calculated for each True Positive Detection with a single coordinate pair as the absolute difference (in meters) between the reported coordinate and the location where the Controlled Release occurred.

6.3.6 Localization Accuracy (Bounding Box)

Localization Accuracy will be calculated for each True Positive Detection with a bounding box coordinate set as the absolute difference (in meters) between the center of the reported bounding box and the location where the Controlled Release occurred.

6.3.7 Bounding Box Accuracy

A true/false value will also be calculated for each True Positive Detection with a bounding box coordinate set to indicate if the Controlled Release was within the reported bounding box. The Bounding Box Accuracy will be calculated as the fraction of True Positive Detections with a bounding box reported where the Controlled Release was within the bounding box.

6.3.8 Localization Precision (Bounding Box)

Localization Precision will be calculated for each True Positive Detection with a bounding box coordinate set as the area (in square meters) of the bounding box.

6.3.9 Localization Stability (Equipment Unit)

Localization stability is an indication of how frequently the location estimate changed between subsequent detection reports for a single *EmissionSourceID*. The localization stability will be calculated as

$$\mathrm{LS} = \begin{cases} 1 & if\ n_{reports} = 1 \\ 1 - \left(\dfrac{\mathrm{n_{changes}}}{\mathrm{n_{reports}} - 1} \right) & if\ n_{reports} > 1 \end{cases}$$

where $\mathrm{n_{changes}}$ is the number of times the *EquipmentUnit* changed between subsequent detection reports and $\mathrm{n_{reports}}$ is the total number of detection reports for the *EmissionSourceID*.

6.3.10 Emission Categorization

The emission categorization metric will be evaluated for the second test variation only (see section 7.3.2). The metric will be calculated as the fraction of True Positive Detections which are categorized correctly.

7 Experimental Design

7.1 Facility to be Monitored

The Test Center will define the Facility to be monitored using a bounding box of coordinates. The bounding box may correspond to physical infrastructure, such as a fenceline, or an implied boundary such as a property line, right of way, or easement.

7.2 Selection of Experimental Design Points

Each Experimental Design Point will be selected by the Test Center during the test period to sweep a range of emission rates and environmental conditions. Enough Experimental Design Points should be performed in each combination of Controlled Release emission rate and environmental condition of interest to evaluate a Probability of Detection curve. The Test Center will keep track of the number of Experimental Design Points in each cell of a design matrix similar to the matrix illustrated in Table 6.

Note the Experimental Design does not need to be identical in each application of the protocol. Rather, the experimental design points should be selected considering the observed performance of the CM systems during testing.

Table 6: Example experimental design matrix for emission detection testing. 'Wind Speed' is used as an example; actual experimental matrices will have more dimensions including multiple environmental or release variables. Typical examples include wind speed, wind direction, temperature, and gas composition. Depending upon CM solutions testing, other variables, such as solar irradiation or humidity, may also be tracked.

		Emission Rate			
		Zero	Low	Med	High
Wind Speed	Low				
	Med				
	High				

7.2.1 Gas Composition

Gas composition may vary between Experimental Design Points. The range of expected gas compositions will be provided by the Test Center to the Performer in advance of testing. The Test Center will select the gas composition considering the engineering design of the controlled release system, realism of the test, completion of the test matrix, and operational safety considerations. Gas composition may vary between emission locations included in an Experimental Design Point. Gas composition for each controlled release should not vary during one Experimental Design Point.

The actual gas composition of Controlled Releases will be recorded by the Test Center for inclusion in the analysis. Gas composition will be applied to the flowrate of Controlled Releases to calculate the mass flowrate of each gas species. Probability of Detection curves derived from test results will use the mass flowrate of the gas specified in the Performer detection reports (see *Gas* in Table 3).

7.2.2 Emission Rate

One of the primary objectives of this protocol is to evaluate the Probability of Detection curve across a range of emission rates. Therefore, the Test Center will vary or extend emission rates in the test matrix (Table 6) during the testing to produce detection rates from near-zero to near-100% for the performers participating, and taking into account the range of environmental conditions tested. Experimental Design Points will consider the combination of emission rate and environmental conditions at the time of the experiment to include repeated test conditions (e.g. similar combination of emission rate and wind speed as other Experimental Design Points) and the range of test conditions (e.g. individual experiments spanning a range of emission rates across a range of environmental conditions).

Emission rates will be restricted to within the constraints of the Test Center controlled release system. The lower limit and upper limit of the Test Center will be provided by the Test Center to the Performer(s) in advance of testing. The Test Center has the final authority to select the emission rates considering the engineering design of the controlled release system and operational safety considerations.

7.2.3 Duration

Each design point will operate for an extended, but variable, duration. Durations will be chosen to allow CM systems time to use analytics to report a detection including localization and quantification estimates. The typical duration of each Experimental Design Point will be several hours or greater, but the Test Center retains the flexibility to adjust durations to values reasonable for the CM systems and Test Center capabilities. Durations will be set before testing commences, and the Test Center will move to the next test after the time allotted for the current design point has elapsed. The allotted time may vary for different design points. The start and end of each Experimental Design Point will not be announced to the Performer.

7.2.4 Simultaneous Controlled Releases

Experimental Design Points may include multiple simultaneous Controlled Releases.

Other emission sources may occur near the Facility during testing. These emissions may be associated and controlled by the Test Center, or unassociated with the Test Center. If the Test Center performs Controlled Releases outside the Facility boundary during the test period, they shall be recorded as potentially interfering sources and included in the Final Report.

7.2.5 Environmental Conditions

The environmental conditions during each Experimental Design Point will be summarized using the maximum, minimum, mean and standard deviation of each parameter during the full duration of the test.

7.3 Experimental Variations

Two distinct experimental variations are outlined in this section. Testing may be performed under either or both variations. Metrics are evaluated separately for the two variations. The first variation is intended to evaluate Emission Detection Systems. The second variation is intended to evaluate Emission Detection Systems which categorize emission detections as Fugitive and Vent.

Testing under both variations will (1) occur 24 hours a day, 7 days a week, and (2) be performed “Single-Blind”. Performers *will not* be informed when an individual Experimental Design Point is starting or ending, or of the number, location(s), or emission rate(s) of Controlled Releases during the experiment.

7.3.1 Variation 1: Emission Detection

In this variation Controlled Releases will not be categorized as Fugitive or Vent emissions. All emission detections attributed to the monitored Facility should be reported by Performers. Since it is not necessary for Performers to distinguish “Fugitive” from “Vent” emissions using the *EmissionCategory* (see Table 3), this data field should be omitted from detection reports; if included, it will be ignored.

Testing will include experiments where multiple Controlled Releases occur simultaneously and periods where no Controlled Releases occur within the monitored Facility. Each Controlled Release will operate at a “steady” condition.

Experiments will be selected by the Test Center following the guidance in section 7.2.

7.3.2 Variation 2: Emission Detection and Categorization

When Vented emissions are included at a facility, a Performer needs to understand if an emission detected by a CM system should be classified as Vented or Fugitive. Typically, CM systems perform this classification by learning the pattern of emissions ('baseline emissions') at the facility when no fugitive emissions are present – i.e. all emissions are vented. This learned or programmed pattern is then utilized to distinguish unexpected emissions (fugitives) from expected emissions (vents).

This presents an additional challenge to the CM system which must determine if the emissions at the facility are within expected "baseline" emissions or exceed the "baseline" emissions and therefore represent a Fugitive source which requires corrective action. This test variation is intended to evaluate the ability of CM systems to categorize Vented and Fugitive emission sources using a simulated baseline.

All Controlled Releases will be categorized by the Test Center as Fugitive or Vent emissions during this test variation. All emission detections attributed to the monitored Facility should be reported by Performers. Performers should indicate if the Detection refers to a Fugitive or a Vent emission using the *EmissionCategory* (see Table 3).

Performers will be provided an opportunity to characterize baseline emissions. During this baseline period, the Test Center will include only Controlled Releases considered Vents. Vents may include intermittent and continuous emission sources. Intermittent releases will be modelled on recorded field data and will likely *not* occur at uniform intervals. Performers will be notified of the start and end of the baseline period, but will not be informed of the actual baseline emissions including the location, emission rate, or frequency of individual sources. After performing several experiments on a given baseline, the Test Center may change the baseline emissions and must provide Performers an additional opportunity to characterize the new baseline.

After the baseline period, the Test Center will continue to operate Vent emissions according to the baseline. Experiments will be performed where additional Controlled Releases will be introduced to simulate Fugitive emissions. The location and emission rate of Fugitive Controlled Releases during each experiment will be selected by the Test Center following the guidance in section 7.2. Individual Fugitive Controlled Releases will be designed to represent different source types and may be continuous (e.g. flange leak) or intermittent (e.g. over-pressurization of liquid storage tank).

Intermittent Controlled Releases will be reported as the average metered non-zero emission rate. Performers including quantification estimates for Detections identified as intermittent sources should report an estimate of the average emission rate of the source when it is emitting.

Metrics will be characterized considering all Controlled Releases and all detection reports similar to variation 1. An addition Emission Categorization metric will be calculated under this variation.

During this variation, planned or unplanned disruptions may require the Test Center to stop all controlled releases, including the baseline. If this occurs as a planned event (e.g. refilling or replacing gas cylinders in the controlled release system), the Test Center will notify Performers in advance of the disruption. If this is unplanned (e.g. a safety shutdown) the Test Center may not be able to notify

Performers in advance, but will provide notification when possible. Performers should take appropriate actions to avoid problems with any auto-learning algorithms. After any disruption, the Test Center will resume controlled releases, including baseline emissions.

8 Final Report

The Test Center will perform the classification of detections and calculation of metrics after all experiments are completed and detection reports have been provided by the Performer. The calculation of metrics will be performed across the full duration of the testing program.

The Test Center will provide a Final Report to the Performer. A copy of the original Final Report will be available from the Test Center, by request, with the Performer's consent for release. The Final Report will include, at minimum, the information described in this section.

8.1 Experiment Summary

The experiment summary will include the date range which experiments were performed within, the total number of experiments and the total number of Controlled Releases. Experimental conditions will be summarized including the Controlled Release rates, Controlled Release durations, and environmental conditions during the experiments.

8.2 Performance Metrics

Performance metrics will include all primary metrics as described in section 6.2. Secondary metrics will be reported if the Performer detection reports included the required data for their calculation. Metrics which are calculated individually for each True Positive Detection, for example Quantification Accuracy (section 6.3.1), will be included as histograms. Performance metrics for the two test variations (see sections 7.3.1 and 7.3.2) will be calculated and reported separately.

8.3 Documentation of Test Protocol

A copy of the test protocol utilized in the experiments will be included.

8.4 Documentation of System Under Test

Documentation of the system under test as reported by the Performer to the Test Center in section 5.1.5 and including any maintenance records as reported under section 5.2 will be included.

8.5 Controlled Release and Detection Data

All Controlled Release and Detection data will be included. Each True Positive, False Positive, and False Negative Detection will be included. Each Detection will include:

1) The Detection classification (True Positive, False Positive, False Negative)

2) Performer reported detection data, as received by the Test Center, including all data fields listed in 5.4.1 (applicable to True Positive and False Positive Detections only).

3) The Controlled Release data including timing, metered emission rate with upper and lower 95% confidence limits, Equipment Unit ID, latitude, longitude and height (applicable to True Positive and False Negative Detections only).

4) Meteorological conditions as measured by the Test Center for each Controlled Release (applicable to True Positive and False Negative Detections only).

5) Time to detect, Localization Accuracy, Localization Precision, Quantification Accuracy and Quantification Precision metrics calculated for the individual Detection (applicable to True Positive Detections only).

8.6 Offline Reports

Reported data under section 5.4.2 for when the system was online and when it was offline will be included as a data table.

8.7 Flow Meter Calibrations

The Test Center will include calibration records for the flowmeters used in the experiments.

End of the protocol specification.

9 Example Application: Testing at METEC

This section contains information specific to the first application of the test protocol at the Methane Emissions Technology Evaluation Center (METEC), *and is not part of the protocol*.

METEC is an outdoor research laboratory at Colorado State University comprised of mock natural gas facilities designed to test Emission Detection Systems under Controlled Release experiments.

9.1 Installation and Maintenance

9.1.1 Scheduling Installation

METEC will host Performer personnel for 1-3 days for installation. In general, installation needs to be scheduled >2 weeks in advance, and needs to be flexibly planned for inclement weather.

9.1.2 Location of equipment and subsystems

Fixed posts will be provided to support installation of CM systems in the approximate locations shown in Figure 1. Each post will be a 3" galvanized pipe, approximately 3 meters tall, on which multiple sensor systems may be mounted. A CM system will likely share a mounting pole with other CM systems. METEC staff will work with Performers to maintain equitable mounting locations for all Performers. Performer personnel may not adjust the position of another system already installed.

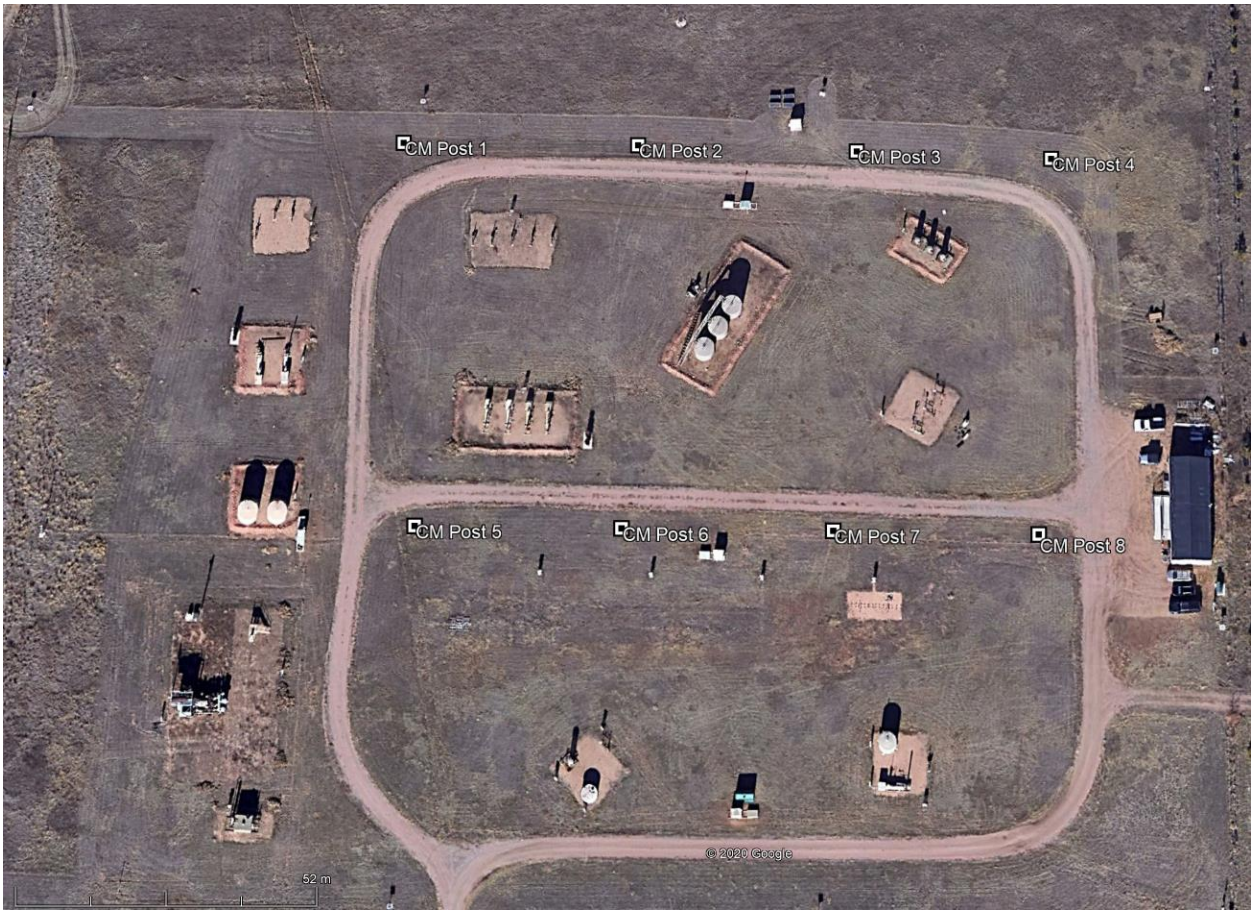

Figure 1: Approximate locations of posts for mounting Continuous Monitoring systems at METEC

Performers may propose an installation plan which includes sensors or subsystems installed at locations other than the provided posts. In general system components may be installed on tripods or masts, placed on the ground, or attached to equipment at METEC. Performers are responsible for providing all components necessary for their deployment configuration. At minimum, installation plans should follow the guidelines in section 5.1.1. METEC will have the final authority to approve or disapprove deployment plans at their discretion.

Performers are responsible for engineering and review of their deployment plan. Installations should be designed for continuous deployment in all weather conditions including high temperature, low temperature, precipitation (rain, snow, sleet, hail), and wind. Installations should be designed for a 110 mph wind zone at METEC. METEC's high elevation has high solar irradiation, with global horizontal irradiance exceeding 1100 W/m^2 at times. METEC is not liable for damage to systems resulting from improper design or installation.

METEC will supervise installation of CM systems, but all work must be completed by the Performer.

9.1.3 Electrical Power

Mounting locations in Figure 1 will include a 120V/60 Hz power distribution box at the base of each pole. Systems which require 120V power will coordinate with METEC in advance and provide all required material to connect their sensors to the power distribution.

Due to fire danger, combustion fueled power sources, including fuel cells, will not be allowed at METEC.

9.1.4 Data Communications

METEC does not have infrastructure to support a wired network connection for Performer data communications.

9.1.5 Maintenance

Maintenance must be scheduled with METEC in advance. METEC will provide an escort while the Performer is onsite to ensure a Performer is only touching/maintaining their equipment.

9.2 Data Reporting

METEC will implement an email reporting system. Detection reports and offline reports will be reported by Performers to METEC via email using defined message formats described in this section. This reporting method simulates automated detection alerts which would be sent to facility operators by an automated reporting system. The time at which an email is received will determine the time when the emission was detected – i.e. reported to the facility operator.

METEC will accept detection reports up to one week (168 hours) after the end of each Experimental Design Point. Detection reports received later than one week after the experiment will not be included in any analysis.

Performers must register the sending email address with METEC. Only data sent from this registered address will be considered in the analysis.

651 METEC will provide a testing email account for Performers to test their reporting software
652 implementation prior to the start of the testing period.

653 METEC will provide a reporting email account to report data to during the testing period. Automated
654 systems at METEC will monitor the email addresses, parse incoming messages, and log reports. Upon
655 receipt, each report will be validated by an automated system and METEC will send an automated reply
656 indicating if the report was successfully added to the database. Reports which do not include all
657 required fields, or with fields not formatted as expected will be returned to the sender with an error
658 message. Incomplete or improperly formatted reports will not be considered in the metrics.

659 ### *9.2.1 Reporting Standards*
660 Items in this subsection apply to all reports discussed in sections 9.2.2 and 9.2.3.

661 All text field names, including subject lines, are case-insensitive.

662 All text field names, including subject lines, must be spelled correctly. Fields with incorrect spellings will
663 not be included in metrics.

664 All times will be reported in coordinated universal time (UTC), since testing may extend across daylight
665 savings time changes and analytics may be in different locations than sensors.

666 Latitude and longitude will be reported in decimal degrees using WGS-84. Latitude and longitude in
667 degree-minute-second format will not be accepted.

668 Fields which are not applicable can be sent with blank values or omitted.

669 ### *9.2.2 Detection Report*
670 Each detection report must be sent as an email with the subject `DETECTION`. Each detection report
671 must contain only a single detection (i.e. information for a single emission per email). Detection data
672 must be reported in the email body of a detection report formatted as *field: value* pairs. Each *field: value*
673 pair must be on a new line. Each detection report must contain, at minimum, all mandatory fields listed
674 in Table 3 (see section 5.4.1). Detection report fields which acceptable values are provided by the Test
675 Center are defined in Table 7 for testing at METEC under this protocol. When updating detection
676 information, the METEC system will accept no more than one detection report for the same
677 *EmissionSourceID* every five minutes.

678 *Table 7: Acceptable values for detection report fields when testing at METEC.*

Field	Acceptable Values

Gas	`THC`
	`NMHC`
	`METHANE`
	`ETHANE`
	`PROPANE`
	`BUTANE`

Field	Acceptable Values
EquipmentUnit	4W-1 4W-2 4W-3 4W-4 4W-5 5W-1 5W-2 5W-3 4S-1 4S-2 4S-3 4S-4 5S-1 5S-2 5S-3 4F-1 4F-2 4T-1 4T-2 4T-3 OTHER OFF_FACILITY
Latitude1	min = 40.594800 max = 40.596550
Latitude2	min = 40.594800 max = 40.596550
Longitude1	min = -105.141480 max = -105.138400
Longitude2	min = -105.141480 max = -105.138400

An example detection report is shown below, as it would appear in the email monitor at METEC (not a real email address):

```
From: Reporter,Auto <auto.reporter@somePerformer.com>
Sent: Sunday, May 10, 2020 5:48 PM
To:   metecCM@colostate.edu
Subject:   Detection

DetectionReportID: 16
DetectionReportDateTime: 2020/05/10 14:42
EmissionStartDateTime: 2020/05/10 14:37
EmissionSourceID:  7
Gas: Methane
EquipmentUnit: 4T-2
Latitude1: 40.595749
Longitude1: -105.139861
EmissionRate:150
```

```
EmissionRateUpper:175
EmissionRateLower:100
```

9.2.3 Offline Reports

Each offline report must be sent as an email with the subject `OFFLINE`. Each email must contain only a single report. Data must be reported in the email body of an offline report formatted as *field: value* pairs. Each *field: value* pair must be on a new line. Each offline report must contain, at minimum, all mandatory fields listed in Table 4 (see section 5.4.2).

9.2.4 Test

Report tests allow Performers to check connectivity to the data reporting system. Each report test must be sent as an email with the subject `TEST`. METEC will send an automated reply indicating the report test was received, and will include all of the text sent in the report. The test will be logged at METEC, but the contents of the test message will not be parsed or analyzed.

9.2.5 Response Messages

When each message is received by METEC, an automated system will parse the message and will return a message to the Performer's registered email address. The subject line of each message will be formatted as

Response:<*type of message*>

Where <type of message> repeats the subject line sent to METEC (e.g. Detection, Offline, or Test).

The body of the message will contain:

- The field:value pairs as parsed by METEC.
- A separator '%ORIGINAL%'
- The original text of the message as received by METEC

Performers are encouraged to periodically scan these messages to assure that fields are being correctly parsed. Report any concerns or issues to METEC. Note, METEC will not be monitoring responses and it is the Performers responsibility their system is producing acceptable detection reports. The example message above would produce the response below (bold text for emphasis only):

```
From: metecCM@colostate.edu
Sent: Sunday, May 10, 2020 5:52 PM
To:   Reporter,Auto <auto.reporter@somePerformer.com>
Subject:   Response:Detection

Report has been successful processed by METEC and was saved to data base.
%PARSED%
DETECTIONREPORTID: 16
DETECTIONREPORTDATETIME: 2020/05/10 14:42
EMISSIONSTARTDATETIME: 2020/05/10 14:37
EMISSIONSOURCEID:  7
```

```
GAS: METHANE
EQUIPMENTUNIT: 4T-2
LATITUDE1: 40.595749
LONGITUDE1: -105.139861
EMISSIONRATE:150
EMISSIONRATEUPPER:175
EMISSIONRATELOWER:100
%ORIGINAL%
DetectionReportID: 16
DetectionReportDateTime: 2020/05/10 14:42
EmissionStartDateTime: 2020/05/10 14:37
EmissionSourceID:  7
Gas: Methane
EquipmentUnit: 4T-2
Latitude1: 40.595749
Longitude1: -105.139861
EmissionRate:150
EmissionRateUpper:175
EmissionRateLower:100
```

9.3 Definition of Facility to be Monitored

Testing at METEC under this protocol will be performed on METEC Pads 4 and 5. The Facility boundary is defined by the maximum and minimum latitude and longitude listed in Table 8 which form the bounding box shown in Figure 2 . Controlled Releases may occur anywhere within the defined Facility boundary during testing under this protocol. Equipment Unit IDs for use in detection reports are shown in Figure 3. Performers will receive kml data including the Facility boundary and markers with Equipment Unit IDs prior to testing.

Table 8: Facility boundary

Limit (Location)	Latitude	Longitude
Max (NE Corner)	40.596060°	-105.139070°
Min (SW Corner)	40.595500°	-105.140600°

Figure 2: Facility boundary

Figure 3: Equipment Unit IDs

9.4 Testing Efficiency

Testing at METEC will require solutions to be installed and operational continuously for an extended period (several months minimum) to complete testing. In order to efficiently perform testing, it is likely that multiple Performers will participate in a given testing period.

9.5 Gas Composition

Controlled Releases at METEC will largely use compressed natural gas (CNG). METEC measures the gas composition to allow emission rates to be reported as whole gas or individual species (e.g. methane). The composition of CNG varies, however METEC gas composition has typically been measured at

approximately 85% methane, 10% ethane, and 1% propane. METEC will include some Experimental Design Points with higher ethane and propane content in the test matrix.

9.6 Experimental Variations

Generally, METEC will perform testing under both experimental variations (see section 7.3) with a period of performance defined for each.

9.7 Quality Control

METEC will perform some quality checking to make sure emissions are occurring as intended. METEC personnel will use a combination of audio/visual/olfactory (AVO), optical gas imaging (OGI), and portable gas monitors to validate the location of emission sources. Quality control (QC) issues will be documented including the experiment ID, date and time, and emission point affected. Detections associated with experiment IDs with QC issues will be addressed on a case-by-case basis and may be flagged for exclusion from the results analysis.

Leak surveys will also be performed periodically by the Test Center to ensure no leaks occur from the controlled release system. Leaks identified during routine leak surveys will be documented by the Test Center and included in the Final Report.

Maintenance performed by the Test Center resulting in vented emissions will be logged by the Test Center, including the location, date and time of the vent.