# Quality Assurance Project Plan

# for

# NYSERDA Support for Development of Test Methods for Residential Wood Heaters at Hearthlab Solutions

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NYSERDA Agreement 123059, Task Work Order No. 14

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NESCAUM would like to acknowledge that the Quality Assurance Project Plan for EPA-funded wood stove testing in a west coast laboratory to evaluate a draft IDC-TEOM protocol (approved for EPA research purposes) served as a model for preparation of this document. The QAAP for the EPA-funded west coast test program was prepared for EPA by prime contractor RTI International and its subcontractor, SC&A Inc.

# 1.0 Title and Approval Sheet

**Quality Assurance Project Plan for NYSERDA Support for Development of Test Methods for Residential Wood Heaters at Hearthlab Solutions**

______________________________ 11/21/22
Lisa Rector, Project Manager, NESCAUM — Date

______________________________ 11/21/22
Ellen Burkhard, Project Manager, NYSERDA — Date

______________________________ 11/21/22
Mark Champion, QA lead
Hearthlab Solutions — Date

______________________________ 11/21/22
George Allen, Chief Scientist
NESCAUM — Date

## Abbreviations

| | |
|---|---|
| ANSI | American National Standards Institute |
| AQAD | Air Quality Assessment Division |
| ASTM | American Society for Testing and Materials |
| CFR | Code of Federal Regulations |
| DQA | Data quality assessment |
| DQI | Data Quality Indicators |
| DQO | Data quality objectives |
| EDO | Environmental Data Operation |
| EEE | Environmental Engineering and Economics (RTI Division) |
| EPA | U.S. Environmental Protection Agency |
| FRM | Federal Reference Method |
| ISO | International Organization for Standardization |
| ISO 17025 | International standard for testing and calibration laboratories |
| MTG | Measurement Technology Group |
| NESCAUM | Northeast States for Coordinated Air Use Management |
| NSPS | New Source Performance Standards |
| NYSERDA | New York State Energy Research and Development Authority |
| OAQPS | Office of Air Quality Planning and Standards |
| PM | Program manager |
| PM | Particulate matter |
| PM2.5 | Particulate matter ≤ 2.5 microns in diameter |
| POP | Period of performance |
| QA | Quality assurance |
| QAM | Quality Assurance Manager |
| QAPP | Quality Assurance Project Plan |
| QC | Quality control |
| QMP | Quality Management Plan |
| SOW | Scope of work |
| SOP | Standard Operation Procedures |
| RPL | Research Project Lead |
| TEOM | Tapered Element Oscillating Microbalance |
| TO | Task order |
| TOCOR | Task Order Contracting Officer's Representative |
| TOL | Task Order Leader |

**Quality Assurance Project Plan**
**for**
**NYSERDA Support for Development of Test Methods for Residential Wood Heaters at Hearthlab Solutions**

# 2.0 Table of Contents

# List of Tables and Figures

## 3.0 Distribution List

Electronic or paper copies of this Quality Assurance Project Plan (QAPP), including any revisions to this QAPP as needed, will be provided to the following individuals:

- George Allen, Chief Scientist, NESCAUM, gallen@nescaum.org
- Ellen Burkhard, NYSERDA Project Manager, Ellen.Burkhard@nyserda.gov
- Angelina Brashear, Alternate TOCOR, EPA, brashear.angelina@epa.gov
- Steffan Johnson, Measurement Technology Group Leader, EPA, johnson.steffan@epa.gov
- Lisa Rector, Project Manager, NESCAUM, lrector@nescaum.org
- Mark Champion, Hearthlab Solutions, mark@hearthlabsolutions.com
- Michael Toney, Quality Assurance Manager, EPA, toney.mike@epa.gov

# 4.0 Introduction

This project, Support Development of Test Methods for Residential Wood Heaters, is completed under NYSERDA Agreement 123059 with NESCAUM. NYSERDA's Contracting Officer's Representative (TOCOR) is Ellen Burkhard. The NESCAUM Program Manager is Lisa Rector. NESCAUM would like to acknowledge that the Quality Assurance Project Plan for EPA-funded wood stove testing in a west coast laboratory to evaluate a draft IDC-TEOM protocol (approved for EPA research purposes) served as a model for the preparation of this document. The QAAP for the EPA-funded test program was prepared for EPA by prime contractor RTI International and its subcontractor, SC&A Inc.

For residential wood heating test methods, US EPA is leading a technical workgroup (Particulate Matter [PM] Measurement Method Evaluation and Fueling Protocol/Appliance Operation Workgroup) and other workgroups that may eventually form. The technical workgroup has determined the need to move away from the more traditional EPA Method 28/ASTM E2515 measurement approach and toward an integrated duty-cycle (IDC) protocol/operation approach using a tapered element oscillating microbalance (TEOM) for PM measurement. NYSERDA contracted with NESCAUM to gather information and data necessary to support test method promulgation or improvement work based on the pathway recommended by the workgroup.

The overarching task required for this order is to provide technical support related to wood heating appliance testing and to support the development of an EPA cordwood emissions test method. Specific requirements are to conduct test method variability analyses (including precision and ruggedness testing), to report results of the testing, and to develop technical documents, as needed, which will provide support for a possible suite of EPA cordwood reference test methods both for particulate testing and wood burning appliance operation protocols. Emissions measurement efforts will be conducted to assess precision as part of a variability study, including ruggedness testing, to support the proposal and promulgation of a new PM measurement method and new IDC operating protocols. This data will inform policy and regulatory actions, not compliance or enforcement activities.

This Quality Assurance Project Plan (QAPP) is based on the guidance and requirements for EPA Quality Assurance Project Plans, as specified by the EPA[1, 2] and by the Quality Management

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[1] U.S. Environmental Protection Agency. Guidance for Quality Assurance Project Plans (QA/G-5). Office of Environmental Information, Washington, DC 20460. EPA/240/R-02/009. December 2002.

[2] U.S. Environmental Protection Agency. EPA Requirements for Quality Assurance Project Plans (QA/R-5). Office of Environmental Information, Washington, DC 20460. EPA/240/B-01/003. March 2001, reissued 2006.

Plan (QMP) of the EPA's Office of Air Quality Planning and Standards (OAQPS).[3] EPA's OAQPS utilizes a four-tiered project category approach to its QA Program to focus QA effectively. This document is based on the QAPP prepared by SCA to support EPA testing at a west coast lab. This QAPP is for work supported by NYSERDA, managed by NESCAUM at an east coast lab. NYSERDA's Contractor (NESCAUM) and Subcontractor (Hearthlab Solutions) are completing this plan to meet the requirements for a Category 1 QAPP.

The four basic element groups for a QAPP are:

- Group A Project Management (9 elements)
- Group B Measurement/Data Acquisition (10 elements)
- Group C Assessment and Oversight (2 elements)
- Group D Data Validation and Usability (3 elements)

All 24 total elements apply to a Category I QAPP. However, as indicated in the EPA guidance, not all elements will pertain to every project. In addition, the extent or level of detail written in the QAPP for each element will depend on the type of project, the data to be obtained, the decisions to be made, and the consequences of potential decision errors. For example, for a basic research project, complete information for many elements may not be available at the start, and the plan will be revised as needed.

The QAPP elements and their corresponding sections in this document are presented in Table 1. The title of each QAPP element in Exhibit 1 and in each section of this document adheres to EPA's Guidance for Quality Assurance Project Plans (QA/G-5).

[3] U.S. Environmental Protection Agency. The OAQPS Quality Management Plan, (Revision 06), Research Triangle Park, North Carolina. May 20, 2020.

*Table 1. Crosswalk Between Document Sections & EPA's OAQPS QAPP Elements*

**Table 1. Crosswalk Between Document Sections & EPA's OAQPS QAPP Elements**

| Quality Assurance Project Plan Element | | Document Section |
|---|---|---|
| A1 | Title and Approval Sheet | 1.0 |
| A2 | Table of Contents | 2.0 |
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| A5 | Problem Definition/Background | 6.0 |
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| A8 | Special Training Needs/Certification | 9.0 |
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| B2 | Sampling Methods | 12.0 |
| B3 | Sample Handling and Custody | 13.0 |
| B4 | Analytical Methods | 14.0 |
| B5 | Quality Control | 15.0 |
| B6 | Instrument/Equipment Testing, Inspection, & Maintenance | 16.0 |
| B7 | Instrument/Equipment Calibration and Frequency | 17.0 |
| B8 | Inspection/Acceptance of Supplies and Consumables | 18.0 |
| B9 | Non-direct Measurements | 19.0 |
| B10 | Data Management | 20.0 |
| C1 | Assessments and Response Actions | 21.0 |
| C2 | Reports to Management | 22.0 |
| D1 | Data Review, Verification, and Validation | 23.0 |
| D2 | Verification and Validation Methods | 24.0 |
| D3 | Reconciliation with User Requirements | 25.0 |

This QAPP addresses the QA/QC necessary for the activities conducted under this research project, including data acquisition, data management, data analysis, documentation, and preparation of other project deliverables. To accomplish these goals, the NYSERDA team will:

- Work with EPA to obtain a thorough understanding of EPA's requirements;
- Select, direct, and supervise laboratory services provider(s);
- Perform quality control (QC) checks on work products prior to submission; and
- Before submission, perform a technical review on all major milestone deliverable documents (e.g., technical reports).

# 5.0 Project/Task Organization

The key personnel for this research project includes NYSERDA, NESCAUM, and Hearthlab Solutions staff tasked with QA/QC activities. Their duties are outlined briefly in this section. The Quality Management Plan (QMP) describes the overall QA program for the NYSERDA research project to include staff responsibilities. The research project organization is shown in Figure 1.

## 5.1 Program Managers

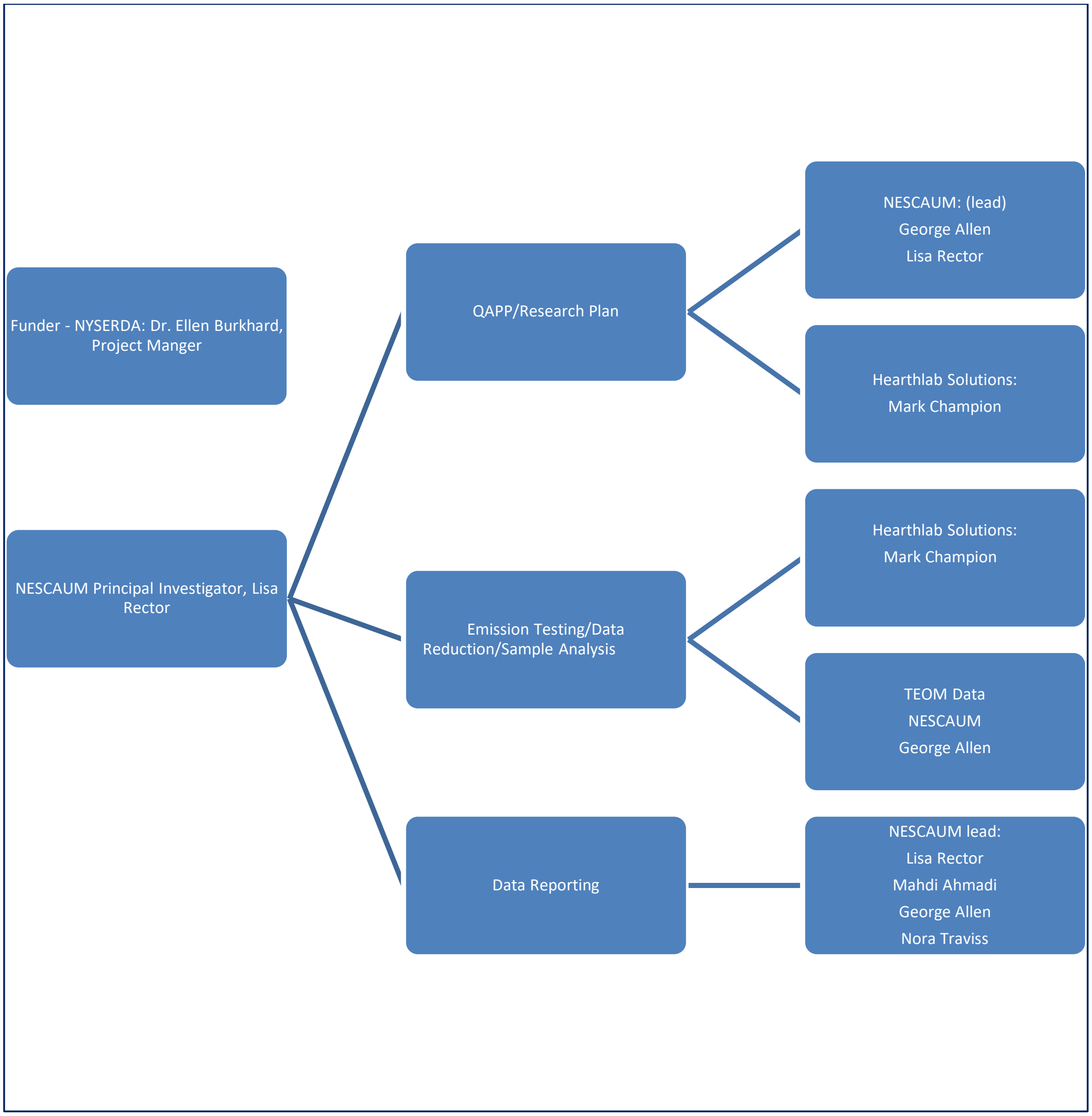
The NYSERDA Project Manager is Dr. Ellen Burkhard. The NESCAUM Project Manager is Ms. Lisa Rector. They are responsible for their respective organization's technical and financial performance. NESCAUM will serve as the primary contact for discussing the EPA testing plan, developing the QAPP, and obtaining EPA confirmation that the research study comports with EPA quality procedures. Ms. Rector is responsible for managing oversight and conduct of program and project activities; ensuring that quality procedures are incorporated into all aspects of the project; developing, conducting, and/or overseeing QA plans as necessary; ensuring that any corrective actions are implemented; operating project activities within the documented and approved QMP; and ensuring that all products delivered to the EPA are of the specified type, quantity, and quality.

## 5.2 Research Project Leaders (RPL)

*Ms. Lisa Rector and Mr. George Allen* will serve as the NESCAUM research project leaders (RPL). Ms. Rector is responsible for the day-to-day technical activities of the tasks, including planning, data gathering, documentation, reporting, and controlling technical and financial resources. Ms. Rector will approve all QA-related plans and reports and is responsible for transmitting them to NYSERDA and EPA for review and approval. Thus, the RPL is primarily responsible for the quality of all work completed and submitted to the EPA for consideration.

As the RPL, Ms. Rector and Mr. Allen are responsible for producing all deliverables and ensuring that quality procedures are implemented. Any concerns about QA/QC elements identified while processing data through QA/QC procedures shall be identified, reported, and resolved by the RPL. In addition, they will work with their respective QAMs to identify and implement quality improvements. The RPL is responsible for overseeing the work performed by technical staff and ensuring that all required QA/QC procedures are implemented.

*Figure 1. Project Organization*



## 5.3 Quality Assurance Lead

NESCAUM Quality Assurance Lead is George Allen. Mr. Allen oversees the program quality system, monitors and facilitates QA activities, and generally helps the research team understand and comply with EPA QA requirements. Mr. Allen is the Chief Scientist at NESCAUM. In addition, NESCAUM staff - Dr. Nora Traviss and Dr. Mahdi Ahmadi - shall provide support and data review services

NESCAUM staff are responsible for conducting periodic independent audits of the QA program for these tasks. They will produce written documentation of any audit results and recommendations. They will work closely with the NYSERDA and NESCAUM Project Managers to improve any deficiencies noted during these audits.

## 5.4 Quality Control Coordinator

The QC Coordinator, *Dr. Paul Miller,* is responsible for assisting the NESCAUM Project Manager in planning, documenting, and implementing the QA requirements for this research project. Working with the NESCAUM and Hearthlab Solutions staff, and in consultation with the NYSERDA, he will ensure that process- and project-specific QA documents are developed; that required or recommended protocols are followed; that data is reduced, validated, and reported according to specific criteria; and that QC assessments are performed. As needed, the QC Coordinator will report to the NYSERDA Project Manager on quality issues.

## 5.5 Technical Staff

For work done under this research project include persons with expertise in industrial processes, combustion expertise, air pollution engineering, technical reviewers, database specialists, quality auditors, and technical editors. Technical staff will carry out QC functions for this project and will be carefully monitored by the Project Managers, who will work with the QAMs to identify and implement quality improvements. The project manager will ensure that technical staff does not review work in a QA capacity for which they were the primary or contributing developer.

## 5.6 Laboratory Testing Services

QC functions for this project at the selected testing laboratory will be carried out following this QAPP and per the QA/QC programs well established at the contracted testing laboratory. The testing laboratory supervisor/manager of Hearthlab Solutions will report to Ms. Rector as the NESCAUM RPL and PM and ensure adherence to this QAPP. The selected east coast laboratory for this project, Hearthlab Solutions, is a research laboratory. Mark Champion has more than 30 years experience conducting testing on residential wood stoves.

## 6.0 Problem Definition/Background

Numerous stakeholders from industry, EPA, state, and local agencies generally agree that new fueling and operational protocols are needed within a new test method to obtain emissions data that better reflect "real-world" emissions from residential wood heaters. NESCAUM has participated in EPA's workgroup (PM Measurement Method Evaluation and Fueling Protocol/Appliance Operation Workgroup). The technical workgroup has determined the need to move away from the traditional EPA Method 28 / ASTM E2515-based test methods toward an integrated duty-cycle (IDC) protocol/operation approach using a TEOM for PM measurement, as developed by NESCAUM under contract to NYSERDA.[4] EPA determined that a test program must be conducted to assess IDC test method precision as part of a variability study, including ruggedness testing, to support the proposal and promulgation of a new PM measurement method as well as new IDC operating protocols (for wood stoves, hydronic heaters, pellet heaters, and forced-air furnaces). Previous residential wood heater test methods did not attempt to characterize the test method bias, precision, or variability.

[4] This IDC protocol for wood stoves is the property of NYSERDA and can be used to test technologies in a laboratory setting. Any deviations or changes to this IDC protocol for wood stoves are not approved or sanctioned by NYSERDA.

## 7.0 Project/Task Description

The work performed under this research plan will gather data to inform EPA efforts to propose test methods for wood stoves, hydronic heaters, and forced-air furnaces, including the assessment of draft IDC/TEOM protocols as possible bases for new methods. The specific tasks included in this research project are listed below.

- Task 1. Project Management
- Task 2. Quality Assurance
- Task 3. Conduct Validation Testing for Residential Wood Heaters (pellet and cordwood)
- Task 4. Document Test Results for Cordwood Validation Testing

EPA provided NESCAUM with the test plan EPA developed to assess precision and variability at a west coast lab. The NYSERDA-funded work plans to mirror that stove research at Hearthlab Solutions.

The work performed under this QAPP centers on emission testing of residential cordwood and pellet stoves. Per EPA's original work, EPA's research plan provided to NESCAUM is sufficient to meet the requirements of assessing precision according to ASTM E691-20.[5]

The testing plan to support cordwood appliances is shown in Table 2. The test plan for pellet appliances is shown in Table 3. Testing will be conducted by selected laboratories (on both the east and west coasts). EPA contracts shall fund the west coast lab; the east coast lab(s) will be funded by NYSERDA under contract to NESCAUM. This QAPP covers work at Hearthlab Solutions, which houses its lab in Bethel, Vermont. Hearthlab Solutions cannot test hydronic heaters or forced air furnaces, so it's primary focus shall be wood stoves.

There are special equipment needs for the performance of this project. These are the wood-burning appliances to be tested and the sampling and analytical equipment needed for direct PM measurements. In this phase of the testing program, the focus is wood-burning stoves. Three pairs of cordwood stoves and two pairs of pellet stoves will be tested. In all labs participating in this study, paired tests will be run on separate test stands to allow for replicate testing and sampling.

The appliances used in NESCAUM's research are the property of NESCAUM or on loan from

[5] ASTM E691-*20 Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method* was last updated on March 8, 2021, and is available for purchase from ASTM at https://www.astm.org/e0691-20.html.

EPA. NESCAUM work shall use dichotomous ("dichot") TEOMs, owned by NESCAUM, for dilution tunnel testing, and single channel TEOMs for ambient (lab) air monitoring (also owned by NESCAUM). The dichot TEOMs shall follow all the QA/QC requirements set forth in this QAPP, in dilution tunnels designed to ensure proper mixing of the air samples. NESCAUM has completed research to assess tunnel mixing at the Hearthlab Solutions facility and has provided EPA with the results of that testing, confirming proper mixing occurs in the Hearthlab Solutions tunnel. A copy of the Hearthlab Solutions mixing analysis can be found in Annex B.

Table 2. Testing Plan to Support Development of Cordwood Residential Wood Heater Test Methods

| **Method/Appliance** | **IDC/ Wood Stoves** | | | **IDC/ Hydronic Heaters** | | **IDC/ Forced-Air Furnaces** |
|---|---|---|---|---|---|---|
| **Sub-category (if applicable)** | Small non-catalytic | Medium catalytic hybrid | Large catalytic hybrid | Partial thermal storage | No thermal storage | N/A |
| **Testing objectives** | 3 paired tests w/ hardwood and 3 paired tests w/ soft wood | 7 paired tests w/hardwood and 7 paired tests w/soft wood | 3 paired tests w/ hardwood and 3 paired tests w/ softwood | 3 solo tests w/hardwood and 3 solo tests w/soft wood | 7 paired tests w/hard wood and 7 paired tests w/softwood | 7 paired tests w/hardwood and 7 paired tests w/soft wood |
| | Testing will be done in east and west coast labs, using western and eastern hardwood and softwood fuels. Goals include validation of IDC operation and determination of precision, intra-lab and inter-lab variability, using various fuels. | | | | | |

Table 3. Testing Plan to Support Development of Pellet Residential Wood Heater Test Methods

| **Method/Appliance** | **Pellet Stoves** | | **Hydronic Heaters** |
|---|---|---|---|
| **Sub-category (if applicable)** | Medium-output pellet stove | High-output pellet stove | Partial thermal storage |
| **Testing objectives** | 7 paired tests with hardwood pellets | 7 paired tests with hardwood pellets | |
| | Testing will be done in east and west coast labs using the same pellet fuel. Goals include validation of IDC operation and determination of precision, intra-lab, and inter-lab variability. | | |

**Note:** Tables 2 and 3 show the current testing plan. As of the date of this QAPP revision, the test plan for pellet stoves and forced air furnaces has not been finalized. This QAPP will be updated to another version when the forced air furnace and pellet stove test plans are finalized.

For cordwood stove testing, the non-catalytic stove is a small firebox size Hearth & Home Technologies® Quadra-fire® 2100 Millennium model, the medium firebox size stove is a catalytic hybrid Hearthstone® Castleton model, and the large firebox size stove is a catalytic hybrid Regency® Pro-Series model F3500. As noted, future revisions to the QAPP will be made as necessary to reflect changes/updates to the testing program.

This current QAPP version is focused on the IDC testing on cordwood stoves and hydronic heaters. This QAPP is directed explicitly for testing and data acquisition at the Hearthlab Solutions facility, where the testing focus is cordwood and pellet stoves. The Hearthlab Solutions QAPP may also be updated, depending on the project's needs for additions or revisions revealed by testing.

## 8.0 Quality Objectives and Criteria for Measurement Data

The objective under the current contract is to provide QA and QC to ensure that the data obtained under this research are of high technical quality. Accordingly, NESCAUM will implement a quality management plan (QMP) for this research. The QMP describes the organization and QA approach to be followed in all activities performed under this research to conform to EPA guidelines and requirements for quality management systems. As described in the QMP, the quality system under this contract is the joint responsibility of the project managers, RPLs, the test lab, and an organizationally independent QAM. All activities performed under this project will conform to the QMP. QC activities are documented in Annex A.

In addition to the contract-level QMP, NESCAUM and NYSERDA have quality systems that apply to all of their contracts, as outlined in their corporate QMPs. Their corporate QMPs are designed to produce high-quality results in projects where collecting and evaluating environmental data or designing, constructing, and operating environmental technology are important. Their QMP requirements are mandatory on all projects and for all personnel. The NYSERDA and NESCAUM QMPs include requirements for QA related to a range of project types, including processes, document preparation, and data collection and analysis. The specific nature of the QA undertaken for each project depends on the work, its intended use, and client requirements. NESCAUM's QMP is based on the criteria and guidance provided in American National Standard ANSI/ASQC E4, "Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs" (adopted by EPA Order 5360.1, now CIO 2105.0, as the basis for Agency QA/QC), and written to comply with EPA/240/B-01/002, "EPA Requirements for Quality Management Plans" (EPA QA/R-2). The QMPs are updated at a minimum every five years or more frequently to reflect changing requirements and other factors that affect a quality program.

Determining quality criteria will be a dynamic process through which NESCAUM will work with EPA project contacts to collaboratively determine the "significant" elements of data and the appropriate level of effort for a given operation. Throughout the project, the elements that are deemed to be "significant" may change. An element that was not significant in one phase of the project may become important in a subsequent phase. Conversely, an element that was significant in early deliberations may become inconsequential in future phases. Through these changes, NESCAUM will revisit significant elements based on EPA information and thus require review and will determine the appropriate level of effort for review. The measures of data quality that will be used to judge whether the data are acceptable for their intended use will be documented.

The variability and verification testing during the first phase will inform the development of a cordwood federal reference method (FRM) for wood stoves based on burning cordwood. Six stoves representing three different models and stove technologies will be tested using the IDC fueling and operating protocols developed by NYSERDA while burning cordwood. A dichot TEOM will be used within a dilution tunnel to sample PM on separate side-by-side test stands during paired testing. As shown above, in Table 2 of Section 7, tests will include burning a hardwood (e.g., maple on the east coast) and, in other tests, a different wood species (e.g., birch on the east coast) in three paired stove models: each pair is two of the same model. The stoves consist of a pair small non-catalytic ("non-cat") stoves, a pair of medium hybrid stoves, and a pair of catalytic stoves.

The variability and verification testing during this second phase will inform the development of the federal reference method (FRM) for hydronic heaters burning cordwood and wood pellets. Five appliances representing three different models and technologies will be tested using the IDC Hydronic Heater fueling and operating protocols developed by NYSERDA. Like stoves, a dichot TEOM will be used within a dilution tunnel to sample PM on separate side-by-side test stands during paired testing. As shown above, in Table 2 Section 7, cordwood tests will include burning a hardwood (e.g., maple on the east coast) and, in other tests, a softer wood (e.g., birch on the east coast) in three hydronic heater models. Pellet boiler work will use Pellet Fuels Institute (PFI) certified hardwood pellets.

<u>Cordwood Stove Testing</u>

Cordwood stove testing will use two of the same model small non-catalytic stoves, two of the same model medium catalytic ("cat") hybrid stoves, and two of the same model large cat hybrid stoves. The testing will consist of 26 paired (52 total) test runs, including three paired (6 total) test runs using hardwood in the two medium non-cat model stoves: three paired (6 total) test runs using softwood in the two medium non-cat model stoves; seven paired (14 total) test runs using hardwood in the two medium cat hybrid model stoves; seven paired (14 total) test runs using softwood in the two medium cat hybrid model stoves; three paired (6 total) test runs using hardwood in the two large cat hybrid model stoves; and three paired (6 total) test runs using softwood in the two large cat hybrid model stoves.

The Data Quality Objectives (DQO) for these 52 tests using the IDC-TEOM methodology are discussed below. The DQO Process is a type of systematic planning for data collection described in EPA QA/G-4.[6] The QA/G-4 document provides a general framework for establishing performance/ acceptance criteria, which inform a plan design for collecting data of sufficient quality and quantity to support the project goals. This process ensures that the data collected by any Environmental Data Operation (EDO) meets the needs of the intended decision-makers and data users. The process establishes the link between the data's specific end use(s) with the data collection process and the data quality (and quantity) needed to meet the project or study goals. The following sections provide the required information for the DQO process undergirding the testing using the IDC-TEOM methodology.

**Note**: In addition to performing 52 tests using the IDC-TEOM methodology, EPA decided to add Method 5G/ASTM E2515 filter train collection to the testing program to obtain additional data for comparison. These filter measurements will be made while operating the stoves according to the IDC protocol, in addition to the real-time measurements made by the dichot TEOM during the same IDC run. The TEOM protocol specifies multiple filter changes during testing, while the ASTM E2515 provides no guidance on filter changes, suggesting that filter changes should be avoided. For the Hearthlab Solutions test runs, ASTM 2515 filter trains shall be used alongside the TEOM measurements. Therefore, filters will be gathered with the objective of avoiding filter changes during the test run. However, if test conditions warrant a filter change, front filter changes will be made. The number of E2515 filters used during each test run will be reported as the number of filter changes impacts the particulate matter value.

The IDC-TEOM methodology frames the QA/QC requirements outlined in this QAPP for clarity and because the goal of this testing program is to assess the variability of this methodology within and across laboratories, while the ASTM E2515 filters merely provide supplemental data. However, as noted in Section 12, any laboratory performing the IDC-TEOM methodology within this testing program must be familiar with performing Method 5G/ASTM E2515, including analyses. Such laboratories – including PFS TECO on the west coast as well as laboratories funded by NESCAUM/NYSERDA on the east coast – must have a QA/QC system in place that would ensure the quality of not only the IDC-TEOM measurements but also ensure the quality of the ASTM E2515 filter measurements. Selecting laboratories with a history of wood heater testing using Method 5G/ASTM E2515 helps ensure this quality. Hearthlab Solutions is not an EPA-approved, ISO-accredited laboratory; however, quality will be ensured with appropriate calibration and techniques consistent with the intent of the relevant methods.

### 8.1 The Data Quality Objectives (DQO) Process

This section presents an overview of the seven steps in EPA's QA/G-4 DQO process as applied to the objectives of this project.[6] The purpose of this section is to discuss the specific issues used in developing the DQOs for the IDC-TEOM testing program.

The DQO process is a seven-step process based on the scientific method to ensure that the data collected by NESCAUM and Hearthlab Solutions meet the needs of its data users and decision-makers regarding the information to be collected and, in particular, the desired quality and quantity of data. It also provides a framework for checking and evaluating the program goals to ensure they are feasible and that the data are collected efficiently. The seven steps are usually

[6] U.S. Environmental Protection Agency. Guidance on Systematic Planning Using the Data Quality Objectives Process – EPA QA/G-4. Office of Environmental Information, Washington, DC 20460. EPA/240/B-06/001. February 2006.

labeled as:

Step 1: State the Problem
Step 2: Identify the Goal of the Study
Step 3: Identify the Information Inputs
Step 4: Define the Study Boundaries
Step 5: Develop the Analytic Approach
Step 6: Specify Performance or Acceptance Criteria
Step 7: Develop the Detailed Plan for Obtaining Data

As applicable to this project, each of these elements is discussed below.

## 8.2 State the Problem

There is broad agreement among stakeholders from industry and federal, state, and local regulators that an improved testing method for wood heaters is needed to better represent real-world in-home emissions from wood heaters than the current crib wood-based EPA test method represents. The primary purpose of the tasks covered by this QAPP is to oversee testing in support of the development of an EPA cordwood FRM for wood stoves, including a suite of EPA cordwood reference test methods both for PM testing and appliance fueling (wood burning) and operation protocols.

## 8.3 Identify the Goals of the Study

Emission measurement efforts will be conducted to meet the requirements of assessing precision according to ASTM E691-20 and performing ruggedness testing to support the proposal and promulgation of a new PM measurement method IDC operating protocols.

During the first phase, testing will be focused on wood stoves. Multiple paired rounds of (replicate) testing of the IDC fueling and operation protocol with the dichot TEOM PM measurement method are needed to inform the development of a cordwood stove FRM. The goal of the replicate side-by-side stove testing on identical models is to determine repeatability and intra-lab variability and thereby verify (or not) the test method within the laboratory setting. Another goal is that identical test methods for fueling, operation, and analytical methods be used by all laboratories participating in this research study – in the contracted lab on the west coast covered by this TO (using west coast cordwood), as well as in the lab(s) on the east coast performing parallel testing (with east coast cordwood). Using the same methods in all labs allows for a measure of the inter-lab reproducibility using different wood fuels, and ensures that overall precision, variability, potential bias and detectability will be similar, thereby verifying (or not) the test method across different labs. However, the labs will not share any data regarding appliance instructions to determine the impact of different lab interpretations.

During the second phase, testing is focused on hydronic heaters. Multiple paired rounds of (replicate) testing of the IDC fueling and operation protocol with the dichot TEOM PM measurement method are needed to inform the development of a cordwood and pellet hydronic heater FRM. The goal of the replicate side-by-side stove testing on identical models is to determine repeatability and intra-lab variability and thereby verify (or not) the test method within the laboratory setting. Another goal is to use identical fueling, operation, and analytical methods by all laboratories participating in this research study – in the contracted lab on the west coast, as well as in the lab(s) on the east coast performing parallel testing (with east coast cordwood). Using identical test methods in all labs allows for a measure of the inter- lab reproducibility using different wood fuels. It ensures that overall precision, variability, potential bias, and detectability will be similar, thereby verifying (or not) the test method across different labs. What will be assessed is whether or not the test method language is sufficient to ensure tests run in different labs are run similarly.

During the third phase, testing is focused on pellet stoves. Multiple paired rounds of (replicate) testing of the IDC fueling and operation protocol with the dichot TEOM PM measurement method are needed to inform the development of a pellet stove FRM. The goal of the replicate side-by-side stove testing on identical models is to determine repeatability and intra-lab variability and thereby verify (or not) the test method within the laboratory setting. Another goal is that use identical fueling, operation, and analytical methods by all laboratories participating in this research study – in the contracted lab on the west coast, as well as in the lab(s) on the east coast performing parallel testing using the pellet fuel institute (PFI) hardwood pellet fuel in each lab. Using identical methods in all labs allows for a measure of the inter-lab reproducibility using different wood fuels. It ensures that overall precision, variability, potential bias, and detectability will be similar, thereby verifying (or not) the test method across different labs.

Additional goals of the study include reporting results of the testing and developing technical documents, as needed, to provide support for a suite of EPA cordwood and pellet reference test methods for particulate sampling and analysis, as well as for wood-burning appliance fueling and operation protocols (for wood stoves under this first phase and hydronic heaters, forced-air furnaces, and pellet stoves under subsequent phases).

## 8.4 Identify the Information Inputs

This section discusses the variety of inputs that are needed to meet the requirements of assessing method precision according to ASTM E691-20 and performing ruggedness testing on cordwood fuel in three (3) wood stove models, three (3) hydronic heaters, and (2) pairs of pellet stoves. The pollutant of primary interest is particulate matter (PM, although carbon monoxide (CO) and carbon dioxide ($CO_2$) will also be measured, and other exhaust products will be calculated to determine efficiency based on fuel properties.

Cordwood Stoves

The basic inputs required to perform the laboratory testing to collect the emissions data during the variability and verification study include:

- An operational understanding of the wood stoves in which the testing will be performed -
  - Two small firebox non-cat wood stoves,
  - Two medium cat hybrid wood stoves, and
  - Two large cat hybrid wood stoves.
- An understanding of the IDC fueling and operational protocol for wood stoves developed by NYSERDA to be used for the testing.
- Familiarity with the appropriate sampling and analytical methods to be used for testing, including the dichot TEOM within a properly designed dilution tunnel for proper sample mixing, as well as the TEOM software used to record the continuous PM measurements.
- Familiarity with collecting and analyzing ASTM E2515-11 filters for PM measurement (to supplement the PM data obtained from the IDC-TEOM methodology).

In addition to the basic inputs listed above, other inputs potentially critical to decision-making for this project include, but are not limited to, the following items (not listed in any priority order):

- The current EPA certification operational method for wood stoves, Method 28R;
- Sampling and analytical methods including EPA Methods 1, 2, 3, 4, 5G, 10 and 28;
- Other research/testing efforts underway by stakeholders or partner organizations;
- Experience of experts in the field, including certification and other laboratories that can meet the data quality objectives of this study;
- Available funding;
- Laboratory capacity; and
- Availability of resources (fuel, equipment, personnel).

Other information inputs specific to this project include fuel load calculation, fuel moisture, ambient pressure, ambient relative humidity, and draft and air velocities, all of which are discussed in the IDC documentation.

Hydronic Heaters

The basic inputs required to perform the laboratory testing to collect the emissions data during the variability and verification study include:

- An operational understanding of the hydronic heaters on which the testing will be performed
  - Two partial thermal storage pellet hydronic heaters,
  - Two outdoor cordwood hydronic heaters, and
  - One partial thermal storage cordwood hydronic heater.
- An understanding of the IDC fueling and operational protocol for cordwood and pellet

hydronic heaters developed by NYSERDA to be used for the testing.

- Familiarity with the appropriate sampling and analytical methods to be used for testing, including the dichot TEOM within a properly designed dilution tunnel for proper sample mixing, as well as the TEOM software used to record the continuous PM measurements.
- Familiarity with collecting and analyzing ASTM E2515-11 filters for PM measurement (to supplement the PM data obtained from the IDC-TEOM methodology).

In addition to the basic inputs listed above, other inputs potentially important to decision-making for this project include, but are not limited to, the following items (not listed in any priority order):

- The current EPA certification operational method for wood stoves, Method 28R;
- Sampling and analytical methods including EPA Methods 1, 2, 3, 4, 5G, 10, and 28;
- Other research/testing efforts underway by stakeholders or partner organizations;
- Experience of experts in the field, including certification and other laboratories that can meet the data quality objectives of this study;
- Available funding;
- Laboratory capacity; and
- Availability of resources (fuel, equipment, personnel).

Other information inputs specific to this project include fuel load calculation, fuel moisture, ambient pressure, ambient relative humidity, and draft and air velocities, all of which are discussed in the IDC documentation.

<u>Pellet Stoves</u>

The basic inputs required to perform the laboratory testing to collect the emissions data during the variability and verification study include:

- An operational understanding of the pellet stoves in which the testing will be performed -
    - Two medium-output pellet stoves from a mass marketing outlet
    - Two medium/high output pellet stoves from a specialty retailer
- An understanding of the IDC fueling and operational protocol for pellet stoves developed by NYSERDA to be used for the testing.
- Familiarity with the appropriate sampling and analytical methods to be used for testing, including the dichot TEOM within a properly designed dilution tunnel for proper sample mixing, as well as the TEOM software used to record the continuous PM measurements.
- Familiarity with collecting and analyzing ASTM E2515-11 filters for PM measurement (to supplement the PM data obtained from the IDC-TEOM methodology).

In addition to the basic inputs listed above, other inputs potentially important to decision-making for this project include, but are not limited to, the following items (not listed in any priority order):

- The current EPA certification operational method for wood stoves, Method 28R;
- Sampling and analytical methods, including EPA Methods 1, 2, 3, 4, 5G, 10, and 28;
- Other research/testing efforts underway by stakeholders or partner organizations;
- Experience of experts in the field, including certification and other laboratories that can meet the data quality objectives of this study;
- Available funding;
- Laboratory capacity; and
- Availability of resources (fuel, equipment, personnel).

### 8.5 Define the Study Boundaries

The target "population" is defined as the total collection of sample units. This section contains information for the first and second phase of the residential wood heater test method research project.

Cordwood Stoves

This phase focuses on supporting the development of an FRM for wood stoves using cordwood. The target population is the PM measurements collected during the IDC fueling and operation protocol developed by NYSERDA for cordwood stoves, using the dichot TEOM sampling and analytical measurements made within a dilution tunnel, through which the sample flows (i.e., the smoke emitted from the stoves). As noted above, additional supplemental PM measurements will be made by collecting and analyzing ASTM E2515 filters obtained during the same IDC run in which the dichot TEOM samples are collected.

The spatial boundaries define the physical area to be studied, where samples will be collected. For this initial study phase, two (2) of three (3) wood stove models will be fueled with hardwood loads and separately with softwood loads, operated, sampled, and analyzed for PM. The stoves and sampling plans are discussed in later sections of this QAPP. This QAPP will be adhered to for sampling of these six (6) wood stoves on the U.S. east coast.

The temporal boundaries define the time within which the study will take place. Testing for this first phase of the study on the west coast focused on wood stoves occurred primarily from June to November of 2021. The sampling on the east coast will depend on laboratory scheduling and staff availability, testing stands, and seasoned cordwood (both hardwood and softwoods). The IDC protocol is designed to complete each test run within a day, and there will be 26 paired wood stove tests – 52 total individual test runs – on both the west and east coast. Depending on the familiarity, comfort level, and trained staff available at each lab, some of the paired testing may occur simultaneously on separate test stands. It should be noted that simultaneous testing is not a requirement under this TO and QAPP as long as side-by-side test stands are used. It is expected that testing at each lab could take several months after the start of the first test run. It should be noted that a real-time review of the testing results may highlight the need for a revision to the plan and timing of the remaining testing to be performed under this QAPP.

<u>Hydronic Heaters</u>

The hydronic heater phase supports the development of an FRM for cordwood and pellet hydronic heaters. The target population is the PM measurements collected during the IDC fueling and operation protocol developed by NYSERDA for hydronic heaters, using the dichot TEOM sampling and analytical measurements made within the dilution tunnel, through which the sample flows (i.e., the smoke emitted from the stoves). As noted above, additional supplemental PM measurements will be made by collection and analysis of ASTM E2515 filters, pulled during the same IDC run in which the dichot TEOM samples are collected.

The spatial boundaries define the physical area to be studied, where samples will be collected. For this study phase, the cordwood hydronic haters will be fueled with hardwood (maple at the east coast lab) loads and separately with softwood (birch at the east coast lab) loads, operated, and sampled and analyzed for PM. Pellet hydronic heaters shall use the same hardwood pellet at east and west coast labs. The hydronic heaters and sampling plans are discussed in later sections of this QAPP. This QAPP will be adhered to for sampling of the five (5) hydronic heaters at the U.S. east coast.

The temporal boundaries define the time within which the study will take place. Testing for the hydronic heater phase of the study will take place on the west coast primarily from June 2022 to December of 2023. The sampling on the east coast will take place primarily depending on laboratory scheduling and staff availability, testing stands, and seasoned cordwood (both hardwood and softwoods). The IDC protocol is designed to complete each test run within a day, and there will be 24 paired hydronic heater tests – 48 total individual test runs – on both the west coast and east coast. Depending on the familiarity, comfort level, and trained staff available at each lab, some of the paired testing may occur simultaneously on separate test stands.
It should be noted that simultaneous testing is not a requirement under this QAPP as long as side-by-side test stands are used. It is expected that testing at each lab could take several months after the start of the first test run. It should be noted that a real-time review of the testing results may suggest a need to revise the plan and timing of the remaining testing to be performed under this QAPP.

## 8.6 Develop the Analytic Approach

<u>Cordwood Stoves</u>

Testing on each of the six (6) wood stoves will be conducted according to the fueling and operational instructions in the "NYSERDA Integrated Duty Cycle Test Method for Certification of Wood-Fired Stoves Using Cordwood: Measurement of Particulate Matter (PM) and Carbon Monoxide (CO) Emissions and Heating Efficiency", and the sampling and analytical instructions in the "NYSERDA Standard Operation Procedures for Thermo Scientific 1405-D TEOM™ for use in a dilution tunnel" (June 3, 2021), both of which are provided in the EPA's non-regulatory docket for this effort at https://www.regulations.gov/docket/EPA-HQ-OAR-2016-0130, along with other supporting documents including a fuel calculator and data template for the TEOM.[7] The specific TEOM used for sampling is Thermo part # 1405D-ANF, within a modified ASTM E2515-11 dilution tunnel or equivalent dilution method. It should be noted that the HLS dilution tunnel hood is 24 inches in diameter. ASTM 2515 specifies a 40-inch hood with 10" diameter dilution tunnels at HLS. ASTM E2515 assumed a stack diameter of six inches. HLS staff discussed this issue and determined that the 24-inch tunnel hood was sufficient, perhaps superior to a 40-inch hood, to capture all emissions from the stove chimney. This hood diameter specification is believed to be better related to chimney diameter, as it increases the velocity at the entrance to the hood, reducing spillage due to cross draft.

One feature of the PM sample train systems at HLS is using mass flow controllers to measure and control sample flow. ASTM 2515 refers to a flow measurement system and graphically implies using rotameters and dry gas meters for measurement. Mass flow meters offer precise control and automatic adjustment to mass flow in response to filter loading. Manually adjusted systems are inferior in this regard. The mass flow controllers transmit real-time flow rates, and the total STP mass flow is totalized. These are calibrated for the expected use range of 1 to 5 slpm.

A known deviation from ASTM E2515 specifications is that stack gas sample and temperature measurement locations at HLS are lower than the 8-foot level in ASTM E2515. HLS cannot sample at 8 feet for practical reasons. The actual height of the sampling ranges between 6.5 and 7.5 feet, depending on the stove height. Custom chimneys are not constructed for each stove; this is believed to be true at other labs.

Under the IDC method, PM emissions from each of the four burn phases will be collected by the TEOM and reported: start-up phase, high-fire phase, maintenance-fire phase, and low burn rate phase. All data will be collected and recorded by the TEOM at intervals of 1 minute. The primary data to be obtained from each test run include total PM in a variety of calculated units (in grams per hour, grams per kilogram of dry fuel, and pounds per million Btu output); the average PM emission rates (g/hr) for the full run and for each phase of the runs as prescribed in the IDC; a plot of PM emission rate (g/hr) vs. time-based on 1-minute averages; and the maximum 1-minute, 5-minute, and 60-minute PM emission rate (g/hr) on a rolling basis. Similar data will be obtained and reported for CO and $CO_2$. Additional data to be collected, calculated, and summarized are provided in the IDC method. As noted in Section 8.0, to supplement the IDC-TEOM data and provide a basis of comparison for variability, ASTM E2515 filters will be collected and analyzed for PM as well.

As described in Sections 7 and 11, a minimum of 3 test runs will be performed on each stove (with up to 7 test runs performed on the medium cat hybrid stove), and each of these triplicate sets will be replicated in the other identical stove model of the paired testing regime. These paired sets of test runs allow for statistical analyses of the collected data, including the range, variance, and standard deviations of the collected data for the various phases of stove operation prescribed in the IDC, as well as other statistical techniques to analyze the data. In addition, testing different stove fireboxes and technologies (non-cat and cat/hybrid) using different fuel (hardwood versus softwood and west coast species versus east coast species) will allow for statistical analyses to gauge the relative importance and variability caused by such different parameters.

Hydronic Heaters

Testing on each of the five (5) hydronic heaters will be conducted according to the fueling and operational instructions in the "NYSERDA Integrated Duty Cycle Test Method for Certification of Hydronic Heaters Using Cordwood: Measurement of Particulate Matter (PM) and Carbon Monoxide (CO) Emissions and Heating Efficiency" or "NYSERDA Integrated Duty Cycle Test Method for Certification of Hydronic Heaters Using Wood Pellets: Measurement of Particulate Matter (PM) and Carbon Monoxide (CO) Emissions and Heating Efficiency," and the sampling and analytical instructions in the "NYSERDA Standard Operation Procedures for Thermo Scientific 1405-D TEOM™ for use in a dilution tunnel", both of which are provided in the EPA's non-regulatory docket for this effort at https://www.regulations.gov/docket/EPA-HQ-OAR-2016-0130, along with other supporting documents including a fuel calculator and data template for the TEOM.[7] The specific TEOM to be used for sampling is Thermo part # 1405D-ANF, within a modified ASTM E2515-11 dilution tunnel or equivalent dilution method.

Under the IDC method, emissions from each of the six burn phases will be collected by the TEOM and reported: start-up phase, high-fire phase, low fire, idling, cycling, and recovery from the night setback phase. All data will be collected and recorded by the TEOM at intervals of 1 minute. The primary data to be obtained from each test run include total PM in a variety of calculated units (in grams per hour, grams per kilogram of dry fuel, and pounds per million Btu output); the average PM emission rates (g/hr) for the full run and for each phase of the runs as prescribed in the IDC; a plot of PM emission rate (g/hr) vs. time-based on 1-minute averages; and the maximum 1-minute, 5-minute, and 60-minute PM emission rate (g/hr) on a rolling basis. Similar data will be obtained and reported for CO and $CO_2$. Additional data to be collected, calculated, and summarized are provided in the IDC method. As noted in Section 8.0, to supplement the IDC-TEOM data and provide a basis for comparison for variability, ASTM E2515 filters will be collected and analyzed for PM.

As described in Sections 7 and 11, a minimum of 3 test runs will be performed on each hydronic heater (with up to 7 test runs performed on the outdoor hydronic heater and pellet hydronic heater), and each of these triplicate sets will be replicated in the other identical hydronic heater model of the paired testing regime. These paired sets of test runs allow for statistical analyses of the collected data, including the range, variance, and standard deviations of the collected data for the various phases of stove operation prescribed in the IDC, as well as other statistical techniques to analyze the data. In addition, testing different technologies using different fuels (hardwood versus softwood and west coast species versus east coast species) will allow for statistical analyses to gauge the relative importance and variability caused by such different parameters.

### 8.7 Specify Performance or Acceptance Criteria

The tests conducted under this research plan are part of a method of precision analysis according to ASTM E691-20 and ruggedness testing. Due to the research nature of this project, specific acceptable (statistical) limits on estimation uncertainty will not be set before data collection. Methods to reduce measurement error are discussed in more detail in this QAPP in Section 15 (Quality Control), Section 17 (Instrument/Equipment Calibration and Frequency), Section 18 (Inspection/Acceptance of Supplies and Consumables), Section 23 (Data Review, Verification, and Validation) and Section 24 (Verification and Validation Methods).

If the following criteria are met, the data will be considered of sufficient quantity and quality for the variability and verification study:

(1) The IDC fueling and operation protocol was followed by the laboratory personnel, as evidenced by video footage for wood stoves and photos for hydronic heaters;[7]
(2) The dichot TEOM sampling within the dilution tunnel followed the standard operation procedures provided; and
(3) Limitations or known deviations in the data accompany the testing results from the lab so that EPA is fully informed.

Once a DQO is established, the quality of the data must be evaluated and controlled to ensure that it is maintained within the established performance and acceptance criteria. Data Quality Indicators (DQI) are designed to evaluate and control various phases (i.e., sampling, preparation, and analysis) of the measurement process to ensure that total measurement uncertainty is within the range prescribed by the DQOs. The DQI can be defined below:

- Precision - a measure of agreement among repeated measurements of the same property, usually under identical or substantially similar conditions. This is the random component of error and is calculated as either the range or standard deviation. Precision may also be estimated by other statistical techniques, such as the percentage of the mean of the measurements, including relative range or relative standard deviation (coefficient of variation).
- Bias - the systematic or persistent distortion of a measurement process which causes error

[7] The IDC protocol, SOP, and supporting materials are property of NYSERDA. See restrictions listed in footnote 4.

in one direction. Bias is determined by estimating the positive and negative deviation from the true value as a percentage of the true value.

- Representativeness - a measure of the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition.
- Comparability - a measure of confidence with which one data set can be compared to another.
- Completeness - a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under correct, normal conditions.
- Detectability- the determination of the low range critical value of a characteristic that a method specific procedure can reliably discern.
- Ruggedness - the ability of an analytical method to remain unaffected by small variations in method parameters (e.g., log lengths) and influential environmental factors (e.g., room temperature, background PM concentration, air humidity, etc.) and characterize its reliability during normal usage.

In theory, if these DQI are met, measurement uncertainty should be controlled to the levels required by the DQO.

DQI for this project will, at a minimum, follow those for the standard test methods used for residential solid fuel-burning devices. These methods include EPA Method 28/28R, ASTM E2515-11 and elements of EPA Method 5G. A portion of this work is intended to examine the current IDC fueling and operating protocol and the TEOM SOP and recommend improvements.

Results for the testing done under this research plan will be compared across replicate sampling of identical wood stove or hydronic heater models, and fuel, across the hardwood and softwood runs, and across the west coast and east coast runs. The analysis will also reveal how variable the results are based on random precision differences, stove technology and size, hardwood versus softwood fuel, and west coast versus east coast fuel. In this way the intra-lab repeatability and inter-lab reproducibility of the IDC-TEOM method can be determined.

Specific performance and acceptance criteria will be established as the test program proceeds. The initial objective will be to determine the precision and repeatability of the cordwood fueling protocol and PM emission measurement. Once precision is established, the ruggedness of the protocol will be assessed. (Note: The EPA Office of Research and Development [ORD] is separately performing ruggedness testing on the TEOM when used with pellet stoves.) As specific criteria performance and acceptance are established, this QAPP will be revised accordingly.

## 8.8 Develop the Detailed Plan for Obtaining Data

The plan for obtaining the data for this project was developed in discussions with EPA's OAQPS, because the data obtained will be used in support of developing an FRM for wood heaters. The plan ensures the data obtained will be sufficient for a method precision analysis according to ASTM E691-20, and ruggedness testing, to support the proposal and promulgation of a new PM measurement method for wood heaters burning cordwood as well as new IDC operating protocols (for wood stoves, pellet stoves, hydronic heaters, and forced-air furnaces). This version of the QAPP focuses on the plan for obtaining the data from east coast labs to propose and promulgate a cordwood method for wood stoves and hydronic heaters.

The detailed plan for obtaining the data under this study/project are discussed in this QAPP under Section 11 (Sampling Process Design), Section 12 (Sampling Method), Section 13 (Sample Handling and Custody), Section 14 (Analytical Methods), Section 19 (Non-direct Measurements), and Section 20 (Data Management).

The dichot TEOM provides real-time data and data acquisition is automated so that initial results of testing are available immediately after tests are completed and decisions on next steps can be made rapidly.

## 9.0 Special Training Needs/Certification

Specific requirements under the NESCAUM project are to conduct a method precision analysis according to ASTM E691-20 with ruggedness testing on cordwood fuel using an IDC protocol/ operation approach that incorporates a TEOM for PM measurement. This differs from the more traditional EPA Method 28/ASTM E2515 measurement approach; thus, some training will be necessary. For any laboratory participating in this study, set up and operation will be performed in accordance with written instructions provided in the draft IDC and TEOM SOP. Initial steps (described below and now completed) were taken to familiarize/train Hearthlab Solutions laboratory in implementing the draft IDC and TEOM SOP.

Hearthlab Solutions has conducted more than 200 variants of the IDC cordwood stove test method that included obtaining PM emissions with both ASTM E2515 methods and TEOM measurements on more than 20 different stove models. Hearthlab Solutions reviewed both the TEOM SOP and cordwood stove IDC protocol. Prior to the start of method validation testing, the laboratory conducted initial equipment set up and training test runs to ensure all equipment was operating properly prior to testing and become familiar with the fueling protocol and TEOM operation. The technical team and experts were also available for consultation as necessary, with the east coast laboratory to ensure proper equipment setup and operation when the test program began.

## 10.0 Documents and Records

Project tasks, deliverables, and the QC techniques planned for use on these deliverables are presented in **Annex A**.

All project/quality documents, including copies of the QAPP, all technical products and deliverables, and all records of QC activities, will be maintained in the electronic project files. The NESCAUM Project Manager will be responsible for ensuring that QC forms are properly maintained and that the QAPP is distributed to all people on the project listed in Section 3.

Records will be closed when NYSERDA closes the relevant task work orders (TWO). At that time, inactive or obsolete records and documents will be identified, and will be retired to clearly marked, separate archive computer directories until the transfer or destruction date. Typically, records will be removed to archival storage once the project is completed.
Records associated with IDC testing will be maintained by the contracted testing lab, with complete records transferred to NESCAUM at the end of the testing program.

Record retention times will be based on contractual and statutory requirements or will follow NESCAUM practices of storing materials up to three (3) years after the contract's end date per NESCAUM's 2018 Quality Management Plan. As soon as allowed by applicable regulations or the contract, records will be destroyed according to NESCAUM's Policy & Procedures protocols. NESCAUM's policy is consistent with EPA's recommended methods of destruction, which include degaussing, reformatting, or secure deletion of electronic records; physical destruction of electronic media; recycling; shredding; incineration; and pulping. Should the contract specify some other manner of disposition (e.g., transfer to the client), that directive will be followed.

The approved QA project plan will be held by NESCAUM and made available to Hearthlab Solutions any time updates are made. A hard copy of the QA plan will be kept at the laboratory operated by Hearthlab Solutions. Of particular importance will be documentation procedures and data handling.

Data reporting will take several forms including:

1. Preliminary data reporting
2. Interim data reporting
3. Final Reporting

### *Preliminary Data Reporting*

Preliminary results of laboratory testing will be transmitted to NESCAUM typically within 24-48 hours of test completion. A preliminary report of TEOM PM emissions results, parsed real-time data, data acquisition quality, test notes, graphs of comparative preliminary results, and a summary of tests to-date will be provided.

### *Interim Data Reporting*

Interim data reporting captures sets of data intended for QA/QC procedures. These data will be delivered to NESCAUM in a single consolidated electronic spreadsheet and indicate final PM emissions results in a summary page with spreadsheet-linked summary graphs and a complete set of all measured results and laboratory conditions on separate pages. Additionally, interim data will include the complete real-time and filter data set from each test run.

### *Final Reporting*

Final reporting under this project will be completed by NESCAUM with assistance from Hearthlab Solutions. The final report will include a discussion of the overall project, including outcomes and limitations of data, reflecting the professional opinion of Hearthlab Solutions. All real-time data, results summaries, calibration logs, and handwritten data sheets will be included. This final report is intended to capture the entirety of the test program. HLS will provide all their data to NESCAUM. NESCAUM will send the final report to NYSERDA. Final reporting, including all electronic files and associated documents, will be transferred from NESCAUM to NYSERDA completion of the project.

The final report will be provided to the NYSERDA project manager, who will make final determinations on using the project information.

# 11.0 Sampling Process Design

As noted in Section 8, the data obtained from the sampling performed under this project must be sufficient for a method precision analysis according to ASTM E691-20 and ruggedness testing in support of developing an FRM for wood stoves. Triplicate testing of the paired identical stoves, hydronic heaters, and furnace models is essential, as is testing a variety of wood technologies and sizes and testing using hardwoods and softwoods from each U.S. coast. Table 4 provides the overall breakdown of the paired and total tests to be run on each wood stove model in the east coast lab funded by NYSERDA. Table 4 also indicates the current model brands planned for testing, including a range of firebox sizes and non-cat and cat/hybrid technologies. Table 5 provides and overview of the hydronic heater testing.

*Table 4. Paired Test Runs and Total Tests on Wood Stove Models*

| Stove No. | Stove Model* | Fuel | Protocol | No. of Test Runs with each Pairing | No. of Tests per stove |
|---|---|---|---|---|---|
| 1 | Model A | Hardwood | IDC w/ dichot TEOM #1 plus ASTM E2515 | 3 | 3 |
| 2 | Model A | Hardwood | IDC w/ dichot TEOM #2 plus ASTM E2515 | | 3 |
| 1 | Model A | Softwood | IDC w/ dichot TEOM #1 plus ASTM E2515 | 3 | 3 |
| 2 | Model A | Softwood | IDC w/ dichot TEOM #2 plus ASTM E2515 | | 3 |
| 3 | Model B | Hardwood** | IDC w/ dichot TEOM #1 plus ASTM E2515 | 7 | 7 |
| 4 | Model B | Hardwood** | IDC w/ dichot TEOM #2 plus ASTM E2515 | | 7 |
| 3 | Model B | Softwood | IDC w/ dichot TEOM #1 plus ASTM E2515 | 7 | 7 |
| 4 | Model B | Softwood | IDC w/ dichot TEOM #2 plus ASTM E2515 | | 7 |
| 5 | Model C | Hardwood | IDC w/ dichot TEOM #1 plus ASTM E2515 | 3 | 3 |
| 6 | Model C | Hardwood | IDC w/ dichot TEOM #2 plus ASTM E2515 | | 3 |
| 5 | Model C | Softwood | IDC w/ dichot TEOM #1 plus ASTM E2515 | 3 | 3 |
| 6 | Model C | Softwood | IDC w/ dichot TEOM #2 plus ASTM E2515 | | 3 |
| **Total Paired Test Runs** | | | | **26** | |
| **TOTAL TESTS** | | | | | **52** |

* Model A = small non-catalytic (HHT Quadra-fire® 2100 Millennium);
Model B = Medium catalytic hybrid (Hearthstone Castleton);
Model C = large catalytic hybrid (Regency™ Pro-Series model F3500)

**ASTM E2515 filters were added to the testing program after maple (hardwood) testing on Model B was already completed at the contracted west coast laboratory, PFS TECO. It is intended that east coast lab testing include ASTM E2515 filters on all runs.

*Table 5. Paired Test Runs and Total Tests on Hydronic Heater Models*

| HH No. | HH Model* | Fuel | Protocol | No. of Test Runs with each Pairing | No. of Tests per stove |
|---|---|---|---|---|---|
| 1A | Model A | Cordwood Hardwood | IDC w/ dichot TEOM #1 plus ASTM E2515 | 7 | 7 |
| 1B | Model A | Cordwood Hardwood | IDC w/ dichot TEOM #2 plus ASTM E2515 | | 7 |
| 1A | Model A | Cordwood Softwood | IDC w/ dichot TEOM #1 plus ASTM E2515 | 7 | 7 |
| 1B | Model A | Cordwood Softwood | IDC w/ dichot TEOM #2 plus ASTM E2515 | | 7 |
| 2A | Model B | Cordwood Hardwood | IDC w/ dichot TEOM #1 plus ASTM E2515 | NA | 3 |
| 2B | Model B | Cordwood Softwood | IDC w/ dichot TEOM #1 plus ASTM E2515 | NA | 3 |
| 3A | Model C | Hardwood pellet | IDC w/ dichot TEOM #1 plus ASTM E2515 | 7 | 7 |
| 3B | Model C | Hardwood pellet | IDC w/ dichot TEOM #2 plus ASTM E2515 | | 7 |
| **Total Paired Test Runs** | | | | **21** | |
| **TOTAL TESTS** | | | | | **48** |

* Model A = medium outdoor cordwood hydronic heater (Central Boiler 560);
Model B = indoor cordwood hydronic heater with partial thermal storage (Froling S3 Turbo);
Model C = pellet boiler with PTS (Windhager BioWin 152 Lite)

As noted previously in this QAPP, testing will occur and be funded under this project at the east coast lab, using a hardwood species (maple) and a softwood species (birch[8]) commonly used for cordwood on the east coast. Pellet appliance testing will use a PFI-certified hardwood pellet. These species were selected by the EPA to ensure real-world cordwood fuel is used for this testing and ultimately for the wood heater FRM.

As Tables 4 and 5 indicate, the protocol that will be used for sampling is the IDC with dichot TEOM. Simultaneous sampling will also be performed using ASTM E2515 filters to supplement the data collected by the IDC-TEOM method. The IDC fueling and operation protocol, developed by NYSERDA, as well as the dichot TEOM sampling and analytical method within the dilution tunnel,

[8] While birch is a hardwood, it is softer than maple and a common fuel used for heating in the Northeast. Use of softwoods in the east coast is not as prevalent as in the west coast.

are provided in EPA's non-regulatory docket at https://www.regulations.gov/docket/EPA- HQ-OAR-2016-0130, along with other supporting documentation including a fuel load calculator for the IDC protocol and data template for the TEOM sampling data. The IDC pellet boiler protocol is entitled "A Test Method for Certification of Pellet-Fired Hydronic Heating Appliance Emissions Based on a Load Profile: Measurement of Particulate Matter (PM) using a TEOM, Carbon Monoxide (CO), Carbon Dioxide (CO2), Oxygen (O2), and Heating Efficiency." The IDC cordwood boiler protocol is entitled "A Test Method for Certification of Cordwood-Fired Hydronic Heating Appliance Emissions Based on a Load Profile: Measurement of Particulate Matter (PM) using a TEOM, Carbon Monoxide (CO), Carbon Dioxide (CO2), Oxygen (O2), and Heating Efficiency." The cordwood stove protocol is entitled, "NYSERDA Integrated Duty Cycle Test Method for Certification of Wood- Fired Stoves Using Cordwood: Measurement of Particulate Matter (PM) and Carbon Monoxide (CO) Emissions and Heating Efficiency" and is available for download at https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0020. The fuel loading and appliance manipulations prescribed and allowed in NYSERDA's IDC fueling and operational protocol for wood-fired heating appliances are meant to capture realistic fueling and appliance operational activities. The IDC Fuel Calculator is a tool designed and prescribed to perform fuel calculations for cordwood stove and hydronic heater testing using the IDC, and is also provided in EPA's non regulatory docket for download at https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0023. Fueling calculators for pellet appliances are not required.

Filter Testing

The primary sampled metric for this work is PM measurement. ASTM E2515-11 (consistent with EPA method 5g) is the current EPA reference method for PM measurement in solid fuel burning residential heaters. These methods employ a dilution tunnel of specific dimensions and dual-train sampling (with 47 mm diameter filter media) with post-test gravimetric analysis. The methods specify the operation of the sampling system, sampling procedures, calibration requirements, and post-test analysis. Although the methods will be followed, because the methods themselves are under examination, the experimental design group may elect to deviate from the method requirements. It is anticipated that deviations, if any, will result in greater precision than the referenced methods provide. A few known deviations are as follows:

- The dilution tunnel dimensions will be consistent with ASTM E2515-11, except as follows
    - Hood size will remain at 24 inches.
    - Sampling will only employ 47 mm Polytetrafluoroethylene (PTFE) coated glass fiber filters rather than the Method specific glass fiber filters.
    - Constant dilution tunnel and sample flows will be maintained more precisely than required by ASTM E2515-11, to allow for higher precision and the nature of the data outputs required.
    - O-rings are not weighed as they are not a wetted surface. Filter residue on them only needs be accounted for. O-ring residue is typically not problem but when encountered, it is accounted for by either peeling residue and placing it on the filters,

or by taring the o-ring, wiping the residue and re-weighing for a direct measurement of residue; this is noted on the data sheets as "Residue".

The IDC protocol calls for collecting samples of PM in a dilution tunnel. Dilution tunnel requirements follow the specifications detailed in ASTM E2515-11 method (https://www.astm.org/Standards/E2515.htm) or an equivalent dilution method. However, the IDC protocols specify modifications and additional requirements to ensure proper mixing, no liquid water, appropriate tunnel temperature, and relative humidity, and a minimum tunnel flow rate. A schematic of the modified dilution tunnel being used for the IDC- TEOM testing by the east coast lab, Hearthlab Solutions, is provided in Figure 2. PM emissions are measured in the modified dilution tunnel with a Thermo model 1405-D 2-channel ("dichot") TEOM using the "NYSERDA Standard Operation Procedures for Thermo Scientific 1405-D TEOM™ for use in a dilution tunnel", available for download at https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0022. An Excel spreadsheet template for the dichot TEOM sampling data is also available for download at https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0021, and includes incorporated formulas to convert the raw TEOM measurements into the required tunnel PM concentration data.

Of secondary interest is stack gas analysis for $CO_2$ and CO. Measurements will be made in the flue of the subject appliance in accordance with CSA B415.1-10. Measurements of CO and $CO_2$ will provide measures of CO emissions, combustion efficiency, overall efficiency, and air-to-fuel ratio. While these data are secondary to the primary PM data, they are useful in diagnosing run-to-run variability, examining how different wood species and/or loading configurations react when burned, and may be useful in diagnosing stove variability between labs.

Sampling equipment preparation is performed in a clean room. Sample filters and probes will be kept desiccated and clean until just prior to use. Preparation will take place about 2 hours prior to the start of sampling. The weights of clean, desiccated filters and sample probes will be recorded manually on the test data sheets. Once two trains are assembled and labeled (train 1 and train 2), they are immediately leak-checked and installed in the dilution tunnel sampling location. Mass flow meter totals are reset to zero prior to the start of sampling.

Post-test analysis of the samples is performed within one hour of the test end. Mass flow meter totals are recorded on the test data sheet. A leak check at the post-test sample vacuum is performed, and the probes are taken straight to the clean room for analysis. Probe assemblies will be disassembled, and the components weighed, labeled, and placed in desiccation cabinets. Filters, O-rings, and probes will be desiccated to constant weight consistent with the requirements of ASTM E2515-11, except as noted above. Filters will be labeled and retained in a clean desiccated condition for delivery if so desired. Sample probes will be cleaned with an isopropyl alcohol solution in preparation for use in later tests.

Detection and correction of sampling system failures are the responsibility of Hearthlab Solutions.

Failures and any corrective actions will be recorded in the run notes for the individual tests, including an assessment of the impact on data quality (limitations, impact on one train vs. two, etc.).

Filter data generated for this project is generally consistent with methods associated with those used for laboratory evaluation of residential solid fuel burning appliances. These operational protocols and sampling/analytical methods include EPA method 28R, EPA method 5g, ASTM E2515-11, and CSA B415.1-10. The PM measurement methodologies themselves are one focus of this work so variation from the currently practiced methods is probable during this project. Such variations are identified for particular test runs (or series of runs). Of primary interest is PM measurement, the metric used to certify wood-burning appliances. Hearthlab Solutions will follow its Standard Operating Procedures for filter weights.

The primary metric for wood stove emissions is PM measurement practiced in a dilution tunnel according to ASTM E2515-11 (which closely mimics EPA Method 5g). PM measurement is the primary data output for all work under this project, and sampling is consistent with ASTM E2515-11 with few exceptions. An automated data acquisition/control system will maintain test parameters and collect scale, stack gas, sample flow, dilution tunnel flow, stove temperature, and calculated real-time data such as air-to-fuel ratio, CO emissions factors, and burn rate. Data is recorded at one-minute intervals. While PM emissions are the primary metric, real-time scale and stack gas analysis will provide data to evaluate these other parameters of interest for this study.

Dilution Tunnel

In testing using the IDC-TEOM method conducted to date by NYSERDA/NESCAUM and analyzed in detail by an expert in turbulent flow and computational fluid dynamics (CFD) modeling, it was determined that the traditional dilution tunnel design provides poorly mixed PM that may be stratified due to the bends in the tunnel. This is believed to be an issue with the ASTM E2515-11 method (which is silent on mixing). NYSERDA/NESCAUM continues to research this issue and work towards a resolution. To address this issue, prior to initiating the test program at Hearthlab Solutions, NESCAUM conducted a mixing assessment that provided data to ensure the proper mixing at the HLS tunnel. A copy of this memo has been included in Annex B.

Data Reporting

Initial results of laboratory testing are transmitted to the NESCAUM “Basecamp” web site within 72 hours of test completion. This includes parsed real-time data and fueling details. Final PM emissions data is transmitted the same website usually a few days later once PM samples are processed.

# 12.0 Sampling Methods

As noted in previous sections, testing on wood stoves and hydronic heaters will be conducted according to the fueling and operational instructions contained in the relevant protocol.

- Cordwood stoves
  - NYSERDA Integrated Duty Cycle Test Method for Certification of Wood- Fired Stoves Using Cordwood: Measurement of Particulate Matter (PM) and Carbon Monoxide (CO) Emissions and Heating Efficiency
  - Docket: https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0020.
- Auto-feed (Pellet) Hydronic Heaters
  - A Test Method for Certification of Pellet-Fired Hydronic Heating Appliance Emissions Based on a Load Profile: Measurement of Particulate Matter (PM) using a TEOM, Carbon Monoxide (CO), Carbon Dioxide (CO2), Oxygen (O2), and Heating Efficiency
  - Docket link: https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0032
- Manual feed Cordwood Hydronic Heaters
  - A Test Method for Certification of Cordwood-Fired Hydronic Heating Appliance Emissions Based on a Load Profile: Measurement of Particulate Matter (PM) using a TEOM, Carbon Monoxide (CO), Carbon Dioxide (CO2), Oxygen (O2), and Heating Efficiency
  - Docket link: https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0030
- TEOM
  - Before August 2022 for cordwood stoves:
    - NYSERDA Standard Operation Procedures for Thermo Scientific 1405-D TEOM™ for use in a dilution tunnel
    - Docket:
      - https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0021
      - https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0022.
  - Update September 2022 for pellet and cordwood hydronic heaters:
    - NYSERDA Standard Operation Procedures for use of a Thermo Scientific 1405-D TEOM™ in a dilution tunnel with wood-fired stoves, hydronic heaters, and furnaces. Revised September 29, 2022.
    - Docket: https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0031 and https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0028

The specific TEOM to be used for sampling is Thermo part # 1405D-ANF, within a modified ASTM E2515-11 dilution tunnel or equivalent dilution method. Teflon coated glass fiber filters as supplied by the TEOM manufacturer are required for use with the TEOM model 1405D-ANF. These are Pallflex Emfab (TX40) with an exposed diameter of 13 mm, without organic binder, exhibiting at least 99.95 percent efficiency. The detailed procedures and equipment needed to perform the IDC fueling and operation protocol, with the sampling and analyzing by the dichot TEOM in the dilution tunnel, are provided in the documents cited above.

In addition to PM sampling by the IDC-TEOM method, PM will also be simultaneously sampled using ASTM E2515 filters. This sampling will provide supplemental data for comparison.
For example, the standard deviation determined for the ASTM E2515 filter measurements will provide some context for the standard deviation variability assessment of the IDC-TEOM method for each stove type and across fuels. The sampling method requirements for ASTM E2515 are available at https://www.astm.org/Standards/E2515.htm. The sampling method requirements contained in ASTM E2515 derive from and require knowledge of EPA's Method 5G (Determination of Particulate Matter from Wood Heaters [Dilution Tunnel Sampling Location]) and EPA Method 5 (Determination of Particulate Matter Emissions from Stationary Sources), which are available at https://www.epa.gov/sites/production/files/2017- 08/documents/method_5g.pdf and https://www.epa.gov/sites/production/files/2019- 08/documents/method_5_0.pdf, respectively.

While the sole method of PM collection and sample analysis under the IDC method is via the dichot TEOM using Pallflex Emfab filters, it should be noted that the IDC test method does not include all the specifications and procedures necessary for its performance because some material (e.g., equipment, supplies, sampling and analytical procedures) is incorporated by reference from other methods. The IDC protocol requires knowledge of and incorporates by reference the following EPA methods: Method 1 (Sample and Velocity Traverses for Stationary Sources), Method 2 (Determination of Stack Gas Velocity and Volumetric Flow Rate [Standard Pitot Tube]), Method 3 (Gas Analysis for the Determination of Dry Molecular Weight), Method 4 (Determination of Moisture Content in Stack Gases), Method 10 (Carbon Monoxide - Instrumental Analyzer), Method 5G, and Method 28 (Certification and Auditing of Wood Heaters). Documentation for each of these methods is available on EPA's website. The laboratory personnel using the IDC-TEOM test method have a thorough understanding of ASTM E2515-11 and EPA Methods 1, 2, 3, 4, 5G, 10 and 28 and TEOM and IDC test methods, having worked with NESCAUM on these protocols since 2017.

NESCAUM shall provide data to the NYSERDA Project Manager and, as allowed by the NYSERDA contract, share information with EPA to confirm that the sampling protocol is being followed correctly and for immediate corrective action if necessary.

## 13.0 Sample Handling and Custody

All sampling and analysis for stove testing will be performed at Hearthlab Solutions, under contract to NESCAUM, under contract with NYSERDA. This testing is meant to parallel sampling and analysis that will be performed in the laboratory (or laboratories) on the west coast with EPA funding. Custody of the samples will be with each laboratory, although the use of TEOM 1405D-ANF allows raw data logged by the TEOM to be available electronically almost immediately upon completion of the sampling. As such, the PM measurements logged by the TEOM in the Hearthlab Solutions lab will be electronically shared in almost real-time with NESCAUM.

All sampling and analysis is done in the laboratory operated by Hearthlab Solutions in Bethel, VT. The custody of samples is with Mark Champion of Hearthlab Solutions at all times. Mr. Champion performs all the sampling preparation, post-test analysis, data recording. Sample labeling always refers to the test run number associated with a particular test run.

Sample analysis will begin within one hour of test completion except when tests extend past 5 pm, in which case analysis will begin the following morning. The desiccation process typically takes several days. The sample handling procedures and requirements for sampling done under this project's testing regimen are described in the following documents:

Cordwood stoves
The "NYSERDA Integrated Duty Cycle Test Method for Certification of Wood-Fired Stoves Using Cordwood: Measurement of Particulate Matter (PM) and Carbon Monoxide (CO) Emissions and Heating Efficiency" available at https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0020.[8] Although the IDC is a fueling and operational protocol for wood stoves, it includes a list of equipment and supplies, requirements for the test facility and flue, the reagents and standards for sample collection, and modifications to the dilution tunnel requirements under ASTM E2515-11. In addition to ASTM E2515-11 and Method 5G, the IDC protocol also incorporates by reference and requires knowledge of other EPA Methods, as listed in Section 12 above.

The "NYSERDA Standard Operation Procedures for Thermo Scientific 1405-D TEOM™ for use in a dilution tunnel" (June 3, 2021) is available at https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0022. This document covers the operation and sampling procedures for using the 1405D-ANF dichot TEOM to measure and report continuous PM measurements for a cordwood stove in a modified ASTM E2515-11 dilution tunnel or equivalent dilution method. The following sections are included: instrument software and installation, supplies and parts, routine operation and quality assurance checks, flow settings, filter temperature zone settings, TEOM filter dynamics, testing operations, filter temperature adjustment, sample flow check and adjustment, leak test and transducer K0 checks, filter change procedure, data storage, data download, data validation, data calculations, and TEOM configuration changes and parameter values.

Thermo Fisher Scientific's Manual and Protocol for the tapered element oscillating microbalance: 1405-D TEOM™ Continuous Dichotomous Ambient Particulate Monitor (https://www.ThermoFisher.com/order/catalog/product/TEOM1405D#/TEOM1405D). The Operating Guide includes sections on the application, setup, installation, basic operation, screen settings, maintenance procedures, calibration procedures, and troubleshooting.

For the supplemental PM sampling using ASTM E2515 filters, the sampling method requirements for ASTM E2515-11, the "Standard Test Method for Determination of Particulate Matter Emissions Collected by a Dilution Tunnel" are available at https://www.astm.org/Standards/E2515.htm. EPA's Method 5G is available at https://www.epa.gov/sites/production/files/2017-08/documents/method_5g.pdf. Sample collection, preservation, transport, and storage are detailed in the documentation for the methods and include proper preparation of the sampling train, proper handling of the filters, maintaining the filters at the proper temperature, proper storage of the filters, proper transport, and proper sample weighing. Note that the sample handling procedures contained in EPA's Method 5G and ASTM E2515 derive from and require knowledge of EPA Method 5, available at https://www.epa.gov/sites/production/files/2019- 08/documents/method_5_0.pdf.

Hydronic Heaters

The protocol, "A Test Method for Certification of Pellet-Fired Hydronic Heating Appliance Emissions Based on a Load Profile: Measurement of Particulate Matter (PM) using a TEOM, Carbon Monoxide (CO), Carbon Dioxide (CO2), Oxygen (O2), and Heating Efficiency will be posted in the EPA docket for public access. Although the IDC is a fueling and operational protocol for automatic feed hydronic heaters that use pellets or wood chips, it includes a list of equipment and supplies, requirements for the test facility and flue, the reagents and standards for sample collection, and modifications to the dilution tunnel requirements under ASTM E2515-11. In addition to ASTM E2515-11 and Method 5G, the IDC protocol also incorporates by reference and requires knowledge of other EPA Methods, as listed in Section 12 above.

The protocol, "A Test Method for Certification of Cordwood-Fired Hydronic Heating Appliance Emissions Based on a Load Profile: Measurement of Particulate Matter (PM) using a TEOM, Carbon Monoxide (CO), Carbon Dioxide (CO2), Oxygen (O2), and Heating Efficiency will be posted in the EPA docket for public access. Although the IDC is a fueling and operational protocol for manually fed hydronic heaters that use cordwood, it includes a list of equipment and supplies, requirements for the test facility and flue, the reagents and standards for sample collection, and modifications to the dilution tunnel requirements under ASTM E2515-11. In addition to ASTM E2515-11 and Method 5G, the IDC protocol also incorporates by reference and requires knowledge of other EPA Methods, as listed in Section 12 above.

The hydronic heaters use an updated TEOM protocol, "NYSERDA Standard Operation Procedures for use of a Thermo Scientific 1405-D TEOM™ in a dilution tunnel with wood-fired stoves, hydronic heaters, and furnaces", revised September 29, 2022 that is available in EPA's docket. This document covers the operation and sampling procedures for using the 1405D-ANF dichot TEOM to measure and report continuous PM  measurements in a modified ASTM E2515-11 dilution tunnel or equivalent dilution method. The following sections are included: instrument software and installation, supplies and parts, routine operation and quality assurance checks, flow settings, filter temperature zone settings, TEOM filter dynamics, testing operations, filter temperature adjustment, sample flow check and adjustment, leak test and transducer K0 checks, filter change procedure, data storage, data download, data validation and calculations, and TEOM configuration changes and parameter values.

Thermo Fisher Scientific's Manual and Protocol for the tapered element oscillating microbalance: 1405-D TEOM™ Continuous Dichotomous Ambient Particulate Monitor (https://www.ThermoFisher.com/order/catalog/product/TEOM1405D#/TEOM1405D).  The Operating Guide includes sections on the application, setup and installation, basic operation, screens, settings, maintenance procedures, calibration procedures, and troubleshooting.

For the supplemental PM sampling using ASTM E2515 filter pulls, the sampling method requirements for ASTM E2515-11, the "Standard Test Method for Determination of Particulate Matter Emissions Collected by a Dilution Tunnel" are available at https://www.astm.org/Standards/E2515.htm. EPA's Method 5G is available at https://www.epa.gov/sites/production/files/2017-08/documents/method_5g.pdf. Sample collection, preservation, transport, and storage are detailed in the documentation for the methods and include proper preparation of the sampling train, proper handling of the filters, maintaining the filters at the proper temperature, proper storage of the filters, proper transport and proper sample weighing. Note that the sample handling procedures contained in EPA's Method 5G and ASTM E2515 derive from and require knowledge of EPA Method 5 available at https://www.epa.gov/sites/production/files/2019- 08/documents/method_5_0.pdf.

All sampling at Hearthlab Solutions will follow their quality management plans as required by their ISO accreditation.

## 14.0 Analytical Methods

The IDC test methods for residential wood heating appliances calls for measuring and analyzing PM emissions using real-time TEOM direct measurements. The sole method of PM collection and sample analysis under the IDC method is via the dichot TEOM 1405D-special using Pallflex Emfab filters. The carbon monoxide (CO) and carbon dioxide (CO2) emission rates are also measured in the stack's flue gas using a flue gas sample probe and NDIR analyzers (or equivalent), under the IDC test method, and are used to calculate efficiency.

The analytical method requirements for analysis of the samples collected under this project's testing regimen are described in the following documents:

Cordwood stoves

The "NYSERDA Integrated Duty Cycle Test Method for Certification of Wood-Fired Stoves Using Cordwood: Measurement of Particulate Matter (PM) and Carbon Monoxide (CO) Emissions and Heating Efficiency" available at https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0020.[8] Although the IDC is a fueling and operational protocol for wood stoves, it includes a list of equipment and supplies, requirements for the test facility and flue, the reagents and standards for sample collection, and modifications to the dilution tunnel requirements under ASTM E2515-11. In addition to ASTM E2515-11 and Method 5G, the IDC protocol also incorporates by reference and requires knowledge of other EPA Methods, as listed in Section 12 above.

The "NYSERDA Standard Operation Procedures for Thermo Scientific 1405-D TEOM™ for use in a dilution tunnel" available at https://www.regulations.gov/document/EPA-HQ- OAR-2016-0130-0022. This document covers the operation and sampling procedures for using the 1405D-ANF dichot TEOM to measure and report continuous PM measurements in a modified ASTM E2515-11 dilution tunnel or equivalent dilution method. The following sections are included: instrument software and installation, supplies and parts, routine operation and quality assurance checks, flow setting, filter temperature zone settings, TEOM filter dynamics, testing operations, filter temperature adjustment, sample flow check and adjustment, leak test and transducer K0 checks, filter change procedure, data storage, data download, data validation and calculations, and TEOM configuration changes and parameter values.

Thermo Fisher Scientific's Manual and Protocol for the tapered element oscillating microbalance: 1405-D TEOM™ Continuous Dichotomous Ambient Particulate Monitor (https://www.ThermoFisher.com/order/catalog/product/TEOM1405D#/TEOM1405D). The Operating Guide includes sections on the application, setup and installation, basic operation, screens, settings, maintenance procedures, calibration procedures, and troubleshooting.

For the supplemental PM sampling using ASTM E2515 filters, the sampling method requirements for ASTM E2515-11, the "Standard Test Method for Determination of Particulate Matter Emissions Collected by a Dilution Tunnel" are available at https://www.astm.org/Standards/E2515.htm. EPA's

Method 5G is available at https://www.epa.gov/sites/production/files/2017-08/documents/method_5g.pdf. Sample collection, preservation, transport, and storage are detailed in the documentation for the methods and include proper preparation of the sampling train, proper handling of the filters, maintaining the filters at the proper temperature, proper storage of the filters, proper transport, and proper sample weighing. Note that the sample handling procedures contained in EPA's Method 5G and ASTM E2515 derive from and require knowledge of EPA Method 5 available at https://www.epa.gov/sites/production/files/2019- 08/documents/method_5_0.pdf.

<u>Hydronic Heaters</u>

The protocol, "A Test Method for Certification of Pellet-Fired Hydronic Heating Appliance Emissions Based on a Load Profile: Measurement of Particulate Matter (PM) using a TEOM, Carbon Monoxide (CO), Carbon Dioxide (CO2), Oxygen (O2), and Heating Efficiency will be posted in the EPA docket for public access. Although the IDC is a fueling and operational protocol for automatic feed hydronic heaters that use pellets or wood chips, it includes a list of equipment and supplies, requirements for the test facility and flue, the reagents and standards for sample collection, and modifications to the dilution tunnel requirements under ASTM E2515-11. In addition to ASTM E2515-11 and Method 5G, the IDC protocol also incorporates by reference and requires knowledge of other EPA Methods, as listed in Section 12 above.

The protocol, "A Test Method for Certification of Cordwood-Fired Hydronic Heating Appliance Emissions Based on a Load Profile: Measurement of Particulate Matter (PM) using a TEOM, Carbon Monoxide (CO), Carbon Dioxide (CO2), Oxygen (O2), and Heating Efficiency will be posted in the EPA docket for public access. Although the IDC is a fueling and operational protocol for manually fed hydronic heaters that use cordwood, it includes a list of equipment and supplies, requirements for the test facility and flue, the reagents and standards for sample collection, and modifications to the dilution tunnel requirements under ASTM E2515-11. In addition to ASTM E2515-11 and Method 5G, the IDC protocol also incorporates by reference and requires knowledge of other EPA Methods, as listed in Section 12 above.

The hydronic heaters use an updated TEOM protocol, "NYSERDA Standard Operation Procedures for the use of a Thermo Scientific 1405-D TEOM™ in a dilution tunnel with wood-fired stoves, hydronic heaters, and furnaces", revised September 29, 2022, available in EPA's docket. This protocol covers the operation and sampling procedures for using the 1405D-ANF dichot TEOM to measure and report continuous PM measurements in a modified ASTM E2515-11 dilution tunnel or equivalent dilution method. The following sections are included: instrument software and installation, supplies and parts, routine operation and quality assurance checks, flow setting, filter temperature zones settings, TEOM filter dynamics, testing operations, filter temperature adjustment, sample flow check and adjustment, leak test and transducer K0 checks, filter change procedure, data storage, data download, data validation, data calculations, and TEOM configuration changes and parameter values.

Thermo Fisher Scientific's Manual and Protocol for the tapered element oscillating microbalance: 1405-D TEOM™ Continuous Dichotomous Ambient Particulate Monitor (https://www.Thermo Fisher.com/order/catalog/product/TEOM1405D#/TEOM1405D). The Operating Guide includes sections on the application, setup and installation, basic operation, screens and settings, maintenance and calibration procedures, and troubleshooting.

For the supplemental PM sampling using ASTM E2515 filter pulls, the sampling method requirements for ASTM E2515-11, the "Standard Test Method for Determination of Particulate Matter Emissions Collected by a Dilution Tunnel" are available at https://www.astm.org/Standards/E2515.htm. EPA's Method 5G is available at https://www.epa.gov/sites/production/files/2017-08/documents/method_5g.pdf. Sample collection, preservation, transport, and storage are detailed in the documentation for the methods and include proper preparation of the sampling train, proper handling of the filters, maintaining the filters at the proper temperature, proper storage of the filters, proper transport and proper sample weighing. Note that the sample handling procedures contained in EPA's Method 5G and ASTM E2515 derive from and require knowledge of EPA Method 5 available at https://www.epa.gov/sites/production/files/2019- 08/documents/method_5_0.pdf.

Hearthlab Solutions Practices

The primary measurements of importance are gravimetric analysis of filters and probes, dilution tunnel flow measurement, and sample volume measurement. Operationally, dilution tunnel and sample flows should maintain constant proportionality to the extent possible (some variation of the latter is allowed in the reference methods).

The gravimetric analysis employs a 100 g x 0.1 mg analytical balance. The balance is calibrated daily using an internal calibration routine, and this calibration is confirmed with each critical use (pre-test and final mass) with combinations of 100 g, 200 mg, and 50 mg ASTM class 1 calibration weights. These weights are selected based on the nominal tare weight of a probe (85 g), the nominal tare weigh of a set of filters (170 mg), and the expected catch of nominally 5 to 20 mg. Calibration values may change depending on the balance required and PM catches. Results of calibration are recorded on an "Analytical Balance Log."

Sample volume measurement is made with calibrated and NIST traceable mass flow controllers (MFCs). The MFC calibrations will be relied on for the accuracy of results, and dual sampling trains will be run to detect potential problems and confirm the precision.

Dilution tunnel flow measurement will use a pitot tube in conjunction with differential pressure and temperature measurements to determine mass flow (or standardized volumetric flow). Computer data acquisition reads and logs differential pressure and temperature and calculates tunnel flow at one-minute intervals. The electronic pressure transducer is checked and recalibrated as necessary prior to each test. Two measurement devices are used to ensure proper differential pressure readings:

- Dwyer 475 1” x 0.001” w.c. electronic manometer, NIST traceable. This device will be used for calibration of the other two devices used during testing.
- Setra 0.1” w.c. full scale pressure transducer. This device sends the signal to the computer.

Prior to each test, the Dwyer 475 manometer is used to check the computer signal. Each device will be zeroed (or the zero checked) and spanned by inducing a differential pressure of nominally 0.08” w.c. Lines from the pitot tube are closed to produce a steady pressure. (This procedure also functions as a leak check of the pitot lines.) The computer reading should match the Dwyer 475 to within 0.002” w.c. at the computer. If not, the devices will be recalibrated or adjusted as necessary. Zero check and span values are recorded on the test run data sheet.

An additional level of quality is provided by computer data acquisition, consistent application of calculations, and automatic storage of test parameters. This avoids transcription errors but also provides the opportunity for automatic control of dilution tunnel flow. This is important since the sampling-to-tunnel flow ratio is intended to be constant throughout a test. Variation in tunnel flow results from temperature changes, and variation in sample flow results from filter loading. The computer will be employed to maintain a constant tunnel flow. Additionally, the real-time sample flow rate is displayed and stored at one-minute intervals and is controlled very precisely by the MFCs. Mass flow controllers automatically maintain the sample flow rate regardless of filter loading. The MFC is totalizing devices read manually post-test, but the sample flow rate is transmitted to the computer at one-minute intervals.

A further quality check is in the post-test analysis of the dual train precision. This calculation is in Method 5g and is defined as the equivalent deviation from the mean of each sample train. Up to 7.5% is acceptable but the goal for this work is to maintain dual train precisions below 3%. Although not an acceptance criterion, a value greater than 3% will trigger an investigation of methods, including review of the gravimetric analysis, sample volume readings and leak checks.

Additional measurements, while not mission critical, require calibration procedures. The wood weighing scale and test stand stove scale will both be checked with an ASTM Class 1 (or equivalent) traceable 10.0 lb. calibration weight. Checks are performed before and after runs or prior to use as necessary. The check information is recorded on the data sheets.  Values from the scales are recorded on the test data sheet manually. The wood moisture meter is checked against a fixed resistance 12 and 22% calibration block before and after runs or prior to use as necessary. The check information is on the data sheets.  Published correction factors for wood species are used with an analog moisture meter having a resolution of 1% dry basis moisture.

# 15.0 Quality Control

The quality control (QC) requirements under the NESCAUM project derive from the QC procedures required by the two methods comprising the testing: the IDC fueling and operation protocol and the real-time dichot TEOM sampling and analysis within the modified ASTM E2515-11 or equivalent dilution tunnel. The test protocol shall dictate methods that measure bias; and the calibration check samples required by the methods will measure calibration drift. The paired triplicate testing of this study will measure the imprecision or random error inherent in this testing, assuming the QC checks and procedures of the sampling methods are followed.

As noted above, in addition to PM sampling by the IDC-TEOM method, PM will also be simultaneously sampled using ASTM E2515 filter pulls. This sampling will provide supplemental data for comparison. For example, the standard deviation determined for the ASTM E2515 filter measurements will provide some context for the standard deviation variability assessment of the IDC-TEOM method, for each appliance type and across fuels. The quality control requirements for ASTM E2515 are available at https://www.astm.org/Standards/E2515.htm. The quality control requirements contained in ASTM E2515 derive from and require knowledge of EPA's Method 5G and EPA Method 5, which are available at https://www.epa.gov/sites/production/files/2017-08/documents/method_5g.pdf and https://www.epa.gov/sites/production/files/2019-08/documents/method_5_0.pdf, respectively.

## 15.1 IDC Test Method Quality Control Checks

The IDC test methods for stoves, furnaces, and hydronic heaters require the QC checks and procedures applicable to a dilution tunnel for PM sampling, with added QC measures for the TEOM:

- Dilution tunnel: Sampling equipment leak check is required pre- and post- testing;
- TEOM: Flow and leak checks are required pre- and post- every test run per "NYSERDA Standard Operation Procedures for Thermo Scientific 1405-D TEOM™ for use in a dilution tunnel".

In addition to the above QC checks, the IDC test method requires certain modifications to the ASTM E2515-11 dilution tunnel for quality assurance. These modifications are listed in Section 10 of the IDC protocol and pertain to constraints on what constitutes a valid test run, including the absence of water in the sample, acceptable maximum tunnel temperature and relative humidity, acceptable tunnel dew point temperature, and a minimum tunnel flow rate. These modifications to ASTM E2515-11 (and, by extension Method 5G) are essentially QC checks that must be met for a sample to be considered valid.

In addition to ASTM E2515-11, the IDC protocol also incorporates by reference and requires knowledge of other EPA Methods, as listed in Section 12 above. The applicable QC checks required within the cited methods must be documented by the contracted lab and, if a test run is conducted in which these QC checks are not met within any of the cited method's stated allowances, that test run will be repeated by the laboratory as necessary. **The contracted lab must save all data and QC check results, from both valid and invalid test runs.**

### 15.2 TEOM 1405-D Quality Control Checks

The quality assurance requirements and routine QC checks and procedures for the dichot TEOM (Thermo Fisher Scientific part # 1405D-ANF) are listed throughout multiple sections of the "NYSERDA Standard Operation Procedures for Thermo Scientific 1405-D TEOM™ for use in a dilution tunnel" provided in EPA's non-regulatory docket at https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0022. Section 2 of the SOP includes quality assurance checks to be completed before and after each set of test runs, routine procedures before every test run to be conducted one to two hours prior to testing, and operation during testing. Section 3 of the SOP includes leak and flow checks and flow calibration for the 1405-D TEOM. Section 4 of the SOP includes the procedure for calibration checks of the mass transducer K0, to be done before and after each set of test runs for both TEOM channels. These sections and subsections provide detailed guidance, including numerous QC checks, allowances within which the TEOM should operate for testing performed under this TO and beyond which the results should not be considered valid, and instructions for handling potential QC issues. It should also be noted that key 1405-D TEOM parameters are stored with the concentration data and are used to perform quality control of the data during review and processing, as detailed in the TEOM SOP.

The manufacturer's Operating Guide for the TEOM 1405 also includes QC checks and procedures for the TEOM. Thermo Fisher Scientific's Manual and Protocol for the tapered element oscillating microbalance: 1405-D TEOM™ Continuous Dichotomous Ambient Particulate Monitor (https://www.Thermo Fisher.com/order/catalog/product/TEOM1405D#/TEOM1405D) includes sections on setup and installation, basic operation, screens and settings, maintenance and calibration procedures and troubleshooting.

In addition to the two-channel dichot TEOM to be used for PM sampling and analysis, the IDC method calls for a single-channel TEOM to be used to measure ambient lab air PM during the test. This single-channel TEOM should be configured as indicated in the "NYSERDA Standard Operation Procedures for Thermo Scientific 1405-D TEOM™ for use in a dilution tunnel" provided at https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0022. A data template for the single channel TEOM to be used to measure ambient lab air PM is also provided in EPA's non-regulatory docket (https://www.regulations.gov/docket/EPA-HQ-OAR-2016-0130).

As noted above regarding the IDC fueling and operation protocol and methods incorporated by reference (ASTM E2515-11, Methods 1, 2, 3, 4, 5G, 10, and 28), the QC checks must be documented by the laboratory, including the QC checks required in the dichot TEOM SOP and the manufacturer's Operating Guide for the dichot TEOM. The results of these QC checks must be validated to be within the allowances provided in these documents for the data collected by the TEOM to be considered valid. The laboratory must save all data, even from invalidated runs.

## 16.0 Instrument/Equipment Testing, Inspection, and Maintenance

Lists of all equipment and supplies required by the IDC test method with the dichot TEOM within a modified dilution tunnel are provided in the documentation for each method provided in EPA's non-regulatory docket (https://www.regulations.gov/docket/EPA-HQ-OAR-2016-0130) at https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0020 for the IDC test method and https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0022 for the dichot TEOM SOP. Section 8 of the IDC test method ("NYSERDA Integrated Duty Cycle Test Method for Certification of Wood-Fired Stoves Using Cordwood: Measurement of Particulate Matter (PM) and Carbon Monoxide (CO) Emissions and Heating Efficiency") lists the required equipment and supplies. Likewise, the SOP for the 1405-D TEOM in the dilution tunnel ("NYSERDA Standard Operation Procedures for Thermo Scientific 1405-D TEOM™ for use in a dilution tunnel") plus the manufacturer Thermo Fisher Scientific's User Guide for the 1405-D TEOM (https://www.Thermo Fisher.com/order/catalog/product/TEOM1405D#/TEOM1405D) provides instrumentation lists, testing and maintenance, and troubleshooting instructions for the dichot TEOM to be used for the testing under this TO. Finally, the list of all equipment and supplies required for the supplemental sampling of PM using ASTM E2515 filter pulls is provided within the documentation for the method (https://www.astm.org/Standards/E2515.htm).

After a thorough review of the IDC test method's documentation, the dichot TEOM's SOP and documentation, and familiarity with the ASTM E2515 method, Hearthlab Solutions has provided documentation of the testing, inspection, and maintenance of sampling equipment and analytical instruments, which includes:

- a list of equipment and/or systems needing periodic maintenance, testing, or inspection, and the schedule for such;
- a description of how inspections and periodic preventive maintenance procedures will be performed and documented;
- a discussion on how critical spare parts will be supplied and stocked; and
- a description of how re-inspections will be performed and the effectiveness of corrective actions.

Hearthlab Solutions' log to document the testing, inspection, and maintenance of sampling equipment and analytical instruments is provided in Table 6.

*Table 6. Hearthlab Solutions Equipment & Analytical Instruments*

The following chart lists the instruments that are used for this work. Instrument resolution, confirmation and calibration frequency and methods are also listed.

| Equipment Instrument (manufacturer, Model) | FS and Resolution | Use | Check frequency | Record | Standard | Calibration Due |
|---|---|---|---|---|---|---|
| Ohaus analytical balance, AB01 | 100g x 0.1mg | Direct gravimetric analysis | Daily or before critical | Calibration log | Weights, CW2,3,4,5 or CW 6, 7,8 | N/A |
| Calibration Weights CW2,3,4,5 | 100g 129442<br>100 mg 129444<br>100 mg 129443<br>50mg 129445 | Check of analytical balance | Yearly | On File | ASTM Class 1 | Due – will not be used in testing unless calibrated |
| Calibration Weights CW 6, 7, 8 | 100g<br>200mg, 232883<br>50 mg, 232882 | Check of analytical balance | Yearly | On File | ASTM Class 1 | 7/15/23 |
| GE Sensing, pressure transducer, DP03 | 0.1 inch FS | DP transducer, Tunnel | daily | Test data sheet | Manometer, DP01 or DP02 | N/A |
| Setra, 0.25FS, DP04 | 0.25 inch FS | DP transducer, Tunnel | daily | Test data sheet | Manometer, DP01 or DP02 | N/A |
| Setra, 0.1 FS, DP05, 10576501 | 0.1 inch FS | DP transducer, Tunnel | daily | Test data sheet | Manometer, DP01 or DP02 | 6/28/2023 |
| Setra, 0.1 FS, DP06, 10576502 | 0.1 inch FS | DP transducer, Tunnel | daily | Test data sheet | Manometer, DP01 or DP02 | 6/28/2023 |
| Dwyer 475 electronic Manometer, DP01 | 1” x 0.001” w.c. | Check pressure transducers | Yearly | On File | NIST traceable certificate | 8/29/2023 |
| Dwyer 475 electronic Manometer, DP02 | 1” x 0.001” w.c | Check pressure transducers | Yearly | On File | NIST traceable certificate | Due – will not be used in testing unless calibrated |
| Dwyer 475 electronic Manometer, DP07 | 1” x 0.001” w.c | Check pressure transducers | Yearly | On File | NIST traceable certificate | 8/11/23 |
| APEX MFC, MFC01, 230801 | 20 x 0.001 lpm | Sample Flow | Yearly | On File | NIST | 10/15/2023 |

| | | | | | | |
|---|---|---|---|---|---|---|
| APEX MFC, MFC02, 230802 | 20 x 0.001 lpm | Sample Flow | Yearly | On File | NIST | 10/15/2023 |
| APEX MFC, MFC03, 318226 | 20 x 0.001 lpm | Sample Flow | Yearly | On File | NIST | 2/3/23 |
| APEX MFC, MFC04, 318224 | 20 x 0.001 lpm | Sample Flow | Yearly | On File | NIST | 2/3/23 |
| APEX MFC, MFC05, 318223 | 20 x 0.001 lpm | Sample Flow | Yearly | On File | NIST | 2/3/23 |
| APEX MFC, MFC06, 318225 | 20 x 0.001 lpm | Sample Flow | Yearly | On File | NIST | 2/3/23 |
| Wood weighing scale, SCA01 | 50 x 0.02 lbs. | Direct weighing of wood loads | Daily | Test data sheet | Calibration Weight, CW01 | N/A |
| Stove scale, SCA02 | 1000 x 0.02 lb. | Direct weighing of stove | Daily | Test data sheet | Calibration Weight, CW01 | N/A |
| Stove scale, SCA03 | 1000 x 0.02 lb. | Direct weighing of stove | Daily | Test Data Sheet | Calibration Weight, CW01 | N/A |
| Calibration Weight, CW01, 166599 | 10.00 lb. | Check wood and stove scales | Yearly | On File | ASTM Cl 1 | 7/21/23 |
| Horiba VIA510 CO2/ and CO | 20% x 0.1/ 2% x 0.01 | Stack gas concentration | Each Use | On File | Bottle gasses (EPA Pro) | N/A |
| Delmhorst Moisture meter, MC02 | 30 x 1%, 2% point accuracy | Direct wood Moisture | Daily | Test data sheet | Fixed resistor cal block, MC01 | N/A |
| Fixed resistor cal block, MC01 051722 | 12% and 22% | Check moisture meter | Yearly | On File | NIST | 3/22/23 |
| Data Acquisition TC | Type K TC calibrated at computer | Direct temperature measurements | Check adjust weekly | Cal Log | Omega TC Generator, TC01 | N/A |
| Omega CL3512A simulator, TC01 22000140 | Type K range | Check computer DAQ | Yearly | On File | ANSI/Z540 | 3/8/23 |
| Tape Measure 22215514 | 12' x 1/32" | Wood + firebox dimension | Yearly | On File | ISO, ANSI, Mil | 5/31/23 |
| RH HX80 2218.05, RH01 | | Tunnel RH | Yearly | On File | NIST | 6/28/23 |

| | | | | | | |
|---|---|---|---|---|---|---|
| RH HX80<br>79213, RH02 | | Tunnel RH | Yearly | On File | NIST | 3/15/23 |

## 17.0 Instrument/Equipment Calibration and Frequency

Lists of all project tools, gauges, instruments and other sampling, measuring and test equipment requiring calibration by the IDC test method with the dichot TEOM within a modified dilution tunnel are provided in the documentation for each method provided in EPA's non regulatory docket (https://www.regulations.gov/docket/EPA-HQ-OAR-2016-0130). This documentation also lists the calibration method, equipment and/or standards to be used and requirements for calibration records. Section 9 of the IDC test methods posted in EPA's non-regulatory docket provides the required calibration and standardizations.

Likewise, the SOP for the 1405-D TEOM in the dilution tunnel ("NYSERDA Standard Operation Procedures for Thermo Scientific 1405-D TEOM™ for use in a dilution tunnel" available at https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0022) plus the manufacturer Thermo Fisher Scientific's User Guide for the 1405-D TEOM (https://www.Thermo Fisher.com/order/catalog/product/TEOM1405D#/TEOM1405D) provide calibration instructions for the dichot TEOM to be used for the testing under this TO. The IDC requires that all calibration results be recorded and provided in Appendices to the reports containing the summary of the testing results and discussion. Finally, the list of all instruments/ equipment requiring calibration for the supplemental sampling of PM using ASTM E2515 filter pulls is provided within the documentation for the method (https://www.astm.org/Standards/E2515.htm).

Hearthlab Solutions has provided documentation of equipment and instrumentation calibration. After a thorough review of the IDC test method's documentation, the dichot TEOM's SOP and documentation, and familiarity with the ASTM E2515 method, Hearthlab Solutions provided lists of equipment to be calibrated, the calibration requirements and frequency, and descriptions of how calibration records will be maintained and traceable to the instrument/equipment. This equipment and instrumentation calibration log is provided in Table 7.

*Table 7. Hearthlab Solutions Equipment and Instrumentation Calibration Log*

| Equipment/ Instrument | Maintenance Activity | Testing Activity | Inspection Activity | Responsible Person | Inspection Frequency | Acceptance Criteria | Corrective Action | SOP |
|---|---|---|---|---|---|---|---|---|
| Gas Analyzer ($CO/CO_2/O_2$) | | Pre & Post Test Calibration | Visual | M. Champion | Pre & Post | CSA B415.1-10 | N/A | Per Ops Manual |
| Digital Flow Meter | | Pre & Post Test Calibration | Visual | M. Champion | As needed | | | Per Ops Manual |
| Dew Point/RH Transmitter | | Pre & Post Test | Visual | M. Champion | As needed | | | Per Ops Manual |
| Floor Scales | | Verified | Cal. Weight | M. Champion | Before use | Per IDC | | Per Ops Manual |
| Thermo Fisher TEOM | | Pre & Post Test Calibration | Flow and leak checks | M. Champion | Before use | Per IDC | | Per TEOM SOP |
| Thermo Fisher TEOM | | Pre & Post Test Calibration | Flow and leak checks | M. Champion | Before use | Per IDC | | Per TEOM SOP |
| Thermo Fisher TEOM | | Pre & Post Test Calibration | Flow and leak checks | M. Champion | Before use | Per IDC | | Per TEOM SOP |
| Dilution Tunnel A | Clean before each series | | | M. Champion | Before use | ASTM 2515 | | ASTM E2515 |
| Dilution Tunnel B | Clean before each series | | | M. Champion | Before use | ASTM 2515 | | ASTM E2515 |
| Delmhorst G-30 Moisture Meter | | Pre Test | Visual | M. Champion | Before use | | | Per Ops Manual |

## 18.0 Inspection/Acceptance of Supplies and Consumables

Certain critical supplies and consumables will be used for testing performed under this TO, based on the IDC documentation and TEOM SOP. Quality assurance includes the inspection and evaluation of these for fitness of use during the study. A list of these supplies and consumables for testing by the contracted east coast lab Hearthlab Solutions, their inspection specifications, acceptance criteria and other QC checks are documented as indicated in the log shown in Table **8**.

Certain supplies and consumables are used for this work. Quality assurance includes the inspection and evaluation of these for fitness of use during the study. A list of these and their quality criterial are as follows:

Test Fuel – Wood species, wood moisture and dimensions are variables examined in this study. Upon receipt, sourced wood will be inspected for proper dimensions, consistency and quality (rot, large splits, excessive or irregular knots will be rejected). Fuel will be sorted for species and then managed with the use of air drying or humidity controlled conditions until the desired wood qualities are met.

Calcium carbonate indicating desiccant – Unused desiccant is blue in color and changes to purple, then pink with use. The material may be dried for reuse however with time the indicating nature diminishes. Upon drying, should the indicative property of the desiccant be inadequate, fresh material will be mixed to regain proper indication. Eventually, the material must be discarded. This will be managed on a rolling basis and as needed.

Filter Media – Filter media is inspected on receipt for proper size and material specifications. The material for use in this study is Pall Emfab PTFE coated glass fiber. These filters have a nominal tare weight of 80mg. Deviation from this weight in pre-test preparation may indicate an inconsistency and if encountered, this will be noted and investigated.

*Table 8. Inspection/Acceptance Testing Requirements for Consumables and Supplies*

| Part | Manufacturer | P/N | Location – Handling Storage Condition | Serial # | Inspection /Acceptance Criteria | Test Method | Frequency | Responsible Individual | Calibration Service |
|---|---|---|---|---|---|---|---|---|---|
| Filters (Emfab) | Pall | TX40HI20WW 7221 | Test Lab, Gravimetric Analysis Lab | NA | Dry, not torn | N/A | As Received | M. Champion | N/A |
| Fuel – Pellet | American Wood Fibers | NA | Test Lab | Insert lot # when arrives | Visual, send sample for fuel analysis | IDC Test Method Criteria | Before Test | M. Champion | N/A |
| Fuel – cordwood | Maple and birch | NA | Test Lab | NA | Visual, species correct per order. Visual meets IDC requirements for cordwood. Free of decay, fungus, or contaminants. | IDC Test Method Criteria | Continuously monitored for moisture content | M. Champion | Store indoors, location dependent on moisture content. |
| Calibration Gases, CO, CO2, Zero | Airgas | various, dependent on test subject, will list in report | Test Lab | various will list in report | EPA Protocol Gas program through Airgas | EPA Protocol Gas program through Airgas | EPA Protocol Gas program through Airgas | EPA Protocol Gas program through Airgas | EPA Protocol Gas program through Airgas |
| 2 small non-catalytic stoves | (HHT Quadra-fire®) | | | | Visual inspection No damage to unit. Unit can operate as intended | Visual | Upon receipt and before each test run | M. Champion | Store Indoors |
| 2 medium catalytic hybrid stoves | Hearthstone Castleton® | | | | Visual inspection No damage to unit. Unit can operate as intended | Visual | Upon receipt and before each test run | M. Champion | Store Indoors |
| 2 large catalytic hybrid stoves | Regency Pro-Series F3500® | | | | Visual inspection No damage to unit. Unit can operate as intended | Visual | Upon receipt and before each test run | M. Champion | Store Indoors |

# 19.0 Non-direct Measurements

The testing to be performed under this project involves non-direct measurements. As such, there are no data acquisition requirements for non-direct measurements. However, non-direct measurements may be submitted to EPA as secondary data during the course of this project that are intended to be informative to the testing being conducted as part of this research. These include data analyses, documentation, observations, and recommendations submitted by stakeholders resulting from testing performed by researchers, institutions, or state government agencies. The acceptance criteria that will be used to judge the suitability of this submitted data for consideration in development of a cordwood test method (and how this data would be used) is discussed further in Section 23 of this QAPP.

Some data gathering will be included in this work which is not a direct measurement or quantity directly related to calculations or inputs to final results. Additionally, reference materials considered generally informative may also be included. These data and reference materials are given below:

Wood Species Tables – Wood species is one variable in this study. In order to inform decisions on experimental design, published tables detailing density, volatile content and/or geographical extent of different species may be referenced and included in the final reporting. The limitations and utility of these data will be determined based on the source of information.

Moisture Meter Correction Factors – Electronic moisture meters have slight variation in output dependent on the species of wood being measured. For this study, correction factors from the meter manufacturer will be relied upon. Note that moisture meter accuracy is about 2 percentage points even though precision is indicated at 0.1 percent in the case of modern electronic meters. Species correction factors are on the order of about 1% (positive or negative) in the range of moisture anticipated for this study. The inaccuracy in relying on published corrections is considered acceptable.

Ambient Pressure - Barometric pressure, while apparently necessary in some calculations, only relates to correction of dilution tunnel and sample flow standardization. The factor cancels out in the final analysis. Therefore, barometric pressure is extraneous data in this case and may only be related to stove performance. National weather service local barometric (“Station”, not sea level) pressure will be noted daily, for informational purposes only.

# 20.0 Data Management

The data management system used by the contracted laboratory will conform to the requirements stated in the IDC test method with the dichot TEOM within a modified dilution tunnel, which are provided in the documentation for each method provided in EPA's non regulatory docket at https://www.regulations.gov/docket/EPA-HQ-OAR-2016-0130. As indicated in the IDC method (https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0020), all data will be collected and recorded at intervals of no more than 1 minute and TEOM data will be averaged up to 1-minute intervals for reporting. Data will be reported in an Excel or compatible spreadsheet following the minimum data reporting requirements in the IDC test method. In addition to the TEOM SOP documentation (https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0022), an Excel spreadsheet template is provided (https://www.regulations.gov/document/EPA-HQ-OAR-2016-0130-0021) with incorporated formulas to calculate the required data from the raw TEOM measurements. Finally, data will be collected and reported for the supplemental sampling of PM using ASTM E2515 filter pulls in accordance with the documentation for the method (https://www.astm.org/Standards/E2515.htm). Hearthlab Solutions has many years of experience running, collecting and managing data in accordance with ASTM E2515, IDC, and TEOM protocols. As part of their work, Hearthlab Solutions has developed a results template for reporting of pertinent ASTM E2515 data.

All electronic files, including raw instrument data, will be submitted as part of the test report. The primary data to be obtained from each test run include: tunnel flow (standardized volumetric flow, tunnel relative humidity, PM in a variety of calculated units (in grams per hour [g/hr], grams per kilogram of dry fuel [g/kg], and pounds per million Btu [lb./mmBtu] output); the average PM emission rates (g/hr) for the full run and for each phase of the runs as prescribed in the IDC; a plot of PM emission rate (g/hr) vs. time based on 1-minute averages; and the maximum 1-minute, 5-minute, and 60-minute PM emission rate (g/hr) on a rolling basis. PM results will be collected and tabulated by IDC load/burn phase and cumulatively, and will include the PM emissions in grams, g/hr, g/kg of dry wood, grams/megajoule (g/MJ) output, and lb./mmBtu output.

Flue gas composition will also be continuously monitored using non-dispersive infrared analyzers, as outlined in the IDC method, to measure and record CO and $CO_2$ concentrations. In addition to these measured concentrations, other exhaust products including $H_2O$, $O_2$ and $N_2$ will be calculated and recorded to determine efficiency based on fuel properties (including carbon, hydrogen, oxygen, and moisture content of dry fuel) and molar coefficients converted to mass of flue products per kilogram dry fuel. Finally, ASTM E2515 data will be measured and recorded for sample train A and sample train B including total volume, flow rate and elapsed test time; total PM catch (mg); PM concentration (g/dry standard cubic feet); total PM (g); PM emission rate (g/hr); and emissions factor (g/kg). Note: the first hour filter pull will not be collected as part of this supplemental sampling using ASTM E2515.

Hearthlab Solutions has established and maintained procedures to control all documents and data that relate to its certification functions and that form part of its management system (internally generated or from external sources), such as regulations, standards, or other normative documents, test methods, as well as drawings, software, specifications, instructions, and manuals. Hearthlab Solutions has Quality System documents that include the Hearthlab Solutions forms, Hearthlab Solutions work instructions and other supporting Hearthlab Solutions documents, and documents of external origin (such as this QAPP).

In addition to following their standard QA/QC procedures for managing data generated in testing of residential wood heating appliances, Hearthlab Solutions designed and implemented a project-specific data management system for this project. The NESCAUM project manager will determine if it is feasible to use the same or similar data sheets as EPA's contractor used. If not, Hearthlab Solutions will use IDC, TEOM, and ASTM 2515 spreadsheets used in previous research work.

Hearthlab Solutions and NESCAUM created embedded formulas that underwent full QA/QC review for accuracy and, in the case of spreadsheets for ASTM E2515 data, contain self-checking functions that automatically flag values that are out of spec. All data, documents, and spreadsheets are maintained as password-protected, only accessible by authorized persons. These laboratory-specific data management tools will be provided to EPA in the spreadsheet workbooks containing the IDC-TEOM results and the ASTM E2515 filter results.

Data generation for this project occurs entirely at the laboratory in Bethel, VT operated by Hearthlab Solutions. In this laboratory, a combination of hand recorded parameters and computer data acquisition are used to produce final results. These data are ultimately combined into a single database generated by Hearthlab Solutions' proprietary software "HearthLab – 5g".

The laboratory automation software collects and stores run-time data during a test. Stove, laboratory and dilution tunnel temperatures are logged as well as stack gas concentrations, stove scale weight and tunnel flow. Data is logged at one minute intervals to a Microsoft Access database file having a filename unique to the run number (e.g. "RTDVig1609221") which is automatically generated at the beginning of a test and consists of a combination of stove designation, date and the run number for that day. Run numbers are always unique when generated by the software.

During a test, rolling averages of dilution tunnel flow, stack gas concentrations and gas meter temperatures are made. These averages are used in post-test calculations of PM emissions, average air-to-fuel ratio and CO emissions factors. A second database file is created automatically which stores these end-test results in combination with several manually entered data. Wood weight and moisture content, sample volumes (for two sample trains) and filter tare and final weights are the only data entered manually; all other necessary data are automatically logged and averaged as needed. Test run notes are also recorded directly in a text box field and stored in the data base. Post-test changes to the results file are possible, as corrections to manually entered data or notes may need updating until final results and quality checks are complete.

Once sample processing is complete (final desiccated probe and filter weights are known), the laboratory database is updated. At this time, a quality check of all manually entered data is made to ensure no transcription errors took place. Corrections are made as required and the notes associated within the data file are amended to “Final PM Results”. The real-time data (RTD) file and the results file are always linked through the *HearthLab – 5g* software. This allows reporting, review and analysis, which includes test results as well as all run-time data.

Without the proprietary software, several additional steps will be required to report and make use of the data generated. Procedurally, the master copy of the data will be kept in the Bethel, VT laboratory computer. Both the master results database and the real-time data are copied to a thumb drive.

At test completion or when the results database is updated on the laboratory computer, the thumb drive mirror image is updated. This is kept in the possession of Mr. Champion at all times. Reporting of final results in electronic format requires the database to be converted into an Excel spreadsheet format. Microsoft Access database files are exported as Excel files in the Hearthlab Solutions office and consolidated into a single spreadsheet for transmission to the Basecamp website.

Copies of the emissions results databases are kept in three places: the laboratory computer, a designated thumb drive and the Hearthlab office computer. The consolidated spreadsheet is transmitted to Basecamp at approximately weekly intervals and two copies are kept by Hearthlab Solutions; one on the thumb drive and one on the office computer. The office computer is considered the master (most current) copy of the consolidated data spreadsheet.

## 21.0 Assessments and Response Actions

Hearthlab Solutions shall address data quality from a quality assurance and quality control basis as discussed in previous sections of this QAPP.

As part of the NYSERDA supported research effort, NESCAUM will assess the overall project activities on an ongoing basis and at specific junctures to ensure that the QAPP is being implemented as approved, and that the project is proceeding as expected. Specifically, Ms. Rector, the NESCAUM project manager, Mr. Allen, NESCAUM Chief Scientist, and Dr. Nora Traviss, Senior Scientist, are responsible for producing all deliverables and for ensuring that quality procedures are implemented. They will discuss any concerns about quality with their respective QAMs to identify and resolve problems or implement response actions, if needed. The Project Manager (or an approved designee) is responsible for overseeing the work performed by technical staff and providing assurance that all required QA/QC procedures are being implemented.

The assessments regularly scheduled under this research plan, including their frequency and the person responsible for ensuring the assessment occurs are listed in Table 6, 7, an 8. As noted above, the NESCAUM Project Manager will implement any necessary response actions, in consult with their QAMS and with the management and QA personnel of the contracted lab. NESCAUM's Project Manager will report immediately all assessments and response actions to the NYSERDA Project Manager.

*Table 9. Scheduled Assessments*

| Assessment Type under each Task | Frequency | Type of Review and Responsible Person/Title/Affiliation |
|---|---|---|
| **Project Management** | | |
| Monthly progress reports, Financial Tracking | 15th day of each month | 1. NESCAUM Program Manager review<br>2. NESCAUM Financial Manager review<br>3. NESCAUM Executive Director review<br>4. NESCAUM Program Manager reviews costs in monthly report |
| **Quality Assurance** | | |
| Draft QAPP (initial version) | Before any EDO | 1. Technical review by NYSERDA Project Manager and EPA Measurement Group<br>2. Quality Assurance Manager review<br>3. Chief Scientist review |
| Final QAPP (initial version) | One week after receipt of comments | |
| Review/update QAPP | semi-annually | 1. Technical review by NYSERDA Project Manager and EPA Measurement Group<br>2. Quality Assurance Manager review<br>3. Chief Scientist review |
| Final QAPP (updated versions) | One week after receipt of comments | |
| **Conduct Hydronic Heater Validation Testing for Cordwood and Pellet Appliances** | | |
| Description of testing and TEOM results, CO, CO2, O2 | Within 15 days of completion of each test | 1. Laboratory review<br>2. NESCAUM Chief Scientist review<br>3. NESCAUM Project Manager review |
| Results – ASTM E2515 Filter results | Within 30 days of completion of each test | 4. Laboratory review<br>5. NESCAUM Chief Scientist review<br>6. NESCAUM Project Manager review |
| **Document Test Results for Hydronic Heater Validation Testing for Cordwood and Pellet Appliances Cordwood Validation Testing** | | |
| Draft technical report(s) | As specified via technical direction | 1. NESCAUM internal review – Chief Scientist, Project Manager, Executive Director<br>2. NYSERDA Project Manager review |
| Draft technical report(s) | Within 30 days of receiving comments | |

## 22.0 Reports to Management

As depicted in Figure 1 of Section 5 of this QAPP, Hearthlab Solutions (east coast lab #1) reports to the NESCAUM project manager, who reports to the NYSERDA Project Manager. After completing full review processes, the NYSERDA Project Manager will make the determination on when and how to provide data to EPA. All reports to management will follow this hierarchy and will receive QA review at each level. The types of reports to management are shown above in Table 9 of Section 21, including the timing/frequency of each. The data reporting, summaries, and discussions at the heart of this project include the testing results prepared by the contracted lab. The content required in these reports is specified in detail in the IDC test method.

Hearthlab Solutions will provide all documentation required by the IDC method and the NESCAUM Project Team will review this documentation prior to submission to the NYSERDA Project Manager. The goal for providing a description of all testing and results will be to provide this information to the NESCAUM Project Manager within 15 days of completion of each test. (Note: Because the TEOM provides real time measurements, preliminary TEOM data will be available shortly after each test is completed. However, this data will need to be quality reviewed. Also, it will take longer to complete sample recovery, data analysis, and quality review data from the ASTM E2515 train.) The final technical reports will be prepared as, and when, specified via technical direction from the NYSERDA Project Manager, per the contract between NESCAUM and NYSERDA.

# 23.0 Data Review, Verification, and Validation

Data review and verification of the results generated by the testing under this research effort will initially be performed by qualified staff at the contracted laboratory - Hearthlab Solutions. The lab will examine all data generated to ensure the values have been recorded, transmitted and processed correctly. Such an examination entails checking for errors in data entry, transcription, calculation, reduction and transformation errors. These checks are less necessary for data automatically and continuously generated, as is the case for the TEOM data. For automatic data generation, the lab will ensure there were no programming errors or spreadsheet formula corruptions. The contracted lab and NESCAUM's Chief Scientist will also verify that the generated data – from the TEOM's automated outputs (for PM) and from the gas analyzers (for CO and $CO_2$) – is complete, correct and conforms with the requirements set forth in the IDC method and the TEOM SOP. As noted previously, spreadsheets created for ASTM E2515 data by Hearthlab Solutions have undergone rigorous QA/QC reviews, are self-checking, and will identify when a calculated value is out of spec.

Next, the NESCAUM Project Team will be responsible for the first data validation review, with a focus on the goals of the testing performed under EPA's test plan, as stated above in Section 8.3 of this QAPP. NESCAUM's Project Manager will note and report any potentially unaccepted departures from this QAPP to the NYSERDA Project Manager. Ultimately, the NYSERDA Project Manager will determine if this information is provided to EPA. At that time EPA staff experts in laboratory testing and EPA method development will evaluate the data generated to validate its appropriateness for use in a method precision analysis according to ASTM E691-20 to support the proposal and promulgation of a new TEOM-based PM measurement method as well as five new IDC operating protocols as FRMs. As directed by the NYSERDA or NESCAUM Project Manager, technical staff may consult with EPA, as appropriate, as part of the data review, verification and validation process.

## 24.0 Verification and Validation Methods

The testing program under the NYSERDA supported project is designed to verify whether the IDC-TEOM methodology is repeatable within a laboratory and reproducible across different laboratories. As such, the testing program is designed to meet the requirements of a method precision analysis according to ASTM E691-20, in this case to assess the precision of measuring PM2.5 with a dichot TEOM from residential wood heating appliances while operated under the IDC protocol. ASTM E691-20 provides the statistical techniques that allow for formulating the precision of a test method based on an interlaboratory study. Ruggedness testing will also be performed.

As noted in ASTM E691-20's documentation, "this practice does not concern itself with the development of test methods but rather with gathering the information needed for a test method precision statement after the development stage has been successfully completed. The data obtained in the interlaboratory study may indicate, however, that further effort is needed to improve the test method".[10] Ruggedness testing complements the precision analysis and is generally conducted in the laboratory or the field to determine the sensitivity of a method to parameters such as analyte concentration, sample collection rate, interferent concentration, collection medium temperature, and sample recovery temperature.

As previously described, under this test program, multiple paired rounds of (replicate) testing of the IDC fueling and operation protocol with sampling and analysis by the dichot TEOM PM measurement method will be conducted, to meet the requirements of method precision analysis according to ASTM E691-20, and to inform the development of a cordwood FRM.[9] The goal of the replicate side-by-side stove testing on identical appliance models is to determine repeatability and intra-lab variability, and thereby potentially verify the test method within the laboratory setting. Another goal is that identical fueling, operation, and analytical methods be used by both laboratories participating in this research study – in the contracted EPA-certified lab on the west coast (using west coast cordwood), as well as in the lab on the east coast (this QAPP) performing parallel testing (with east coast cordwood). Using identical methods in both labs will allow for a measure of the reproducibility across labs and ensures that overall precision, variability, potential bias and detectability will be similar, thereby potentially verifying the test method across different labs.

Generally, data generated by the test program will be reviewed for completeness, representativeness, and accuracy. The IDC protocol utilizes a TEOM to provide real time PM

[9] Quoted from the Scope of ASTM E691-*20 Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method,* updated on March 8, 2021, and available for purchase from ASTM at https://www.astm.org/e0691-20.html.

measurements. Consequently, data will be available to the NESCAUM project team for review on a regular continuing basis as the testing program progresses. A data housing platform will be developed to receive data as it becomes available, that can be accessed by the project team, and provide for graphical and summary presentation of data.

All final products documenting results will be examined to ensure the data is correctly and clearly displayed in tables and figures. In addition, all data sets, tables, and figures will be reviewed for apparent outlier values, which will be examined to determine whether these are indeed true values, the result of data entry errors, or have some other explanation. These outliers will be discussed in the final report, as they may indicate either data errors or extraordinary circumstances. Discussion will draw upon the thorough documentation requirements in the IDC test method itself, including for example, photographic and video footage of every burn phase of every test run, showing appliance settings, fuel charge placement, changes in appliance settings, and coal-bed and fire conditions. Discussion will also draw upon the continuous (1-minute) TEOM data.

The project team will also examine the uncertainties of any data submitted by stakeholders to verify that all data is of sufficient quality to adhere to the criteria outlined in this QAPP.
In addition to an evaluation of data quality, the project team will seek to identify data sources, assumptions made, changes or modifications to data, and calculations used to develop the draft and final formulations of the data analysis presented in the reports. In cases where a submission includes primarily data summaries, the project team will review the raw data on which the report is based for verification and independent analysis.

All data validation and verification will be sufficiently detailed and transparent, as approved by the NYSERDA Project Manager.

## 25.0 Reconciliation with User Requirements

As noted in Section 23, NESCAUM's Project Manager, with input from the NESCAUM's Project Team and contractors will ultimately evaluate the data generated under this research project. The data will be supplied to the NYSERDA Project Manager who will determine if the data is provided to EPA. EPA, in turn, will determine the data's appropriateness to support the proposal and promulgation of a new PM measurement method as well as new IDC operating protocols as FRMs (for wood stoves burning cordwood and pellets, hydronic heaters burning cordwood and pellets, and forced-air furnaces, respectively, under future testing phases).

The primary user requirement is that the test program be conducted to meet the requirements of a method precision analysis according to ASTM E691-20. As testing progresses data will be reported and evaluated by the project team on a regular basis, with real time PM measurements available from the dichot TEOM used in the IDC protocol. This will allow any anomalies to be identified and investigated quickly, and any adjustments made to meet user requirements.

Generally, the quality measures will be reported in all project deliverables, which will allow the EPA's project technical team and later data users to determine if the data are of sufficient quality for other uses. As more specific data acceptance criteria are established during the test program, the EPA's technical team will work in conjunction with QA staff to determine to what extent (if any) the data that do not meet the specified data acceptance criteria may be used to support further study and how this determination will be documented.

## 26.0 QAPP Reviews and Revisions

The NESCAUM Project Manager, with the assistance of the QAMs, will review this QAPP at least annually to determine if the provisions are current and relevant to ongoing contract activities. This review will be documented, and the records associated with the review will be kept in the contract's electronic files. If the review results in the identification of required revisions, the revisions will be conducted by the NESCAUM Project Manager or a qualified designee, and a record of the changes made will be kept in the electronic contract files. The revision history of the QAPP will be noted in Section 27 of this document. The approval process and signatures will follow those used for the original issue of the QAPP. The approved revised QAPP will replace the previous version as the QAPP in-force, and an e-mail notification of the revision will be sent to all staff listed in the Distribution List in Section 3.

## 27.0 Hearthlab Solutions QAPP Revision History

| Version No. | Description | Author(s) | Date |
|---|---|---|---|
| 1 | Original Version | Graham Fitzsimmons, Jill Mozier, Lisa Rector, Mark Champion | November 18, 2022 |
| 2 | | | |
| 3 | | | |

# Annex A

| Assessment Type under each Task | Frequency | Type of Review and Responsible Person/Title/Affiliation |
|---|---|---|
| **Project Management** | | |
| Monthly progress reports, Financial Tracking | 15th day of each month | 5. NESCAUM Program Manager review<br>6. NESCAUM Financial Manager review<br>7. NESCAUM Executive Director review<br>8. NESCAUM Program Manager reviews costs in monthly report |
| **Quality Assurance** | | |
| Draft QAPP (initial version) | Before any EDO | 4. Technical review by NYSERDA Project Manager and EPA Measurement Group<br>5. Quality Assurance Manager review<br>6. Chief Scientist review |
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| Description of testing and TEOM results, CO, CO2, O2 | Within 15 days of completion of each test | 7. Laboratory review<br>8. NESCAUM Chief Scientist review<br>9. NESCAUM Project Manager review |
| Results – ASTM E2515 Filter results | Within 30 days of completion of each test | 10. Laboratory review<br>11. NESCAUM Chief Scientist review<br>12. NESCAUM Project Manager review |
| **Document Test Results for Hydronic Heater Validation Testing for Cordwood and Pellet Appliances Cordwood Validation Testing** | | |
| Draft technical report(s) | As specified via technical direction | 3. NESCAUM internal review – Chief Scientist, Project Manager, Executive Director<br>4. NYSERDA Project Manager review |
| Draft technical report(s) | Within 30 days of receiving comments | |

# Annex B – Mixing memo

TO: Ellen Burkhard, NYSERDA

FROM: Lisa Rector and George Allen, NESCAUM

RE: Dilution tunnel mixing tests at HLS

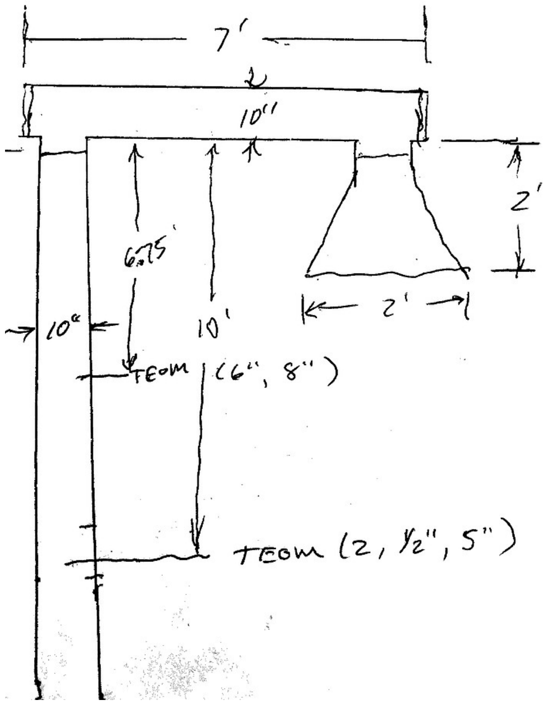
DATE: September 16, 2022

In May 2022, NESCAUM completed a series of tests at Hearthlab Solutions (HLS) in Bethel VT to evaluate dilution tunnel particulate matter (PM) mixing as part of their quality assurance measures for the EPA East Coast acceptance testing of the Integrated Duty Cycle (IDC) protocols. HLS completed the testing using a new 10" dilution tunnel. As shown in Figure 2, the new dilution tunnel is 10 inches in diameter for the entire tunnel and uses a 7-foot mixing section with two tees on each end. Tees have horizontal closed-off ends for easy cleaning. The distance from the centerline of the mixing section to the PM sample port location is 10 feet. This dilution tunnel configuration is similar to the tunnel at the PFS-TECO lab, which conducts West Coast acceptance testing of IDC protocols, but not exactly the same. Key differences between the two labs are the length of the mixing section, diameter, and the orientation of the tee blind ends. At HLS, the mixing section is 7 feet, while at PFS-TECO, the mixing section is 4 feet in length. At HLS, the blind ends of both tees point out, and at PFS both blind ends point up. The HLS tunnel diameter is 10", and at PFS it is 12".

*Figure 1. HLS 10" Dilution Tunnel used for mixing tests.*

A drawing showing tunnel dimensions and the TEOM sampling locations for tunnel mixing tests is shown in Figure 2. The total verticle run of 10" tunnel is 12 ft. from the bottom of the second tee to the change from 10 to 12" at the exhaust.

*Figure 2. HLS tunnel diagram with TEOM sampling locations for mixing assessment.*




## Testing Overview

HLS used Stove 26, a non-catalytic Step-2 stove with a 2.5 cubic foot firebox for this research. Testing used a modified IDC protocol. The IDC protocol was revised to eliminate periods of low PM emissions, which are not informative for mixing assessment. Test runs using the modified IDC cordwood stove protocol took approximately six hours to complete. HLS completed the three runs required by the research plan on May 11, 12, and 13, 2022. Nominal tunnel flow was 550 cubic feet per minute (cfm). HLS measured tunnel PM with a pair of dichot TEOMs at four sample locations.

**TEOM Probe locations**

The "upper" TEOM was s/n 24764, 6.75 ft. below the tee, and sampled 6 and 8" into the tunnel from the right, as shown in Figure 2. This is 4 and 2 inches from the tunnel wall, or 1 and 3 inches from the center of the tunnel, and is closer to the tee than the normal sampling location. The "lower" TEOM was s/n 24854, 10 ft. below the tee and sampled ½ inch into the tunnel on the right side and also at the tunnel centerline (5" from the wall).

## Testing Results

The spread of run-average PM concentration across the four TEOM channels was 4, 13, and 5% for the three runs. The spread was driven by the "upper" TEOM closer to the mixing tunnel, specifically the location 2" from the tunnel wall, 5" from the center of the tunnel, Channel D in Table 1 and the green line in the plots below. This location may not be representative of tunnel mixing further down where normal samples are collected, and is thus not of great concern for assessing proper mixing for this tunnel.

Table 1 shows the run-average PM concentration for each test day for the four TEOM channels. Data after the burn cleaned up and TEOM data went negative are excluded. These concentration values at 550 cfm are slightly higher than the g/h values (at 589 cfm they would be the same). Channels A and B are the "lower" TEOM at the normal sampling elevation, with A at ½ " into the tunnel and B at the tunnel center line. Channels C and D are the "upper" TEOM, with C at 4" and D at 2" from the tunnel wall.

*Table 1. Run average tunnel PM concentrations (mg/m3) by run and Teom channel, K0 corrected..*

| Run # | Date | Channel A | Channel B | Channel C | Channel D |
|---|---|---|---|---|---|
| 1 | 5/11/2022 | 31.68 | 32.99 | 32.47 | 32.83 |
| 2 | 5/12/2022 | 36.86 | 37.15 | 37.63 | 41.64 |
| 3 | 5/13/2022 | 38.57 | 40.04 | 38.45 | 40.29 |

Figures 3, 4, and 5 provide a visual overview of the four-channel TEOM performance for all three test runs. The 5-minute running averages of 1-minute data are shown.

*Figure 3. May 11 first mixing run.*

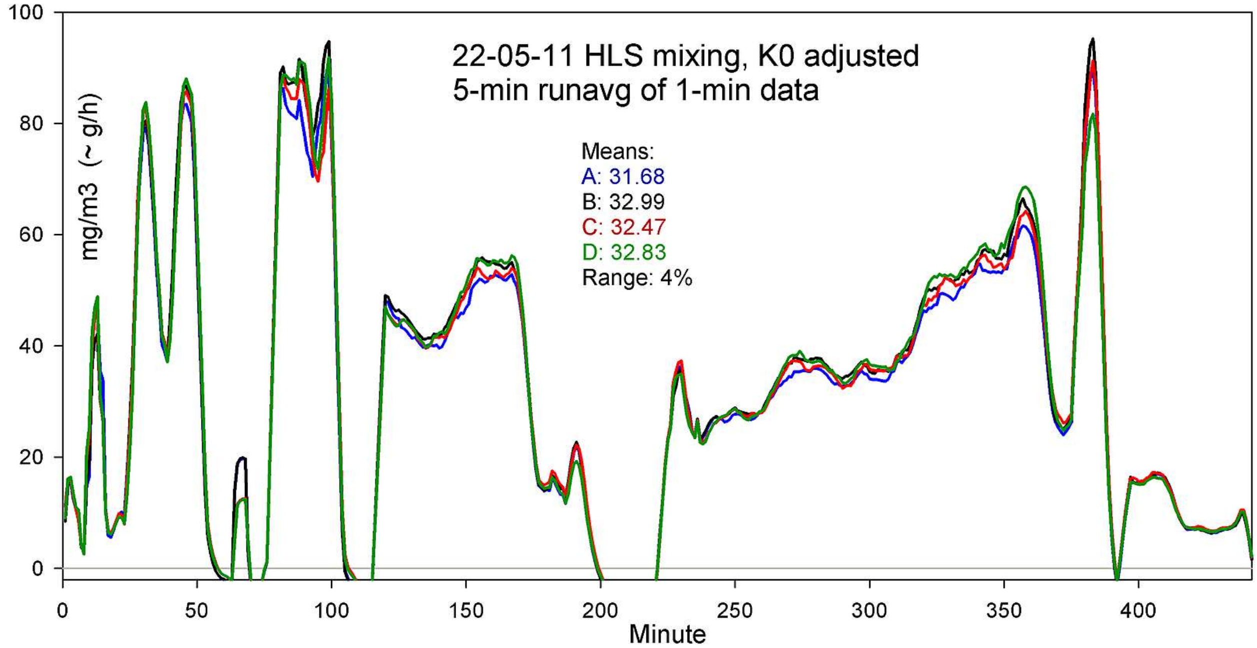



*Figure 4. May 12, second mixing run.*

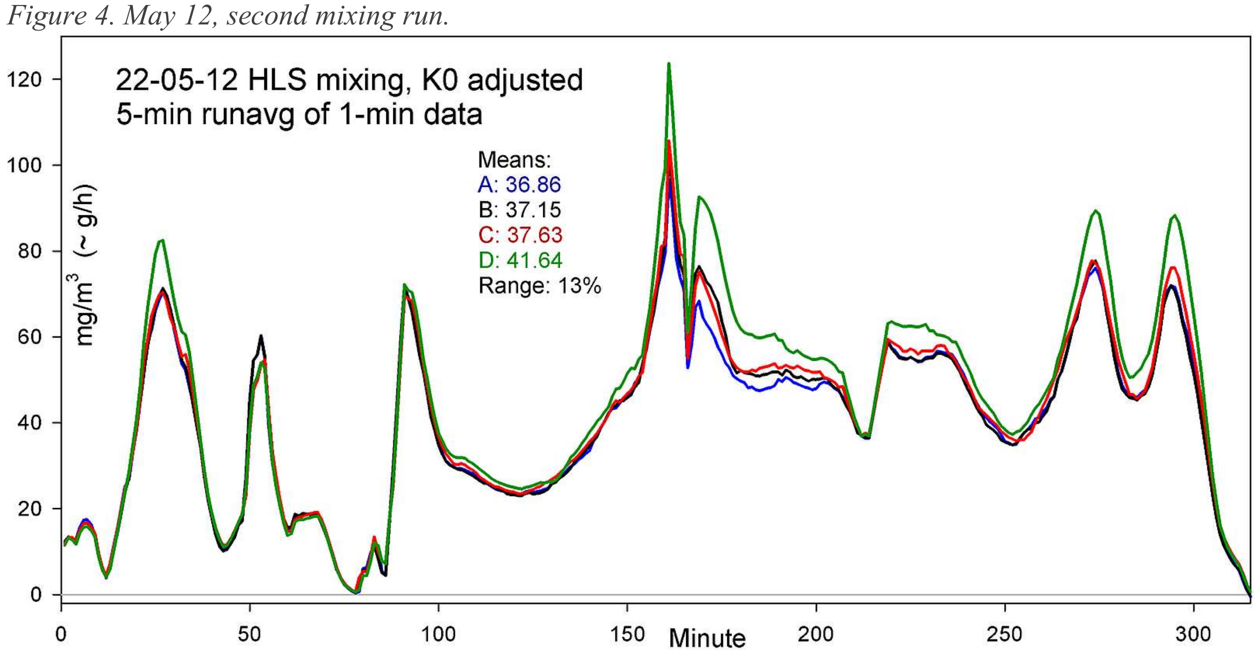
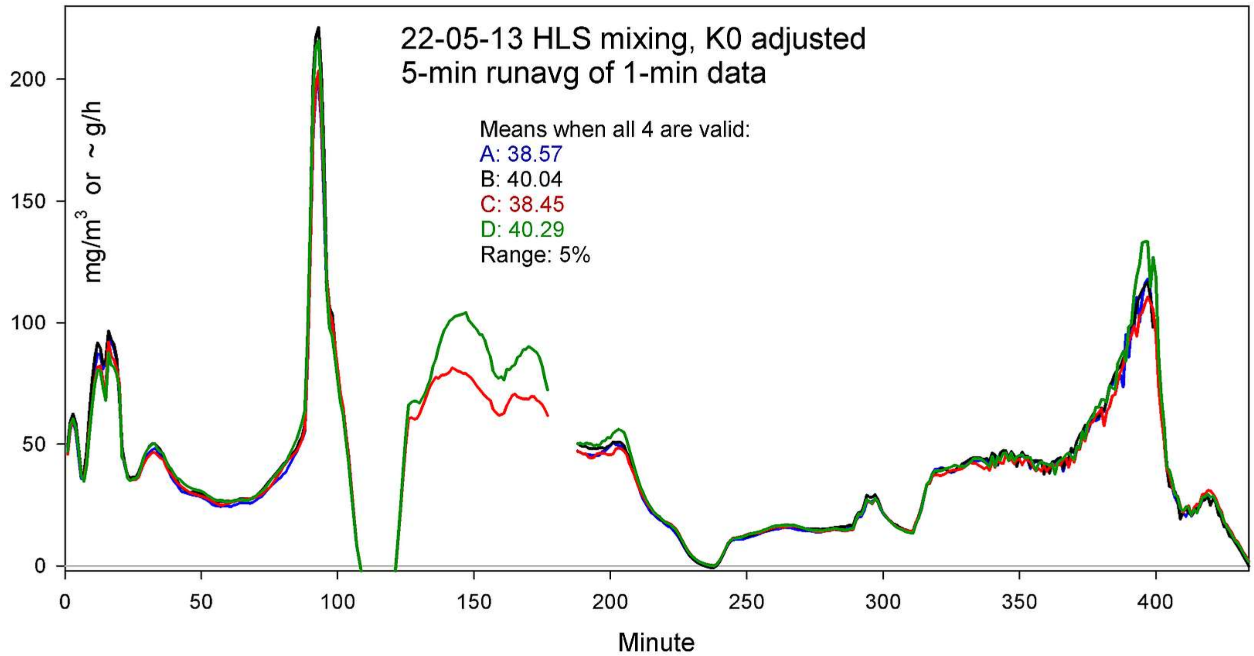



*Figure 5. May 13, third mixing run.*




In addition to these tests, we have data from a 2-channel TEOM sampling at the normal location for nine test runs on three different stoves in July and August 2022. The run-average difference between the two Teom channels in % are as follows: 1.0, 0.1, 0.3, 2.0, 2.3, 0.2, 5.3, 1.8, 2.6. All but one run is less than 3%, indicating good mixing. For the purpose of these tests, good mixing is defined as consistently meeting the 7.5% run average difference limit.

## CONCLUSION

The new HLS 10” tunnel appears to be reasonably well mixed, and adequate for its intended purpose for this research.