**INTRODUCTION**

This document provides a systematic guide for the technician conducting tests to EPA Method 28 OWHH for Measurement of Particulate Emissions and Heating Efficiency of Outdoor Wood-Fired Hydronic Heating Appliances. This guide cannot cover every possible contingency that may develop during a particular test program. Many questions that may arise can be answered by a complete understanding of the test protocol and its intent. When in doubt on any detail check with the laboratory manager and be sure you understand the procedures involved.

The primary measurements to be obtained are particulate emission data and efficiency data. The technician's duties include the following steps. It is critical that all spaces on the data forms be properly filled in. Each test must be represented by a complete record of what was done and when.

I. APPLIANCE INSPECTION AND SET-UP
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II. SAMPLING SYSTEMS - SET-UP
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   - B. Dilution Tunnel

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The technician running this test must be familiar with the following documents that are to be kept in the laboratory at all times.

1. ASTM E2515
2. EPA Method 28 OWHH for Measurement of Particulate Emissions and Heating Efficiency of Outdoor Wood-Fired Hydronic Heating Appliances

# I. APPLIANCE INSPECTION AND SET-UP

## A. Incoming Inspection

1. Check for completeness of unit including parts, accessories, installation and operating instructions, drawings and specifications, etc. Note any discrepancies or missing parts.
2. Check for shipping damage. If damage has occurred, notify the laboratory manager. In some cases repairs may be made, provided the manufacturer and laboratory manager concur that repairs will not affect the units performance. If damage is irreparable, a new unit will need to be obtained.
3. Note whether unit is catalytic or non-catalytic.
4. Mark unit with manufacturer's name, model number, work order number, and date received.
5. If unit is safety listed, note label data including listing agency and serial number.

## B. Unit Set-Up

1. Install a thermocouple tree with at least 6 junctions distributed as so an average water temperature can be measured. Check with the laboratory manager if problems are encountered in proper thermocouple attachment.
2. Prior to placing unit on scale, the scale must be turned on and allowed to warm up for 1-hour minimum.
3. Place unit on scale and align so chimney will be centered in hood. Record the weight of the unit and all accessories. (Do not weigh with chimney attached.)
4. Chimney and connector should be cleaned with a wire brush prior to mounting. Attach chimney and connector then seal all joints. Be sure the single wall stove pipe terminates and insulated pipe starts at proper level above scale platform. Chimney must be supported from scale so that it does not touch test enclosure or hood walls.
5. Measure firebox dimensions and record on appropriate data form. Make a three dimensional sketch of the firebox including firebrick, baffles, and obstructions. Calculate load area volume in cubic feet. See Section 12.2.2 of the EPA Method 28 OWHH for Measurement of Particulate Emissions and Heating Efficiency of Outdoor Wood-Fired Hydronic Heating Appliances for details.
7. Plug thermocouples into data acquisition system jacks and verify that all instrumentation is working properly.
8. Dilution tunnel must be cleaned prior to each certification test series, and at anytime a higher burn rate follows a lower burn rate.

## II. SAMPLING SYSTEMS SET-UP

### A. Gas Analysis

1. All instruments should be turned on and allowed to warm up for 1-hour minimum.
2. Prior to calibrating, make sure that the outlet pressure on each calibration gas bottle reads 10 PSI. Adjust flow meters at each gas analyzer to required flow.

All gas analyzers ($CO_2$, CO, $O_2$) are zeroed on nitrogen. The $O_2$ analyzer is spanned on air and set for 20.93%. $CO_2$ and CO analyzers are spanned with their respective gases.

Calibrate analyzers as follows:

a. With calibration switch at "SPAN", adjust all span controls to values specified on span gas label.
b. Switch to "ZERO" and adjust zero controls to provide 0.00 readout on all analyzers.
c. Repeat a. and b. until no further adjustment is required.
d. Record these values on the appropriate data sheet.
e. Switch to "CAL." and record all analyzer values.

3. Response time synchronization check.

a. With switch at "SAMPLE" and no fire in unit, allow readings to stabilize ($O_2$ analyzer should read 20.93, CO and $CO_2$ should read 0.00).
b. Switch to "CAL" setting and start the stopwatch. Note the time required for each unit to reach the calibration gas bottle value. If all three analyzers reach this value within 5 seconds of each other, synchronization is adequate. If not, contact the laboratory manager. Synchronization is adjusted by either internal instrument setting or adjustment of sample line length.
c. Use section 8 of ASTM E2515 for procedures to check calibration of instruments.

4. Sample clean-up train.

   a. Load a new filter in 4-inch glass filter holder.
   b. Load four Impingers as follows:
      #1: 100 ml. distilled water and 5 ml. $H_2SO_4$
      #2: 100 ml. distilled water and 5 ml. $H_2SO_4$
      #3: Empty
      #4: 200-300 grams Drierite.

   c. Place Impingers in container and connect with greased "U TUBES". (Grease carefully on bottom half of ball joint so that grease will not get into tubes.)
   d. Connect filter to impinger #1 and sample line to impinger #4.
   e. Connect stack probe to filter.
   f. Leak check system as follows:
      1) Plug probe.
      2) Turn on sample system and increase flow rate slowly.
      3) Set vacuum-adjust valve to obtain a vacuum of 10 inches mercury.
      4) If sapphire float in rotometer does not stabilize below 10 on scale, system must be resealed.
      5) Repeat leak-check procedure until satisfactory results are obtained.
      6) Unplug probe slowly, then decrease flow rate slowly before shutting off system.

   g. Just prior to starting test, fill impinger container with ice.

B. Dilution Tunnel Sample Train Set-Up:

1. Filters and holders.

   a. Clean probes and filter holder front housings carefully and desiccate to a constant weight prior to use.
   b. Filters and filter probe combinations should be numbered and labeled prior to use.
   c. Weigh desiccated filters and probe filter units on analytical balance. Record the weights on the appropriate form. Note that the probe and front half of the front filter holder is to be weighed as a unit.
   d. Carefully assemble the filter holder units and connect to sampling systems.

2. Leak checking.

   a. Each sample system is to be checked for leakage prior to inserting probes in tunnel.
   b. Plug probes and start the samplers. Adjust pump bypass valve to produce a vacuum reading of 10 inches mercury. NOTE: During test, highest vacuum recorded is required for posttest leak check.
   c. Allow vacuum indication to stabilize at 10" mercury, record dry gas meter readings, ($DGM_1$, $DGM_2$). At a convenient DGM value start stopwatch. Time for 1 minute then stop vacuum pumps. Record dry gas meter readings again, ($DGM_3$, $DGM_4$). NOTE: If rotometer ball is floating above the 5-mm mark, system is leaking too much and all seals should be checked.
   d. Calculate leakage rate as follows.

      System 1: $DGM3-DGM_1 = CFM_1$
      System 2: $DGM4-DGM_2 = CFM_2$

      If $CFM_1$ or $CFM_2$ is greater than 0.02 cfm, or $_1S$ greater than 0.04 x Sample Rate, leakage is unacceptable and system must be resealed.
      For most tests the sample rate will be 0.25 cfm, thus leakage rates in excess of 0.04 x 0.25 = 0.010 cfm are not acceptable.
   e. To prevent contamination, do not insert probes in tunnel until the start of the test run.

## III. TEST CONDUCT

### A. Pre-Test Fuel Load

1. Using oak wood, until the water is heated and has cycled at least 2 times. Then remove all contents and zero scale
2. Reload with oak wood (pieces approximately 2" thick) and allow to burn down to specified coal bed weight.

### B. Test Fuel Load

1. Determine optimum load weight by multiplying loading area volume ($ft^3$) by 10lbs./$ft^3$. This is the ideal load weight.
2. Test load fuel shall be red or white oak with a dimension of 4"x4" and a length 80% of the firebox depth (± 1"). Moisture content needs to be within 20-25%.
3. Weigh out test load and adjust weight by shortening or lengthening all pieces equally if necessary.
4. Measure and record moisture content of each fuel piece (use three sides). Determine if fuel load moisture content is within required range (20-25%). If not, construct new fuel pieces using wood with required moisture content. Contact laboratory manager if you cannot find suitable pieces.

### C. Unit Start-Up

1. With all doors and air controls closed, zero draft magnehelic using screw located at bottom of meter.
2. Before lighting a fire turn on dilution tunnel and set flow rate to 60 scfm.
3. Check draft imposed on cold stove. All inlets must be closed and a draft gauge in the chimney. If draft is greater than 0.005 inches water column, adjust tunnel to stack gap until draft is less than 0.005 inches water column.
4. With hot wire anemometer check for ambient airflow around unit (must be less than 50 ft/min).
5. Zero scale and start fire with newspaper and kindling. (Make sure stack sample probe is on the unit.)
6. Once kindling is burning well, add preload fuel. Operate at high fire for sufficient time to get fuel load burning well. Then adjust settings to intended test run levels.
7. Perform the dilution tunnel traverse as prescribed in Method 28, Section 6.3. (Pitot tube should be carefully cleaned prior to each test.)
8. Pretest load must burn until the unit has cycled at least 2 times.
9. Stir fire often during preburn (after a reading) to get a good coal bed. Fire can only be raked once (door open 1 minute or less) during the 15 minutes prior to the start of the test.

D. Test Run

1. Stack gas analyzers should be on and in the sample mode.
2. When the fuel bed is between 10-15% of the test load weight the test is to be started.

    a. Insert the sample probes into the tunnel being careful not to hit sides of tunnel with probe tip.
    b. Check tunnel Pitot tube for proper position.
    c. Record initial readings.
    d. Turn on probe sample systems and start timing test.
    e. Tare platform scale.
    f. Open stove doors and load stove. Close door or follow manufacturer's start-up procedures. Five minutes is the maximum time before all doors and controls must be set to final positions for duration of test.
    g. Record length of time door and bypass are open, include any air control setting adjustments.
    h. Every 10 minutes record the following:

        1) Dry gas meter readings.
        2) Weight remaining.
        3) All thermocouple temperatures.
        4) Tunnel Pitot tube reading.
        5) Draft reading.
        6) Rotometer readings.

    i. Filter temperatures shall not exceed 90ºF anytime during the test. If the filters are approaching 90ºF turn on cooling pump. Filters must be kept above the dilution tunnel wet bulb temperature in order to prevent condensation.
    j. Regularly check impinger train for ice level during test.
    k. After 30 seconds of 0.00 lbs. weight, and on the minute, shut off sample trains and record last reading.
    l. Record final dry gas meter values.

## IV. POST TEST PROCEDURES

### A. Leak Checks

1. Dilution Tunnel

    a. Remove both sample probes from tunnel and plug with rubber stopper.
    b. Turn on sample system and set vacuum to 10" mercury or to the highest value reached during the test.
    c. At a convenient value start stopwatch and record the DGM starting value.
    d. After 1 minute stop sample system and record ending DGM value.
    e. Calculate leakage rate per pre-test description (see II.B.2.c.).

2. Gas Analyzers

    a. Set stack sample flow to about 75 mm on the rotometer.
    b. Plug with rubber stopper.
    c. Adjust vacuum to 10" mercury.
    d. Let system stabilize then record rotometer readings.
    e. If the rotometer readings do not equal zero, check with the laboratory manager.
    f. SLOWLY unplug probe and decrease flow rate to zero.
    g. Turn off stack sampling system.
    h. Zero, span and calibrate the analyzers (see Gas Analysis). RECORD ONLY these meter values.

### B. Particulate Sample Recovery

1. Disassemble filter holder and scrape gasket with scalpel. Collect all loose material on filters.
2. Weigh and record probes and filters for each train. NOTE: 24 hours of desiccation must pass before final "no change" weight values can be recorded.
3. Weigh and record probes and fillers at 6-hour intervals until weight change between weighing is less than 0.2 mg.