UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

OFFICE OF
AIR QUALITY PLANNING
AND STANDARDS

Ms. Alice Edwards
Director Air Quality Division
State of Alaska
Department of Environmental Conservation
P.O. Box111800
Juneau, Alaska 99811-1800

04/09/2021

Dear Ms. Edwards,

I am writing in response to your letter dated December 30, 2020, requesting that the Environmental Protection Agency approve for use an alternative test method (ATM) for demonstrating compliance with New Source Performance Standard (NSPS) Subpart AAA, Standards of Performance for New Residential Wood Heaters. Specifically, the State of Alaska Department of Environmental Conservation (DEC) is requesting the use of an ATM to determine compliance for cordwood fueled wood heaters under 40 CFR 60 Section 60.534. **This approval letter supersedes the version approved on March 31st, 2021.**

You state that ADEC has recently reviewed wood heater certification test reports that used Alternate Test Method 125/127 which leverage ASTM E-3053 and that this review has raised serious concerns about certain aspects of the test method. Given your concerns regarding ASTM 3053 and the importance of having and advancing cordwood test methods for certifying wood heaters under the NSPS, you have requested an additional cordwood certification test method option. You state that this will allow additional data collection using another cordwood test that will be beneficial to EPA and state agencies actively engaged in managing wood heat emissions. You are requesting approval for use of the 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 (IDC) developed by NESCAUM, as you feel this approach provides a determination of compliance at an equal or greater stringency as EPA Method 28R; the test method specified under 40 CFR 60 Section 60.534. A detailed IDC test protocol has been attached to this request, and a summary is provided below.

You state that the proposed ATM IDC test protocol for cordwood devices assesses appliance efficiency and emissions during start-up and during transition from various heat output loads that ensures emissions and efficiency values are reflective of typical operations. Cold start measurements are required in this ATM and gravimetric analysis of filters collected using ASTM E-2515 are the basis for compliance determination. Additionally, this ATM enhances appliance assessment by requiring three replicate runs of the integrated protocol, which will allow assessment of appliance performance variability against the current emission standard.

You state that providing this alternative approach for certification of wood heaters under the NSPS, the approval of this ATM would be beneficial to Alaska's regulatory program for new wood heater emission standards within the Fairbanks North Star Borough Serious Fine Particulate Matter Nonattainment Area. Alaska regulations, 18 AAC 50.077, allow the state to accept test results from an ATM if approved by EPA and the Department. Alaska regulations also include a TEOM measured 1-hr standard. By approving the IDC as a Broadly Applicable Test Method you expect would also generate additional data with the IDC operating method that may prove useful to EPA's efforts to further develop cordwood test methods for a future NSPS review.

*Section 11.6.10.3.4 of the attached IDC protocol was modified on 4/8/2021 to allow for operational flexibility.

With the following modifications, we approve your alternative test method request for certifying wood heaters using the 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.

1. First hour filterable emissions must be reported in g/hr
2. Filter treatment and dessication must follow procedures listed in ASTM E-2515
3. Filters must be weighed in pairs to reduce propagation of weighing error, see ASTM E-2515 section 10.2.1 Analytical Procedure
4. Filter temperature must be maintained between 80 and 90 degrees Fahrenheit.
5. Negative filter results must be treated as "zero" in all calculations
6. Dual train comparison must be presented in terms of % difference on a g/hr basis, and as a difference between two g/kg emissions factors values
7. Sample filters must be Pall TX-40 or equivalent Teflon-coated glass fiber, and of 47mm, 90mm, 100mm, or 110mm diameter
8. Only 1 point is allowed outside of the +/-10% proportionality range per test run
9. Each test run must include documented fuel loading per the IDC Fueling Calculator located here: https://www.nescaum.org/documents/integrated-duty-cycle-test-method-for-cordwood-stoves-1/

A copy of this letter must be included in each certification test report where this alternative test method is utilized.

It is reasonable that this alternative test method approval be broadly applicable to all wood heaters subject to the requirements of 40 CFR part 60, Subpart AAA. For this reason, we will post this letter as ALT-140 on our website at *http://www3.epa.gov/ttn/emc/approalt.html* for use by other interested parties. As noted earlier in this letter, this alternative method approval is valid until such time that Subpart AAA and QQQQ are revised or replaced to require a different certification method, and at such time, this alternative will be reconsidered and possibly withdrawn.

If you have additional questions regarding this approval, please contact Michael Toney of my staff at 919-541-5247 or toney.mike@epa.gov.

Sincerely,

STEFFAN JOHNSON

Digitally signed by STEFFAN JOHNSON
Date: 2021.04.09 09:13:01 -04'00'

Steffan M. Johnson, Group Leader
Measurement Technology Group

cc:

Boyd, Rochelle, EPA/OAQPS/SPPD
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*Section 11.6.10.3.4 of the attached IDC protocol was modified on 4/8/2021 to allow for operational flexibility.

Scinta, Robert, EPA/OECA
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*Section 11.6.10.3.4 of the attached IDC protocol was modified on 4/8/2021 to allow for operational flexibility.

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

Note: This method does not include all the specifications (e.g. equipment and supplies) and procedures (e.g., sample and analytical) essential to its performance. Some material is incorporated by reference from other methods. Therefore, to obtain reliable results, persons using this method shall have a thorough knowledge of at least the following EPA Tests

- Method 1- Sample and Velocity Traverses for Stationary Sources
- Method 2- Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)
- Method 3 – Gas Analysis for the Determination of Dry Molecular Weight
- Method 4 – Determination of Moisture Content in Stack Gases
- Method 5G – Determination of Particulate Matter from Wood Heaters (Dilution Tunnel Sampling Location)
- Method 10 - Carbon Monoxide - Instrumental Analyzer
- Method 28 – Certification and Auditing if Wood Heaters

1. Scope and Application

1.1. This test method specifies operation and fueling for certification and auditing of manually operated wood-fired stoves and heaters.

1.2. This test method measures particulate matter (PM) emissions, carbon monoxide, and efficiency.

1.3. Particulate emissions are measured by the dilution tunnel method as specified in ASTM E2515 Standard Test Method for Determination of Particulate Matter Emissions Collected in a Dilution Tunnel using only Emfab Pallflex filters. Additional particulate matter emissions measurements may also use the Tapered Element Oscillating Microbalance (TEOM) continuous PM method, as detailed in this test method.

1.4. Analyte. Particulate matter (PM). No CAS number assigned. Carbon monoxide (CO). No CAS number assigned.

1.5. Applicability. This method is applicable for the certification and auditing of wood space heaters, which burn cordwood fuel. The test quantifies PM and CO emissions and provides overall efficiency ratings, maximum burn time, and heat output.

1.6. Data Quality Objectives. Adherence to the requirements of this method will enhance the quality of the data obtained from air pollutant sampling methods

1.7. Distinguishing features of appliances covered by this standard include:

1.7.1. Cordwood fuel is hand-fed into firebox.

1.7.2. A chimney or vent that exhausts combustion products from the appliance.

1.8. The values stated are to be regarded as the standard, whether in I-P or SI units. The values given in parentheses are for information only.

1.9. Data Quality Objectives.

1.9.1. Adherence to the requirements of this method will enhance the quality of the data obtained from air pollutant sampling methods.

1.9.2. Measurement of emissions and heating efficiency provides a uniform basis for comparison of product performance that is useful to the consumer. It is also required to relate emissions produced to the useful heat production.

1.9.3. This is a laboratory method intended to capture operating periods that are representative of actual field use without excessive test burden.

2. Referenced Methods

2.1. NESCAUM Standard Operation Procedures for Thermo 1405-D TEOM for use in a dilution tunnel

2.2. ASTM 2515: Test Method for Determination of Particulate Matter Emissions Collected by a Dilution Tunnel.

3. Definitions

3.1. Appliance – a wood heater capable of and intended for space heating defined in the applicable regulation. Appliance includes combustion chamber, combustion air settings, operating controls, and a thermostat, if specified, and any other accessory required for standard operation, such as a barometric damper,

3.2. Catch - any mass from the sample probe system on the filter.

3.3. Certification or audit test - a series of at least three test runs conducted for certification or audit purposes that meets the specifications detailed in this protocol.

3.4. Chop – using a poker or another piece of wood to strike a piece of the fuel charge to break it into smaller pieces.

3.5. Coal-bed Stirring – prior to adding a new fuel charge, using a poker or piece of wood to stir or level the coal bed of the appliance for the sole purpose of ensuring ease of loading of the fuel

charge. No special formations can be made, such as creating coal bed formations or pushing coals to one side or creating slopes with the coals.

3.6. East-west stove – a stove where the firebox dimension parallel to the loading door is greater or equal to the stove depth measurement. Logs are loaded so that they are viewed on the long length of the stove.

3.7. Emission factor – the emission of a pollutant expressed in mass per unit of energy (typically) output from the appliance.

3.8. Firebox - the portion of the chamber in the wood heater in which the test fuel charge is placed and combusted.

3.9. Firebox depth - the horizontal length of the fire chamber dimension measured perpendicular to the loading door. If the manufacturer believes that a portion of the firebox depth is not usable for firebox volume calculation, photo documentation and a written basis must be included in the test report.

3.10. Firebox Height - the vertical distance extending above the top of the firebox to the floor of the firebox. Firebox height is not necessarily uniform. The measurement must account for variations caused by internal baffles, air channels, or other permanent obstructions. If the manufacturer believes that a portion of the firebox height is not usable for firebox volume calculation, photo documentation and a written basis must be included in the test report.

3.11. Firebox width - the horizontal fire chamber dimension that is parallel to the loading door. If the manufacturer believes that a portion of the firebox width is not usable for firebox volume calculation, photo documentation and a written basis must be included in the test report.

3.12. Fuel Adjustment –manipulations to the fuel charge to reflect typical owner practices that allow the cordwood fuel to burn appropriately during the test period. A fuel adjustment does not include chopping the wood or stirring the coal bed.

3.13. Fuel load calculator – The locked excel spreadsheet tool that determines the allowable test fuel load weights and required piece sizes for each individual load.

3.14. Fuel loading direction – Fuel shall be loaded parallel to the greater of the width and depth dimensions for loads 2, 3 and 4. Criss-cross is allowed for startup phase and cannot be used as a load configuration for loads 2, 3 or 4. If the firebox length and width are within 2" fuel shall be loaded in an east/west fashion, parallel to the loading door. If the firebox is cylindrical, loading direction shall be east-west.

3.15. Kindling pieces – small pieces of wood less than 1" in diameter. No bark or moisture requirements for these pieces, however kindling pieces shall not be dried or stored anywhere but in laboratory ambient conditions. Kindling length shall be of the same as the fuel charge length. and shall represent weights that would enable 8 to 12 pieces equal one pound.

3.16. Large fuel pieces – pieces that are larger for the appliance as defined by the fuel load calculator.

3.17. L1 – Start-up – period of the test when the unit has kindling and startup fuel under the conditions described in Section 11.6.7.

3.18. L2 – High-fire Phase – period of the test when the unit has a small coal bed and the stoves air settings are fully open. Intended to replicate period when homeowners are trying to quickly heat an area, shortly after starting or restarting the appliance.

3.19. L3 - Maintenance-fire phase– period of the test when a fire is maintained with a medium-sized coal bed, and a smaller batch of wood. This is intended to simulate a period when the operator is trying to maintain consistent heat output.

3.20. L4 - Low-burn Rate Phase – period of the test when the stove has a large coal bed, stove is fully loaded, and the adjustable air settings are set to produce the lowest possible burn rate and have the lowest air settings. Intended to simulate a period the operator is trying to maintain heat over a long period of time, such as overnight or while away for significant periods of time.

3.21. North-south stove: a firebox which has its longest dimension measurement perpendicular to the loading door. In this stove type, logs are loaded so that the ends of the fuel are viewed when loaded.

3.22. Phase – A distinct period in the test run with its own operational procedures and conditions.

3.23. Primary air supply – air supply that introduces air to the wood heater in the combustion chamber and is adjusted to target a desired burn rate. The wood heater manufacturer or test facility can document this through design drawings.

3.24. Secondary air supply - air supply that introduces air to the wood heater such that the burn rate is not altered by more than 10 percent when the secondary air supply is adjusted during the test run. The wood heater manufacturer or test facility can document this through design drawings that show the secondary air is introduced only into a mixing chamber or secondary chamber outside the firebox.

3.25. Small fuel pieces - pieces that are small for the appliance as defined by the fuel load calculator.

3.26. Starter fuel – pieces of cordwood that can be smaller than small and large pieces but larger than kindling, as defined by the fuel load calculator.

3.27. Test data– means the data for all test runs conducted on the wood heater, including any data collected during failed and invalid runs and includes records of preparation of standards, identification of equipment used and personnel present, records of calibrations, raw data sheets for field sampling, raw data sheets for field and laboratory analyses, chain-of-custody documentation, and example calculations for reported results.

3.28. Test facility - the area in which the wood heater is installed, operated, and sampled for emissions.

3.29. Test fuel charge - the collection of test fuel pieces used in each of the four phases of the test run. L2, L3, and L4 require that at least 75% of the individual pieces with at least 80% bark on one side of the fuel piece. Bark shall not be removed for certification testing. Any fuel charge that

suggests bark was purposely removed or shaped shall deem the certification test invalid. Examples of fuel piece manipulation are provided in Section 11

3.30. Test fuel load – the group of test fuel pieces that are loaded, as specified by phase, throughout the test run. Test fuel loading means the arrangement of the test fuel charge.

3.31. Test fuel loading density - the calculation that determines the weight of the as-fired test fuel load. The calculation is based on the usable volume of the firebox.

3.32. Test run - an individual emission test that includes the four operational phases required by the fueling protocol.

3.33. Usable firebox volume - the calculated volume of the firebox determined using its height, width, and depth as defined in this section. This calculation represents the area where wood is likely to be loaded. If the manufacturer claims that portions of the firebox may not be used in the calculation a justification must be submitted with the test report. If the justification is not approved, the test results will be deemed unrepresentative for certification purposes. It is highly recommended that manufacturers obtain regulatory approval if making claims that portions of the firebox are not appropriate for inclusion in the calculation.

3.34. Wood heater - an enclosed, wood-burning appliance capable of and intended for space heating or domestic water heating, as defined in the applicable regulation.

4. Interferences

None.

5. Summary of Method

5.1. Particulate matter emissions are measured from a wood heater burning cordwood test fuel in a test facility maintained at a set of prescribed ambient conditions. Procedures for operating the appliance, measuring PM and CO emission rates, and methods for reducing data and calculating results are provided.

5.2. *Dilution Tunnel*. A dilution tunnel following the specifications detailed in ASTM E2515-11 shall be used for particulate measurements.

5.3. *Particulate Matter:* PM emissions are measured in a dilution tunnel specified in ASTM 2515-11 *Standard Test Method for Determination of Particulate Matter Emissions Collected in a Dilution Tunnel* with exceptions as defined in Section 10.1. The flow rate in the dilution tunnel is maintained at a constant rate throughout the test cycle and accurately measured.

5.4. *Carbon Monoxide*. CO emissions are measured in the stack and used to calculate efficiency determination.

5.5. *Operation*. Appliance operation is conducted on a cold-to-hot test cycle, meaning that the appliance starts the first test run at room temperature and ends with the appliance in fully heated

state. The second and third test runs are started a slightly warmer temperature. The appliance is operated at four operational phases representing start-up emissions, high heat demand, low heat demand, and refueling. To complete the certification test, the appliance shall complete three valid test runs that are averaged to determine the test results.

5.6. *Repeatability.* A series of at least three test runs comprised of six different heat demands or phases conducted for certification or audit purposes

6. Significance and Use

6.1. The measurement of particulate matter emission rates is an important test method widely used in the practice of air pollution control.

6.1.1. These measurements, when approved by state or federal agencies, are often required for the purpose of determining compliance with regulations and statutes.

6.1.2. The measurements made before and after design modifications are necessary to demonstrate the effectiveness of design changes in reducing emissions and make this standard an important tool in manufacturers' research and development programs.

6.2. Measurement of heating efficiency provides a uniform basis for comparison of product performance that is useful to the consumer. It is also required to relate emissions produced to the useful heat production.

7. Safety

7.1. Disclaimer. This method may involve hazardous materials, operations, and equipment. This test method may not address all the safety problems associated with its use. It is the responsibility of the user of this test method to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to performing this test method.

7.2. These tests involve combustion of wood, which releases substantial amounts of heat and combustion products. The heating system also produces large quantities of very hot water and the potential for steam production and system pressurization. Appropriate precautions must be taken to protect personnel from burn hazards and respiration of products of combustion. Exposure of personnel to unsafe levels of carbon monoxide must be avoided, and the use of continuous ambient carbon monoxide monitoring is strongly recommended.

8. Equipment and Supplies. The following items are required for sample collection:

8.1. Anemometer. A device capable of detecting air velocities less than 0.10 m/sec (20 ft/min), for measuring air velocities near the test appliance.

8.2. Appliance Flue.

8.2.1. Steel flue pipe extending to 8.5 ±0.5 ft. (2.6 ±0.15 m) above the top of the platform scale, and above this level, insulated solid pack type chimney extending to 15 ±1 ft (4.6 ±0.3 m) above the

platform scale, and of the size specified by the appliance manufacturer. This applies to both freestanding and inserts type appliances.

8.2.2. Other chimney types (e.g., solid pack insulated pipe) may be used in place of the steel flue pipe if the appliance manufacturer's written appliance specifications require such chimney for home installation (e.g., zero clearance appliance inserts). Such alternative chimney or flue pipe must remain and be sealed with the appliance following the certification test.

8.2.3. Solid pack insulated chimneys shall have a minimum of 2.5 cm (1 in.) solid-pack insulating material surrounding the entire flue and possess a label demonstrating conformance to U.L. 103 (incorporated by reference—see §60.17).

8.3. Appliance Platform Scale and Monitor. For monitoring of fuel load weight change. The scale shall be capable of measuring weight to within 0.01 kg (0.02 lb.) and calibrated to NIST traceable standards at least annually.

8.4. Barometer. Aneroid or another barometer capable of measuring atmospheric pressure to within 0.1 in. Hg (2.5 mm Hg) with an uncertainty of +/- 0.05 in Hg (+/- 1.27 mm Hg).

8.5. Dilution Tunnel must meet the requirements of ASTM E2515, clauses 6.1.6 and 9.2.

8.6. Dilution Tunnel temperature and relative humidity measurement. A probe capable of measuring tunnel temperature to within 0.9 ˚F (0.5 ˚C)) and tunnel RH to within 2%, such as the Omega HX85-A or equivalent.

8.7. Draft Gauge. Electromanometer or other devices for the determination of flue draft or static pressure readable to within 0.005 in. H2O (1.2 Pa)

8.8. Flue Gas Temperature Measurement. A type K- thermocouple or equivalent located in the centroid of the stack located 8.0 +/- 0.5 ft (2.44 m +/- 150 mm) above the platform scale. Capable of measuring with an accuracy of 4.0˚F (2.2˚C) or 0.75% of reading, whichever is greater.

8.9. Flue Gas Composition Measurement. A sample probe and continuous infrared analyzer or equivalent capable of measuring span of carbon monoxide (CO) and carbon dioxide (CO_2) in the flue gas produced by the appliance tested. Continuous analyzers (or equivalent) shall have maximum zero and span drift, over a 24 h period, of 1% of full scale

8.10. Fuel Scale. Balance capable of weighing the test fuel charge to within 0.02 kg (0.05 lb.) and calibrated to NIST traceable standards at least annually.

8.11. Humidity Gauge. Psychrometer or hygrometer for measuring room humidity to within +/- 4% from 25 to 95% RH.

8.12. Moisture Meter. Calibrated electrical resistance meter for measuring test fuel moisture to within 2 percent moisture content.

8.13. Surface Temperatures. Capable of measuring temperature to within 1.5 percent of expected absolute temperatures with an accuracy of 4.0˚F (2.2˚C) or 0.75% of reading, whichever is greater.

8.14. Test Facility Temperature Monitor. A thermistor, RTD, or other equivalent device, located centrally in a vertically oriented 150 mm (6 in.) long, 50 mm (2 in.) diameter pipe shield that is open at both ends, capable of measuring temperature to within 1˚F of expected temperatures.

8.15. TEOM – Thermo Fisher Scientific TEOM model 1405-D (Thermo part # 1405D-ANF, excluding models 1405, 1405-DF, or 1405-F) to measure and report continuous particulate matter (PM) measurements in an ASTM 2515 dilution tunnel or equivalent dilution method, and operated according to the NESCAUM Dichot TEOM Standard Operating Procedures.

9. Calibration and Standardizations

9.1. ASTM E2515-11. Perform all calibrations required by ASTM E2515-11.

9.2. Anemometer. Calibrate the anemometer as specified by the manufacturer's instructions before the first certification test and monthly thereafter.

9.3. Appliance Platform Scale. Perform a multi-point calibration (at least five points spanning the operational range) of the platform scale before its initial use. The scale manufacturer's calibration results are sufficient for this purpose. Before each certification test, audit the scale with the wood heater in place by weighing at least one calibration weight (Class F) that corresponds to between 20 percent and 80 percent of the expected test fuel charge weight. If the scale cannot reproduce the value of the calibration weight within 0.0045 kg (0.01 lb.) or 1 percent of the expected test fuel charge weight, whichever is greater, recalibrate the scale before use with at least five calibration weights spanning the operational range of the scale.

9.4. Barometer. Calibrate using a reference pressure monitor calibrator before the first certification test and semiannually after

9.5. Draft Gauge. Calibrate as per the manufacturer's instructions; a liquid manometer does not require calibration (but must be properly leveled, zeroed and the system leak checked).

9.6. Humidity Gauge. Calibrate as per the manufacturer's instructions before the first certification test and annually thereafter.

9.7. Fuel Scale. Calibrate as described in 9.2.

9.8. Moisture Meter. Calibrate as per the manufacturer's instructions before the first certification test and semiannually thereafter.

9.9. Temperature Sensors. Calibrate using at least five points within operating range within specification and in compliance with NIST Monograph 175. To be calibrated before the first certification test and semiannually thereafter.

9.10. Flue Gas Analyzers. In accordance with CSA B415.1-2010, C

10. Sampling, Test Specimens, and Test Appliances

10.1. Modifications to ASTM 2515 requirements.

10.1.1. Liquid water should not be present anywhere in the sampling system for a valid sample. The presence of condensed water anywhere in the sampling system invalidates the test run. All data from all invalid test runs shall be included in the report. The reviewing authority shall make a final determination on invalidated runs. Data from any invalidated test run shall not be used to calculate results. If the testing agency believes a run has been invalidated, the test run shall be repeated.

10.1.2. Dilution tunnel temperature and relative humidity shall be measured electronically and logged at one-minute intervals near the sample probe to calculate dewpoint. The temperature measurement method shall have an accuracy of 0.5 degrees C (type T-Special TC or a RTD).

10.1.3. The following section details test conditions that shall be maintained for a valid test run. A valid test shall have no more than two individual deviations from any of the conditions below to remain a valid run. An example of an individual deviations is a single, five-minute rolling average where the dilution tunnel exceeded temperature thresholds. Another five-minute period exceeding the tunnel temperature requirement shall be considered a second deviation.

10.1.3.1. Tunnel temperature shall not exceed 104 deg. F (40C) based on ten-minute rolling averages derived from one-minute data, excluding periods when the appliance door is open.

10.1.3.2. Tunnel relative humidity shall not exceed 90% based on ten-minute rolling averages derived from one-minute data excluding periods when the appliance door is open.

10.1.3.3. Tunnel dew point temperature shall be at least 2 deg. C less than filter temperature based on five-minute rolling averages derived from one-minute data.

10.1.3.4. A minimum tunnel flow of 500 CFM is required. Higher tunnel flows may be required to meet the parameters of 8.6.3.

10.1.3.5. All exceedances must be reported in the test anomalies section, even if deviations are within the test method tolerances.

10.2. Sample Collection. The following are required for sample collection:

10.2.1. Proportional Rate Variation shall meet the requirements of ASTM E2515 for all phases.

10.2.2. Particulate Matter Sampling for first-hour filter pull. This method provides two (2) options to obtain PM data for full runs and first-hour PM emissions data.

10.2.2.1. Option 1 – Uses three (3) ASTM 2515 sampling trains. Two trains are run through the entirety of the test to obtain full run data, and the third train obtains measurement for the first hour emissions.

10.2.2.1.1. Train 1 and 2 shall provide dual sampling trains that shall measure PM emissions from run start to run completion. Trains 1 and 2 must meet a precision requirement of 7.5% or lower, regardless of g/kg comparison.

10.2.2.1.1.1. Proportional rate variation shall meet ASTM 2515 requirements for all phases.

10.2.2.1.1.2. Filter conditions must be monitored, and filter changes are required to avoid filter clogging.

10.2.2.1.2. Train 3 will commence at the beginning of the test and cease measurement 60 minutes from the start of the test run.

10.2.2.1.2.1. Proportional rate variation shall meet ASTM 2515 requirements for all phases.

10.2.2.1.2.2. Filter conditions must be monitored, and filter changes are required to avoid filter clogging.

10.2.2.2. Option 2 – Uses two (2) ASTM 2515 sampling trains and a TEOM to obtain real-time data to include the first-hour emission rate. All measurements shall run through the entirety of the test to obtain full run data.

10.2.2.2.1. Train 1 and 2 shall provide dual sampling trains that shall measure PM emissions from run start to run completion. Trains 1 and 2 must meet a precision requirement of 7.5% or lower, regardless of g/kg comparison.

10.2.2.2.1.1. Proportional rate variation shall meet ASTM 2515 requirements for all phases.

10.2.2.2.1.2. Filter conditions must be monitored, and filter changes are required to avoid filter clogging.

10.2.2.2.2. TEOM data shall be collected at 10-second intervals and averaged up to 1-minute intervals for reporting. TEOM operation shall follow the procedures listed on the most recent TEOM Standard Operating Procedures found on the NESCAUM website at www.nescaum.org/topics/testmethods.html

10.2.3. *Blanks*. Test reports shall measure and report data on blanks as follows

10.2.3.1. Lab blank, which is removed from each filter batch, stored in a protective environment, and weighed during each weighing session.

10.2.3.2. Room blank collected during every test run. The blank shall be placed within 10 feet of the intake for the dilution air

10.2.4. Weigh Room Conditions

10.2.4.1. The facility shall use an active ionizing air blower (or 210Polonium alpha sources) to neutralize charge associated with the filter. 210Polonium alpha sources must be replaced annually or more often.

10.2.4.2. Temperature range of 68 to 78 ˚F (20 to 25.6 ˚C).

10.2.4.3. Relative humidity shall be no higher than 45%.

10.2.5. Filter *equilibration / conditioning post sample collection*. Use of desiccation is not allowed. Equilibrate filters at a relative humidity between 30 and 40% for at least 24 hours. A saturated salt solution of magnesium chloride (33% RH) can be used. PREPARATION OF SALT SOLUTIONSU: Use only pure distilled water to make up the solution. Put 200 g of the salt into a beaker. Gradually add distilled water. Stir well after each addition, until the salt can absorb no more water, as will be evidenced by some free liquid on the surface of the mixture. For best results keep the excess liquid to a minimum. The mixture should be slushy but must have a small amount of liquid water on the surface. Put this slushy mixture in the desiccant tray of the equilibration chamber. After equilibration, the chamber RH should measure 33% +/- 3%.

10.2.6. *Probe catch*. Report sampling system catch as a separate number from front and rear filter catch.

10.2.7. Filter *weight measurements.* The test report shall contain the following filter measurements for all filter weights.

10.2.7.1. Day zero – initial filter measurement before going into the equilibrium chamber.

10.2.7.2. Final filter measurement or day-seven measurement, whichever measurement comes first.

10.2.8. *TEOM filters (optional).* Teflon coated glass fiber filters as supplied by the TEOM manufacturer for use with the TEOM model 1405-D. These are Pallflex Emfab (TX40) with an exposed diameter of 13 mm, without organic binder, exhibiting at least 99.95 percent efficiency.

10.3. *Test Specimens.* Appliances shall be supplied as complete systems, including all controls and accessories necessary for installation at the test facility. A full set of specifications, designs, and assembly drawings shall be provided when the product is placed under certification of a third-party agency.

10.4. Preparation of Apparatus

10.4.1. Wood Heater Installation for Certification Testing. Assemble the wood heater appliance and parts in conformance with the manufacturer's provided User Guide. These instructions must match all instructions materials developed by the manufacturer and/or their distributors. Place the wood heater on the platform scale and connect the chimney to the appliance. Clean the flue with an appropriately sized, wire chimney brush before initiating Run 1 of the certification test. Test documentation should include the date and time of flue cleaning.

10.4.2. Wood Heater Temperature Monitors.

10.4.2.1. For catalyst-equipped wood heaters, locate a temperature monitor (optional) about 25 mm (1 in.) upstream of the catalyst at the centroid of the catalyst face area, and locate a temperature monitor (mandatory) that will indicate the catalyst exhaust temperature. This temperature monitor is centrally located within 25 mm (1 in.) downstream at the centroid of the catalyst face area. Record these locations.

10.4.2.2. Locate wood heater surface temperature monitors at five locations on the wood heater firebox exterior surface. Position the temperature monitors centrally on the top surface, centrally on two sidewall surfaces, and centrally on the bottom and back surfaces. Position the monitor sensing tip on the exterior of the firebox surface inside of any heat shield, room air circulation walls, or other wall or shield separated from the firebox exterior surface. Surface temperature locations for unusual design shapes (e.g., spherical, etc.) shall be positioned so that there are four surface temperature monitors in

10.5. Conditioning

10.5.1. Wood Heater Aging Prior to Certification Testing. A wood heater of any type shall be aged at least 50 hours before initiating a certification test. The aging procedure shall be conducted by the manufacturer prior to sending the appliance to the testing laboratory. The certification lab cannot be involved with wood heater aging in any manner. The appliance shall be operated at a variety of burn rates. Documentation for wood heating aging must be included in the test report to include data on individual hour burn rates. The testing laboratory shall not conduct any firing of the appliance prior to conducting the certification test.

10.5.1.1. The manufacturer shall supply wood heater aging information for the final test reports. Aging data that shall be reported include all fuel parameters (species, moisture content, load weights, piece amounts, and size), air settings used, time spent in each air setting phase, amount of fuel burned, and appliance burn rates.

10.5.1.2. If an appliance uses a catalytic combustor, it must be engaged according to the manufacturer's instructions and operate with the catalyst engaged for at least 50 hours during the break-in period. In addition to the reporting requirements listed in 8.1.1, catalytic appliances shall also report hourly catalyst exit temperature data to include the dates and hours of operation.

11. Procedure

11.1. Test Facility Conditions. The test facility shall meet the following requirements during testing.

11.1.1. Shall conform to 9.7 of ASTM 2515-11.

11.1.2. The test facility temperature shall be maintained between 55 and 90°F (13 and 32°C) during each test run.

11.1.3. The flue shall discharge into the same space or into a space freely communicating with the test facility. Any hood or similar device used to vent combustion products shall not induce a draft greater than 0.005 in. H_2O (1.25 Pa) on the wood heater measured when the wood heater is not operating.

11.1.4. For test facilities with artificially induced barometric pressures (e.g., pressurized chambers), the barometric pressure in the test facility shall not exceed 30.5 in. Hg (775 mm Hg) during any test run.

11.1.5. Locate the test facility temperature monitor on the horizontal plane that includes the primary air intake opening for the wood heater. Locate the temperature monitor 3 to 6 ft. (1 to 2 m) from the front of the wood heater in the 90° sector in front of the wood heater.

11.1.6. Use an anemometer, to measure the air velocity. Measure and record the room air velocity before the ignition period in L1 Startup and once immediately following the test run completion. Air velocities within 0.6 m (2 ft) of the test appliance and exhaust system shall be less than 0.25 m/sec (50 ft/min) without fire in the unit.

11.1.7. Measure and record the test facility's ambient relative humidity, barometric pressure, and temperature before and after each test run using equipment as specified in Section 6.

11.2. Wood Heater Firebox Volume.

11.2.1. Determine the firebox volume using the definitions for height, width, and length. Volume adjustments due to the presence of firebrick and other permanent fixtures may be necessary. All adjustments shall be detailed in the test report. Include areas adjacent to and above a baffle.

11.2.2. If a manufacturer deems certain areas of the firebox as unusable for fuel load calculations, written documentation stating the basis for that claim and supporting photographic image(s) must be provided and approved by the regulatory authority prior to conducting the certification test. If approval is not granted prior to the test, then the test may be invalidated if the reviewing agency determines the firebox volume is inaccurate.

11.3. Test Fuel. The test fuel shall conform to the following requirements and meet specifications as required by the fuel loading calculator:

11.3.1. Fuel Species. Untreated, air-dried, cordwood fuel.

11.3.1.1. Allowable species: maple (big leaf, red, silver), oak (red or white), or white birch.

11.3.1.2. Kiln-dried fuel is not permitted.

11.3.1.3. Fuel shall be free of decay, fungus, or other contaminants.

11.3.2. Fuel Moisture.

11.3.2.1. Determine fuel moisture for each fuel piece by averaging four moisture meter readings, one from each of three sides, measured parallel to the wood grain.

11.3.2.2. The test fuel load shall have an average moisture content from 19% to 25%, dry basis.

11.3.2.3. Average individual piece moisture content shall have an average moisture content 18% to 27%.

11.3.2.4. The addition of moisture to previously dried wood is not allowed.

11.3.2.5. It is recommended that the test fuel be stored in a temperature and humidity-controlled room.

11.3.2.6.Fuel moisture shall be measured within 24 hours of using the fuel for the test and shall be stored in a humidity-controlled environment until 2 hours prior to testing.

11.3.3. Fuel Temperature. The test fuel shall be at the test facility temperature of 13 to 32°C (55 to 90°F).

11.3.4. Fuel Dimensions. The dimensions of each test fuel piece shall conform to definitions specified by the protocols using the fuel load calculator.

11.3.4.1.Fuel length:

11.3.4.1.1.The length of the fuel pieces will be determined by the fuel load calculator.

11.3.4.1.2.Measurements shall be taken, and the length of the test fuel will be determined by entering the firebox dimensions, which calculates the length for all the fuel pieces into a generally available commercial size (14, 16, 18, 20 or 22 inches in length).

11.3.4.1.3.Piece length specified by the fuel calculator shall be communicated and specified for use in the owner's manual and website. Piece size shall be within 0.5" of the log length determined by the calculator, as measured on the shortest length measurement.

11.3.5.Fuel Loading Direction

11.3.5.1.Fuel loading direction shall be determined by the firebox measurement.

11.3.5.1.1.Stoves with a depth measurement greater than two inches from the width measurement shall be tested with the fuel in a north-south configuration and may not test with fuel in an east/west or crisscross configuration in any load other than Load 1 and Load 2.

11.3.5.1.2.Stoves with a width measurement greater than the depth measurement or a width measurement within two inches of the depth measurement shall be tested with the fuel loaded in an east-west configuration and may not test with fuel in a north/south configuration or crisscross configuration in any load other than Load 1 and Load 2.

11.3.6.Fuel piece weight for each phase of the protocol shall be determined by the fuel load calculator.

11.3.6.1.Kindling –shall be:

11.3.6.1.1.pieces of wood less than or equal to 1" in diameter.

11.3.6.1.2.No bark requirements for kindling fuel

11.3.6.1.3.Fuel species may be any species allowed in 7.2.1.1.

11.3.6.1.4.No moisture requirements.

11.3.6.1.5.Length of kindling shall be the fuel length specified by the fuel load calculator.

11.3.6.1.6.Kindling fuel shall conform to the rule that 7 to 12 pieces of kindling equal 1 pound of kindling fuel (+/- 10%).

11.3.6.2. Starter fuel: pieces of cordwood shall be used during the startup phase. Individual piece weight for starter fuel shall be determined by the fuel load calculator. Each piece shall be triangular, irregular, or circular in cross-section. Square pieces shall be not be used in testing (see Figure 1). Pieces that have squared cross sections shall be split to represent the typical triangle nature of wood (see Figure 3). Trapezoidal pieces must be minimized to the extent possible and fuel load pieces shall be composed to include different shapes of wood if using any trapezoidal pieces. .

11.3.6.3.Small fuel pieces: smaller pieces of cordwood by weight and pre-defined length, as defined by the fuel load calculator. Each piece shall be triangular, irregular, or circular in cross-section. Square pieces shall not be used (see figure 1). Pieces that have square cross-sections shall be split to represent the typical triangle nature of wood (see Figure 3). Trapezoidal pieces must be minimized to the extent possible. No more than 2 small fuel pieces can be trapezoidal in shape (Figure 2) per fuel load.

11.3.6.4.Large fuel pieces: larger pieces of cordwood, by weight and pre-defined length, as defined by the fuel load calculator. Each piece shall be triangular, irregular, or circular in cross-section. Square pieces shall be not be used (see figure 1). Pieces that have square cross sections shall be split to represent the typical triangle nature of wood (see Figure 3). Trapezoidal pieces must be minimized to the extent possible. No more than 1 large fuel pieces can be trapezoidal in shape (Figure 2) per fuel load.

Figure 1. Schematic of unacceptable cross-sectional profiles

Figure 2.

Figure 3. Schematics of acceptable cross-sectional profiles

11.4. Sampling Equipment.

11.4.1. Prepare the PM and ambient sampling equipment.

11.4.2. Prepare all other equipment as defined by method EPA Method 1, 2, 3, 4, ASTM 2515, and CSA B415.

11.5. Manufacturer participation in certification testing

11.5.1. A representative of the manufacturer may observe testing but may not provide instructions to the certification lab, in any form, with testing staff or equipment once the certification tests begin. The names of testing witnesses cannot be withheld as confidential business information (CBI).

11.6. Test Run Procedure.

11.6.1. Before each test series, the firebox shall be vacuumed. Testing shall begin without any ash or other materials in the appliance.

11.6.2. Before initiating the compliance test, clean the flue and dilution tunnel with an appropriately sized wire chimney brush before each certification test. Test documentation should include the date and time of flue cleaning.

11.6.3. Record fuel weight data, temperature measurements, and gas concentrations at 1-minute intervals.

11.6.4. Wood Heater Operation and Adjustments. Record all adjustments made to the air supply controls, adjustments to and additions or subtractions of fuel, and any other changes to wood heater operations that occur during the test period.

11.6.5. The weight of fuel remaining at the end of the test run is determined as the difference between the weight of the wood heater with the remaining coals and fuel and the weight after loading the fuel charge. The starting weight is the tare weight of the cleaned, dry wood heater.

11.6.6. All runs shall be videotaped in their entirety. Video tape shall be of sufficient quality to determine fuel characteristics, fuel loading procedures, and firebox conditions during any testing or aging conducted by the test lab. The testing lab shall have the capacity to allow appropriate agencies the opportunity to remotely witness the test.

11.6.7.L1: Start-up Phase.

11.6.7.1.L1 Appliance requirements.

11.6.7.1.1. Stove temperature: internal and external stove temperature must not be greater than the ambient temperature +/- 2˚F (1.1˚C) for Run 1. There is no stove starting temperature requirement for Runs 2 and 3 except in the case of a failed first run. In this case, if Run 1 is invalid or incomplete and, the stove must meet Run 1 conditions for at least one valid run. Temperature measurements for the external and internal temperatures shall be taken within 15 minutes before starting the test and shall be reported in the test report.

11.6.7.1.2. Tare the appliance scale before starting the test. Record appliance scale weights at the start and end of L1 phase

11.6.7.2.L1 Fuel requirements.

11.6.7.2.1.L1 Fuel type – during the startup phase newspaper (optional up to six full sheets traditional newspaper size), kindling, and starter fuel pieces are used. No other additions are allowed.

11.6.7.2.2.L1 loading density

11.6.7.2.2.1. Kindling loading density: 1 lb. per cubic foot for dry kindling, +/- 5%. The fuel load calculator determines the amount of kindling that can be used.

11.6.7.2.2.2. Starter Fuel loading density: 3 lb. per cubic foot, +/- 5%. The fuel load calculator will determine the minimum piece weight that can be used as starter fuel.

11.6.7.2.3. L1 fuel loading structure: The loading structure of the fire shall be a bottom-up configuration with newspaper on the bottom, kindling on top of the paper, and starter fuel on top of the kindling. Kindling and starter fuel shall be loaded in a crisscross configuration.

11.6.7.3. L1 Operational parameters.

11.6.7.3.1. All kindling, starter fuel, and newspaper must be in the firebox for light off.

11.6.7.3.2. Air settings are fully open.

11.6.7.3.3. Light the fire with a torch for a period of no more than 30 seconds.

11.6.7.3.4. Immediately after lighting the fire and completing the photo requirement, the appliance door shall be moved to a cracked open position. Cracked open position is defined as opening no more than one inch. The appliance door shall be closed 5 minutes after ignition.

11.6.7.4. L1 Fuel Adjustments: up to three fuel adjustments are allowed in the startup phase. The door may be open for 30 seconds during each fuel adjustment.

11.6.7.5. L1 End of Phase – the end of the startup phase is defined by the weight specified by the fuel load calculator.

11.6.7.6. L1 Documentation – Video of the test to clearly show appliance settings, fuel charge placement while loading, changes in appliance settings, coal-bed and fire when the door is closed sufficient to determine fueling positioning, coal bed conditions, appliance operation, and fuel charge combustion conditions. Photo of the fuel charge before loading.

11.6.8. *L2: High-fire Phase* – the high-fire phase commences immediately after the startup phase ends.

11.6.8.1. L2 Appliance requirements.

11.6.8.1.1. Record the weight of the stove prior to loading the L2 fuel charge, the weight of the fuel charge prior to loading, and the scale weight after loading the L2 fuel charge.

11.6.8.2. L2 Fuel requirements.

11.6.8.2.1. L2 piece size – during the high-fire phase, small cordwood pieces by weight, as defined by the fuel load calculator, are used.

11.6.8.2.2. L2 loading density: 7 lb. per cubic foot, +/- 5%. The fuel load calculator will define the total load weight and the range of allowable piece sizes by weight.

11.6.8.3.L2 Operational parameters: Open the door upon completion of the startup phase and load the L2 fuel load within 60 seconds. Once the fuel has been loaded, the appliance doors shall be closed immediately. Air settings shall be left fully open. When 50% of the L2 fuel load mass has been consumed, the air settings shall be moved to the lowest settings.

11.6.8.4.L2 Fuel Adjustments.

11.6.8.4.1.One fuel adjustment may be made during the high-fire phase prior to moving the primary air control(s) to their lowest setting. The door shall remain open for 30 seconds for fuel adjustments.

11.6.8.4.2.Additional fuel adjustments shall be made if there is a five-minute period without a weight change of 0.1 pounds at any point during the high-fire phase.

11.6.8.4.3.if there is a five-minute period without a weight change at any point during the high-fire phase. The door may only be open for 30 seconds for fuel adjustments.

11.6.8.4.4.All fuel adjustments must be documented in the test report notes and summary.

11.6.8.5.End of L2 Phase –The high-fire phase ends when the scale indicates that 90% of the high-fire fuel mass has been consumed.

11.6.8.6. L2 Documentation - – Video of the test to clearly show appliance settings, fuel charge placement while loading, changes in appliance settings, coal-bed and fire when the door is closed sufficient to determine fueling positioning, coal bed conditions, appliance operation, and fuel charge combustion conditions. Photo of the fuel charge before loading.

11.6.9. *L3: Maintenance-fire Phase* – the L3 maintenance-fire phase commences immediately after the L2 high-fire phase ends.

11.6.9.1.L3 Appliance Requirements.

11.6.9.1.1. Record the weight of the stove prior to loading the maintenance-fire fuel charge, the weight of the fuel charge prior to loading, and the scale weight after loading the maintenance-fire fuel charge.

11.6.9.2.L3 Fuel Requirements.

11.6.9.2.1.Fuel type – during the L3 phase, large cordwood pieces are used. The fuel load calculator will define the total load weight and the range of allowable piece sizes by weight.

11.6.9.2.2.L3 fuel loading structure: fuel shall be loaded in the direction specified by the fueling calculator.

11.6.9.2.3. L3 loading density: 5 lb. per cubic foot, +/- 5%. The fuel load calculator will define the total load weight and the range of allowable piece sizes by weight.

11.6.9.3. L3 Operational Parameters:

11.6.9.3.1.Open door upon completion of the L2 phase and load the maintenance-fire fuel charge.

11.6.9.3.2.L3 Load - L3 fuel loaded within 30 seconds of the door opening. Close the loading door immediately.

11.6.9.4. L3 Fuel Adjustments: Fuel Adjustments: If there is a ten-minute period without weight change (0.1 lb) at any point during the L3-fire phase, a fuel adjustment shall be made to increase the burn rate. The door may be open for up to 30 seconds for fuel adjustments. Only two fuel adjustments may be made during this phase. If after the second fuel adjustment, another period of no weight change (0.1 lb) occurs, the run ends, and it is a failed test run.

11.6.9.5.L3 End of Phase – The L3-fire phase ends when the scale indicates that 90% of the maintenance-fire fuel mass has been consumed.

11.6.9.6.L3 Documentation – Video of the test to clearly show appliance settings, fuel charge placement while loading, changes in appliance settings, coal-bed and fire when the door is closed sufficient to determine fueling positioning, coal bed conditions, appliance operation, and fuel charge combustion conditions. Photo of the fuel charge before loading.

11.6.10.*L4: Low burn rate phase* – L4 phase commences immediately after the L3- ends.

11.6.10.1.L4 Appliance Requirements.

11.6.10.1.1.Record the weight of the stove prior to loading the L4-fire fuel charge, the load of the fuel charge prior to loading, and the scale weight after loading the overnight-fire fuel charge. Alternatively, if the scale was zeroed prior to starting the test, record the scale weight before and after loading the overnight-fire fuel charge.

11.6.10.2.L4 Fuel requirements

11.6.10.2.1. L4 fuel type –a mix of small and large cordwood pieces are used. At least 50% of the fuel charge load, by the number of pieces, must be large pieces.

11.6.10.2.2.L4 Loading structure: fuel will be loaded in one direction.

11.6.10.2.3.L4 loading density: The fuel load calculator specifies a load volume of 12 lb/ft^3 .+/-5%. Fuel shall be loaded in a manner to maximize the number of pieces that will fit in the stove without using force.

11.6.10.3. L4 Operational Parameters:

11.6.10.3.1. Open the loading door upon completion of the L3 maintenance-fire phase.

11.6.10.3.2.Load the L4 fuel charge within two minutes (120 seconds).

11.6.10.3.3.Keep the door in the 1" cracked position for five minutes from the beginning of the L4 phase.

11.6.10.3.4.Air controls may be placed in the fully open position for the first ten minutes of the phase. After ten minutes all air settings shall be placed at the lowest or closed air setting.

11.6.10.4.L4 Fuel Adjustments.

11.6.10.4.1.Unlimited fuel adjustments are allowed within the first five minutes of the phase. After ten minutes, air control(s) shall be moved to their lowest position. A picture of the air setting used must be included in the test report. The door may be open for up to 30 seconds for fuel adjustments.

11.6.10.4.2.If there is a ten-minute period without weight change (0.1 lb) during the first hour of the L4-phase, a fuel adjustment shall be made. The door may be open for up to 30 seconds for fuel adjustments.

11.6.10.4.3.Only two fuel adjustments may be made during the first hour. If after the second fuel adjustment, another periods of no weight change (0.1 lb) is observed, the run ends, and it is a failed test run.

11.6.10.4.4.No fuel adjustments are allowed after the first hour of the phase.

11.6.10.4.5.If there is no weight change for a consecutive period of 20 minutes at any point after the first hour of the phase, the unit has failed the test run.

11.6.10.5.L4 End of Phase – The L4 phase shall end when the scale indicates that 90% of the total L4 fuel mass has been consumed. If the fuel load does not burn to 90%, it is a failed test run.

11.6.10.6. L4 Documentation - Video of the test to clearly show appliance settings, fuel charge placement while loading, changes in appliance settings, coal-bed and fire when the door is closed sufficient to determine fueling positioning, coal bed conditions, appliance operation, and fuel charge combustion conditions. Photo of the fuel charge before loading.

11.7. Test Run. A complete test run requires completion of all four burn phases and loads. For any appliance that will not accommodate the loading arrangement specified in this test method, the test facility personnel shall contact the Agency Administrator to obtain written approval for an alternative loading arrangement:

11.8. Test Run Requirements. The following describes the required parameters for each test run. Each emission test run shall include all phases of the operational and fueling protocol run in order as described.

11.8.1. Consecutive Test Runs. Consecutive test runs may be conducted, provided that the following requirements are met:

11.8.1.1. Run 1 – The appliance shall have an internal and external starting temperature within +/- 2 ˚F (1.1˚C) of laboratory ambient temperature at the beginning of Run 1

11.8.1.2. Run 2 – The second test run may commence 24 hours after the start of Run 1. Stove coals and ash can remain in the stove until 1 hour before conducting Run 2. All coals and ash shall be removed at least one hour prior to commencing Run 2.

11.8.1.3. Run 3 – The third test run may commence 24 hours after the start of Run 2. Stove coals and ash may remain in the stove until 1 hour before conducting Run 3. All coals and ash shall be removed at least one hour prior to commencing Run 2.

11.9. *Failure to Operate at All Test Conditions*

11.9.1. If the appliance fails two runs due to incomplete or invalid test runs, it shall be determined that the appliance has failed the certification test and requires a modification to appliance design. All data for incomplete runs shall be reported. Incomplete failed test runs are defined as the following:

11.9.1.1. If a wood heater fails to complete all four phases of the test run, the run shall be considered a failed test run.

11.9.1.2. If there is no weight change for a consecutive period of 20 minutes at any point during the test, the unit has failed the test run.

11.9.1.3. If the wood heater fails to comply with test protocol parameters

11.9.2. If a test run violates the parameters of the test method, the run is invalid.

11.9.3. If during certification testing a critical component of the stove is damaged or breaks, the certification test will be stopped and considered invalid.

11.9.3.1. If damage is noted during a test, repairs shall be made by the manufacturer (or by laboratory personnel with written direction from the manufacturer). If the repair involves components that would need aging, the appliance shall then undergo another round of wood heater aging as specified in section 10.6. These components may include but are not limited to catalyst elements, gaskets, and refractory components. The aging process is intended not only to 'cure' the stove but also to cycle parts that may fail with extended use. Alternate aging techniques may be approved by the administrator, depending on the nature of the failure, material, and critical nature.

11.10. Test Run Completion. Once three valid runs have been completed, the testing is complete. No additional runs may be completed.

11.10.1. *Additional Test Runs*. If there is an invalid run, may attempt two additional runs to complete the test series. If more than three test runs are conducted, the results from all valid test runs shall be used in calculating the average emission rate. The measurement data and results of all test runs shall be reported regardless of which values are used in calculating the emission rate. No test run data can be eliminated from the reporting requirements of this method.

11.10.2. *Invalid Runs.* When a test run fails to meet one of the QA/QC criteria stipulated in the test method, the data are invalid and the run must be repeated. Data for the invalidated test run must be included in the test report but the data must not be used in calculation of average emission values.

11.11. Auxiliary Wood Heater Equipment Operation. If optional heat exchange blowers are sold for use with the wood heater, three runs with the fan and an additional run without the fan shall be completed. If emissions are more than 1 gram per higher with the fan on, an additional two runs must be completed with the fan on. Heat exchange blowers shall operate in the highest airflow setting. (Automatically operated blowers shall be operated as designed) during the entire test.

11.12. PM Data Recording.

11.12.1. For tests using TEOM. All data shall be collected and recorded at intervals of no more than 1 minute. TEOM data shall be averaged up to 1-minute intervals for reporting. TEOM operation shall follow the procedures listed in NESCAUM Standard Operation Procedures for Thermo 1405-D TEOM for use in a dilution tunnel.

11.12.2. For tests using ASTM 2515 filter pulls

11.12.3. Data shall be reported in an Excel or compatible spreadsheet following the minimum data reporting requirements. All electronic files shall be submitted as part of the test report. Spreadsheet files shall be supplied as part of the publicly available test report.

12. Quality Control Measures

12.1. Dilution tunnel - Conduct sampling equipment leak check and calibration pre- and post-test.

12.2. TEOM – Flow and Leak checks are done before and after every test run per NESCAUM Standard Operation Procedures for Thermo 1405-D TEOM for use in a dilution tunnel.

12.3. Volume Metering System Checks.

13. Data Analysis and Calculations. –

NOTE: If a TEOM is used for PM measurement, proportioning of emission factors and rates per phase according to Appendix A, variables shall have subscript added to determine the relevancy of phase i.e. $E_{T(P1)}$ indicates Total particulate emissions for Phase 1 and $E_{g/hr(P2)}$ indicates emissions factor in grams per hour for Phase 2.

13.1. Emission Calculations. Particulate matter, carbon dioxide, and carbon monoxide shall be calculated using the following methodology and reported in grams per hour, grams per kilogram and pounds per million British Thermal Unit (BTU) heat output. All calculations shall be conducted using all decimal values provided by the instrumentation or recorded by the operator. No truncation of data is acceptable. Only the final calculation of the PM emissions rate shall be rounded, to three significant figures.

13.2. TEOM data shall be reported as follows.

13.2.1. Emissions from each of the 4 phases of the test shall be reported as individual results in grams per hour, grams per kilogram, and lb/MMBtu (heat output).

Emissions from the entire test run in grams per hour, grams per kilogram, and lb/MMBtu (heat output).

Nomenclature

$AER = Ei/\sum N$

BR – average dry fuel burn rate, lb./min

$BR_{(x)}$ – Burn rate for specific phase, BR_{L1}, BR_{L2}, BR_{L3}, BR_{L4}

CO – Carbon Monoxide

CO_2 – Carbon Dioxide

H_2- Hydrogen

O_2 – Oxygen
BT = time of 90% of overnight load consumed – time of overnight loading
C_{steel} − Specific heat of steel (0.1 Btu/ lb., ˚F)
E_T – Total particulate emissions for the full test run in grams
$E_{g/MJ}$ – PM Emissions rate in grams per megajoule of heat output
$E_{g/kg}$ – PM Emissions factor in grams per kilogram of dry fuel burned
$E_{g/hr}$ – PM Emissions factor in grams per hour
E_{Rco} – CO emission rate, g/hr.
EIi – Average CO emission index for interval i
E_{ICO} – CO emission index, g/kg dry fuel
EIco,avg – Average CO emission index for the run
HHV – Higher heating value of fuel = Use accredited test results
LHV – Lower heating value of fuel = Use accredited test results
$\%M_d$ = Fuel moisture content, dry basis, percent.
$\%M_w$ = Average moisture in test fuel charge, wet basis, percent
N = Total number of test runs.
PCTCO2– average CO_2 in the dry flue gas (%)
PPMco -average CO in the dry flue gas (ppm)
Q_{out} − Total heat output in BTU's (megajoules)
SC_i – Scale weight at specific time interval, lb.
$t_{(i)}$ − Data sampling interval in minutes
T1 – Surface Temperature 1 ˚F (˚C)
T2 – Surface Temperature 2 ˚F (˚C)
T3 – Surface Temperature 3 ˚F (˚C)
T4 – Surface Temperature 4 ˚F (˚C)
T5 – Surface Temperature 5 ˚F (˚C)
T6 – Pre Catalyst Temperature 1 ˚F (˚C)
T7 – Post Catalyst Temperature 2 ˚F (˚C)
T8 – Tunnel Temperature ˚F (˚C)
T9 - Flue Gas Temperature ˚F (˚C)
T10 – Room Temperature ˚F (˚C)
$TS_{avg(i)}$ – Initial Average Surface Temperature ˚F (˚C)
$TS_{avg(f)}$ – Final Average Surface Temperature ˚F (˚C)
W_{fuel} – Fuel charge weight in pounds (kg)
W_i – Weight of fuel in pounds (kg)
W_{app} − Weight of empty appliance in pounds (kg)
Θ – Total length of test run, hours
$\Theta_{(x)}$ – Total length of test run in hours per phase, X
$\%M_w = 100(\%M_d)/100+\%M_d$

13.3. Average Wood Heater Surface Temperatures. Calculate the average of the wood heater surface

temperatures at the start of the phase (L4) and end at the end of the test (L4) of the test run.

L4 $TS_{avg(i)}$ – (T1 + T2 + T3 + T4 + T5) / 5

L4 $TS_{avg(f)}$ – (T1 + T2 + T3 + T4 + T5) / 5

Average surface temperatures at the start and end of any phase can be determined by averaging all five sensors at the beginning and end of each phase.

L_x $TS_{avg(i)}$ – (T1 + T2 + T3 + T4 + T5) / 5

L_x $TS_{avg(f)}$ – (T1 + T2 + T3 + T4 + T5) / 5

13.4. Burn Time Rating– A standardized burn time rating shall be determined by rounding the duration of the overnight-fire phase of the test up to the nearest 1 hour. Burn time shall be calculated as the time L4 is loaded into the stove until 90% of the fuel has been consumed. This provides an important rating for consumers and is not intended for any calculation purposes and shall be reported on the all manufacturers materials that provides specifications on appliance performance. Language such as "this stove has demonstrated a low setting burn time of x hours in official testing"

13.5. Determine Burn Rates

BR_{L1} = not applicable

BR_{L2} = (L2 Initial SC_i – L2 Final SC_i) / $\Theta_{(L2)}$, lbs./hr

BR_{L3} = (L3 Initial SC_i – L3 Final SC_i) / $\Theta_{(L3)}$, lbs./hr

BR_{L4} = (L4 Initial SC_i – L4 Final SC_i) / $\Theta_{(L4)}$, lbs./hr

13.6. Emissions

13.6.1. Determine emission rates and emission factors as:

$E_{g/MJ} = E_T/(Q_{out} \times 0.001055)$, g/MJ

$E_{g/kg} = E_T/(W_{fuel}/(1+M\%M_d/100))$, g/dry kg

$E_{g/hr} = E_T/\Theta$, g/hr

13.7. Efficiency calculation.

Ultimate Analysis of dry fuel (% by weight)

Carbon – CA

Hydrogen – HY

Oxygen – OX

Moisture Content – mass of water per mass of dry fuel – Mcdb

Ambient Humidity Ratio – mass of water per unit mass of dry air – ω

Flue gas temperature (F) – Ts

Room temperature (F)-Tr

CO in the dry flue gas (ppm) – PPMco

CO2 in the dry flue gas (%) – PCTCO2

Higher heating value of the dry fuel (lb/MMBtu) – HHV

Combustion Balance Equation:

$$C_xH_yO_z + (1+\alpha)\bullet\gamma(O_2 + 3.76N_2) + \left[\omega\bullet\left(\frac{(1+\alpha)\bullet\gamma\bullet(32+3.76\bullet28)}{18}\right)+\frac{Mcdb}{18}\right]H_2O$$

$$\rightarrow (x-\beta)\,CO_2 + \beta CO + (\alpha\bullet\gamma+\frac{\beta}{2})\,O_2 + (1+\alpha)\bullet\gamma\bullet3.76\,N_2 + \left[\frac{y}{2}+\omega\bullet\left(\frac{(1+\alpha)\bullet\gamma\bullet(32+3.76\bullet28)}{18}\right)+\frac{Mcdb}{18}\right]H_2O$$

Where:

$x = CA/12$

$y = HY$

$z = OX/16$

$\gamma = (x+\frac{y}{4}-\frac{z}{2})$

$\alpha =$ excess air parameter, e.g. if $\alpha =$ 0.5 there is 50 % excess air

From this:

$$PPMco = \frac{1E6\square\beta}{x+\left(\alpha\square\gamma+\frac{\beta}{2}\right)+(1+\alpha)\square\gamma\square3.76}$$

$$PCTCO2 = \frac{100\square(x-\beta)}{x+\left(\alpha\square\gamma+\frac{\beta}{2}\right)+(1+\alpha)\square\gamma\square3.76}$$

With flue gas CO and CO_2 measured, these two equations can be solved simultaneously for β and α.

$$\beta = \frac{100 \cdot x \cdot PPMco}{1E6 \cdot PCTCO2 \cdot + 100 \cdot PPMco}$$

$$\alpha = \frac{\frac{100 \cdot (x - \beta)}{PCTCO2} - x - \frac{\beta}{2} - 3.76 \cdot \gamma}{4.76 \cdot \gamma}$$

Calculation of the Molar Coefficient for Each of the Products

For the assumption of 100 kg of dry fuel, this is the number of moles of each product for the input conditions

$MFCO = \beta$ Molar Coefficient for CO

$MFCO2 = x - \beta$ Molar Coefficient for CO_2

$MFH2O = \frac{\gamma}{2} + \frac{Mcdb}{18} + \frac{\omega \cdot (1+\alpha) \cdot \gamma \cdot (32 + 3.76 \cdot 28)}{18}$ Molar Coefficient for H_2O

$MFO2 = \alpha \cdot \gamma + \frac{\beta}{2}$ Molar Coefficient for O_2

$MFN2 = (1+\alpha) \cdot \gamma \cdot 3.76$ Molar Coefficient for N_2

Heat Capacity of Exhaust Products

The general equation for representing how the heat capacity of the exhaust products varies with temperature is:

$C = A \cdot Tk + B$

Where:

C = heat capacity J/mol K or kJ/kgmol K

A and B are constants

Tk = Temperature in °K

The values for A and B for the exhaust components are provided in the table below

Component	A	B
CO	.0056	27.162
CO2	.029	29.54
H2O	.0057	32.859
O2	.009	26.782
N2	.0062	26.626

For each component, heat capacity is calculated at the stack temperature and at room temperature. The average of these is used to calculate sensible heat loss.

Calculation of Heat Losses for Efficiency Determination

$HHVJ = HHV \square 2.326$ Higher heating value in kJ/kg (conversion from Btu/lb)

$LHWV = 43969$ Latent heat of water vapor in kJ/kgmol

$Llat = MFH2O \square LHWV / HHVJ$ Heat loss in latent heat of water vapor, % of input energy

$Lco = MFCO \square 282993 / HHVJ$ Heat loss in chemical energy in CO, % of input energy

$Lsens = (MFCO \square C\_COm + MFCO2 \square C\_CO2m + MFH2O \square C\_H2Om + MFO2 \square C\_O2m$

$+ MFN2 \square C\_N2) / HHVJ$ Heat loss in sensible heat in flue gas, % of input energy

$Efficiency = 100 - Llat - Lco - Lsens$ Stack loss efficiency, %

14. Reporting Requirements. The report shall include the following:

14.1.1. Introduction

14.1.2. Purpose of test: certification, audit, efficiency,

14.1.3. Name and location of the laboratory conducting the test.

14.1.4. Wood appliance identification – manufacturer, model number/name, design type, description of the appliance tested, stove condition, and date of receipt.

14.1.5. Test information – location of testing, date of tests, sampling methods used, number of test runs,

a statement detailing any previous certification testing completed on the wood appliance.

14.1.6. A list of people who conducted research on the appliance, participated in testing preparation, or witnessed the certification testing. This list shall clearly specify their roles in the testing program for the appliance. The list shall include the participant's name, title, company, contact information and the purpose of their participation.

14.1.7. A statement that the test results apply only to the specific appliance tested.

14.2. Summary and Discussion of Results

14.2.1. Table of results to include test run number, average burn rate for entire run and each phase, carbon monoxide and particulate emission rate for full run, particulate and carbon monoxide emission rate for each load phase (L1, L2, L3, L4), efficiency for the full run and each phase, burn time for total run and each phase. First hour PM emissions for each test run shall also be reported.

14.2.2. For each test run and pollutant with real-time data to include: Θ_1,Θ_2, Θ_3, CO, CO_2, PM, and efficiency for (1) L1 - the startup phase and (2) L2 - high-, (3) L3-maintenance-, and (4) L5 low burn rate fire phases. Calculated results for the emissions shall be reported as total emissions in grams, pounds per million Btu output, grams per MJ, grams per kilogram of dry fuel and grams per hour, and pounds per hour.

14.2.3. A narrative discussion detailing any issues or anomalies that arose during each test run and how those were handled, including comments about the fuel, and loading of the appliance.

14.2.4. A plot of CO emission rate in ppm vs. time, based on 1-minute averages, for the entire test period, for each run. The report shall include a table reporting the maximum 1-minute, 5-minute, and 60-minute grams per hour on a rolling basis for the test run.

14.2.5. A plot of CO_2 emission rate in ppm vs. time, based on 1-minute averages, for the entire test period, for each run. The report shall include a table reporting the maximum 1-minute, 5-minute, and 60-minute grams per hour on a rolling basis for the test run.

14.2.6. If a TEOM used:

14.2.6.1. a plot of PM emission rate in grams/hour vs. time, based on 1-minute averages, for the entire test period, for each run. The report shall include a table reporting the maximum 1-minute, 5-minute, and 60-minute grams per hour on a rolling basis for the test run.

14.2.6.2. A plot of PM emission rate in g/kg vs. time, based on 1-minute averages, for the entire test period, for each run. The report shall include a table reporting the maximum 1-minute, 5-minute, and 60-minute grams per hour on a rolling basis for the test run.

14.2.7. Summary of other data – test facility conditions, surface temperature averages, catalyst temperature averages, pretest fuel weights, test fuel charge weights – total and by phase.

14.3. Discussion. Test run result, specific test run problems, and solutions. Comments on fuel, loading, analysis, and anything that may impact the reported result(s).

14.3.1. Details of deviations from, additions to or exclusions from the test method, and their data quality implications on the test results (if any), as well as information on specific test conditions, such as

environmental conditions. An explanation of the deviations, additions, or exclusions shall be provided along with an analysis as to why these elements had no impact.

14.4. Process description:

14.4.1. Data and drawings indicating the firebox size and location of the fuel charge.

14.4.2. Drawings and calculations used to determine firebox volume to include volume, height, width, and lengths, weight, and volume adjustments.

14.4.3. Firebox configuration – At a minimum to include air supply locations and operation, air supply introduction location, refractory location and dimensions, catalyst location, baffle and by-pass location and operation (include line drawings or photographs)

14.4.4. Appliance operation during the test – shall supply details on air supply settings and adjustments.

14.5. Test fuel properties – the report shall provide information on the species, density, fuel moisture, fuel temperature, and load details from the fuel load calculator to include all measurements including the number of pieces, individual piece weights, piece length, moisture content and weight.

14.6. Sampling

14.6.1. A description of the test procedures and test equipment, including a schematic or other drawing showing the location of all required test equipment. Also, a description of test fuel sourcing, handling and storage practices shall be included.

14.6.2. Describe the sampling location relative to the wood heater, include drawing or photographs.

14.6.3. Provide data on sampling blanks.

14.7. Quality Control and Assurance Procedures

14.7.1. Calibration procedures and results certification procedures, sample and analysis procedures.

14.7.2. Test method quality control procedures to include TEOM leak and flow checks, stratification (velocity) checks, tunnel flow range results, filter temperature range verification and dilution tunnel RH verification.

14.8. Appendices

14.8.1. Results and Example Calculations. Raw data and complete calculations for data included in summary tables.

14.8.2. Raw data. Copies of all files or sheets for sampling measurement, temperature records, and other materials used by lab related to testing.

14.8.3. Calibration Results. Summary of all calibrations, check, and audits pertinent to the certification.

14.8.4. Sampling and Operation Records. Copies of all uncorrected records of activities not included in raw data sheets (e.g., wood heater door open, times and durations) as well as photographs of fuel loading and air flow settings.

14.8.5. Correspondence. Any correspondence to include written, electronic or verbal communications regarding appliance testing. Items shall include:

14.8.5.1.Request to conduct testing

14.8.5.2.Scheduling of testing

14.8.5.3. Notice to EPA to conduct test, and any modifications to that request.

14.8.5.4. Notice and submission of data to EPA after testing completed.

14.8.6.Test Facility Information. Report test facility temperature, air velocity, and humidity information.

14.8.7.Test Equipment Calibration and Audit Information. Report calibration and audit results for the platform scale, test fuel balance, test fuel moisture meter, and sampling equipment including volume metering systems and gaseous analyzers.

14.8.8.Pretest procedures. Report all pretest procedures conducted at the lab on the appliance to burns, rates, and amounts.

14.8.9.All required data for each test run shall be provided in spreadsheet format both in the printed report and in a computer file such that the data can be easily analyzed and calculations easily verified. Formulas used for all calculations shall be accessible for review.

14.8.10.For each test run: report TEOM flow and temperature and verification of all TEOM data validation parameters as required in NESCAUM Standard Operation Procedures for Thermo 1405-D TEOM for use in a dilution tunnel.

14.8.11.Raw data, calibration records, and other relevant documentation shall be retained by the laboratory for a minimum of 7 years.