



Designation: E3053 – 18<sup>ε</sup><sup>1</sup>

# Standard Test Method for Determining Particulate Matter Emissions from Wood Heaters Using Cordwood Test Fuel<sup>1</sup>

This standard is issued under the fixed designation E3053; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

<sup>ε</sup><sup>1</sup> NOTE—Section references in 8.4.2.3 were corrected editorially in October 2018.

## 1. Scope

1.1 This test method covers the fueling and operating protocol for determining average particulate matter emissions from wood fires in wood-burning room heaters and fireplace inserts as well as options for determining heat output, efficiency, and carbon monoxide emissions.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* Refer to 4.3.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

- D7438 Practice for Field Calibration and Application of Hand-Held Moisture Meters
- E176 Terminology of Fire Standards
- E631 Terminology of Building Constructions
- E2515 Test Method for Determination of Particulate Matter

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.54 on Solid Fuel Burning Appliances.

Current edition approved April 1, 2018. Published May 2018. Originally approved in 2017. Last previous edition approved in 2017 as E3053–17. DOI: 10.1520/E3053–18E01.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

Emissions Collected by a Dilution Tunnel  
E2780 Test Method for Determining Particulate Matter Emissions from Wood Heaters

2.2 *Other Standards:*

- ANSI/UL-103 Standard for Factory-Built Chimneys for Residential Type and Building Heating Appliances<sup>3</sup>
- CSA B415.1 Performance testing of solid-fuel-burning heating appliances<sup>4</sup>
- NIST Monograph 175 Temperature-Electromotive Force Reference Functions and Tables for the Letter-Designated Thermocouple Types Based on the ITS-90<sup>5</sup>
- NIST 105-1: Specifications and Tolerances for Field Standard Weights (NIST Class F)<sup>5</sup>

2.3 *ASTM Adjunct:*<sup>6</sup>

Adjunct to ASTM E3053, Excel<sup>7</sup> Files for Cordwood Calculator and Wood Heater Cordwood Test Summary

## 3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of general terms related to building construction used in this test method, refer to Terminology E631.

3.1.2 For definitions of general terms related to fire testing used in this test method, refer to Terminology E176.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *burn rate, n*—the rate at which fuel is consumed in a wood heater.

3.2.2 *combustion air control, n*—an air control device that regulates air to the wood heater that is primarily intended to promote pyrolysis of the fuel load.

3.2.3 *cordwood, n*—conventional firewood, it is typically round wood 12 to 24 in. (300 to 600 mm) long that has been

<sup>3</sup> Available from Underwriters Laboratories (UL), 2600 N.W. Lake Rd., Camas, WA 98607-8542, <http://www.ul.com>.

<sup>4</sup> Available from Canadian Standards Association (CSA), 178 Rexdale Blvd., Toronto, ON, Canada M9W 1R3, <http://www.csagroup.org>.

<sup>5</sup> Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, <http://www.nist.gov>.

<sup>6</sup> Available from ASTM International Headquarters. Order Adjunct No. ADJE305317-EA. Original adjunct produced in 2017.

<sup>7</sup> Excel is a registered trademark of Microsoft Corporation.

split into triangular, half-round, quarter-round, wedge-shaped, or trapezoidal segments.

3.2.4 *firebox, n*—the chamber in the wood heater in which the test fuel load is placed and combusted.

3.2.5 *firebox height, n*—unless otherwise specified in the manufacturer’s written instructions included with the heater, firebox height is the vertical distance extending above the loading door, if fuel could reasonably occupy that space, but not more than 2 in. (50 mm) above the top (peak height) of the loading door, to the floor of the firebox, (that is, below a permanent grate) if the grate allows a 1-in. (25-mm) diameter piece of fuel to pass through the grate, or, if not, to the top of the grate.

3.2.5.1 *Discussion*—Firebox height is not necessarily uniform. Variations are caused by internal baffles, air channels, or other permanent obstructions. A visible indicator or landmark within the firebox that will provide a clear indication to the heater user of the maximum height that fuel should be loaded, and is specifically referenced in the manufacturer’s written instructions, may be used to determine firebox height for the purposes of calculating usable firebox volume.

3.2.6 *firebox length, n*—the longest horizontal firebox dimension where fuel pieces might reasonably be expected to be placed in accordance with the manufacturer’s written instructions that is parallel to a wall of the chamber, in. (mm).

3.2.7 *firebox width, n*—the shortest horizontal firebox dimension where fuel pieces might reasonably be expected to be placed in accordance with the manufacturer’s written instructions that is parallel to a wall of the chamber, in. (mm).

3.2.8 *fuel piece length, n*—the nominal length of the cordwood fuel pieces that comprise the test fuel load, in. (mm).

3.2.9 *kindling, n*—split cordwood fuel pieces used to ignite the start-up fuel and the test fuel load from a cold start condition. Applies to high fire test runs only.

3.2.10 *manufacturer’s written instructions, n*—specific information regarding the fueling and operation procedures recommended by the heater manufacturer and included with the heater at the time of testing.

3.2.10.1 *Discussion*—These instructions may include specific kindling and fueling instructions and recommendations such as kindling dimensions and placement (including newspaper) and ignition, dimensions of start-up fuel pieces, addition and placement of the start-up fuel, addition and placement of the main fuel load, position of the load door(s), and setting heater controls (including bypass dampers, if applicable) during start-up and subsequent operation. Instructions for refueling a hot heater when residual fuel and charcoal are present in the firebox also may be included. These instructions must be consistent with information provided to the heater end-user in the owner’s manual but also may include information that will be useful only during testing and not to the end-user.

3.2.11 *owner’s manual, n*—written information provided to the wood heater end-user regarding the proper installation and operation of the wood heater.

3.2.11.1 *Discussion*—Includes recommended kindling, fueling, and operating procedures that will help the heater user

to achieve the best heater emissions and efficiency performance. It also is referred to as the installation and operation guide or other equivalent title.

3.2.12 *particulate matter (PM), n*—all gas-borne matter resulting from combustion of solid fuel, as specified in this test method, which is collected in accordance with Test Method E2515.

3.2.13 *primary combustion air control(s), n*—an air control device (s) that regulates airflow to the wood heater that is primarily intended to regulate the rate of fuel consumption and heat output.

3.2.13.1 *Discussion*—There may be single, multiple, or automatic primary air controls.

3.2.14 *residual start-up fuel, n*—leftover fuel present in the firebox at the time the test fuel load is added during high fire test runs.

3.2.14.1 *Discussion*—May include charcoal and partially burned or unburned kindling and/or start-up fuel.

3.2.15 *secondary combustion air control(s), n*—an air control device(s) that regulates airflow to the wood heater that is primarily intended to provide the additional oxygen needed to promote secondary combustion of the combustible materials released during pyrolysis of the fuel.

3.2.15.1 *Discussion*—There may be single, multiple, or automatic secondary combustion air controls.

3.2.16 *single burn rate heater, n*—wood heater without user-adjustable primary combustion air control(s).

3.2.17 *start-up fuel, n*—split cordwood pieces intended to provide residual fuel (charcoal or partially burned wood) for ignition of the test fuel load. Applies to high fire test runs only.

3.2.18 *test facility, n*—the area in which the wood heater is installed, operated, and sampled for emissions and efficiency.

3.2.19 *test fuel load, n*—a specified grouping of test fuel pieces.

3.2.20 *test fuel loading density, n*—the weight of the as-fired test fuel load per unit volume of usable firebox, lb/ft<sup>3</sup>(kg/m<sup>3</sup>).

3.2.21 *test fuel pieces, n*—the individual cordwood pieces that comprise the test fuel load.

3.2.22 *test fuel specific gravity, n*—the nominal dry basis (oven dry weight and oven dry volume) specific gravity of test fuel load, kindling, and start-up fuel.

3.2.23 *test fuel sub-load, n*—a division of the test fuel load for the sole purposes of specifying the test fuel pieces that comprise the test fuel load.

3.2.24 *test run, n*—an individual emission/efficiency test.

3.2.25 *test series, n*—a group of test runs on the same wood heater which includes at least one test run in each burn rate category.

3.2.26 *usable firebox volume, n*—the volume of the firebox determined using its height, length, and width as defined in this section, ft<sup>3</sup> (m<sup>3</sup>).

3.2.27 *wood heater, n*—an enclosed, wood burning appliance capable of, and intended for, space heating and/or domestic water heating. This includes wood heaters designed

for installation in a fireplace cavity, that is, fireplace inserts, and wood heaters that are built into a wall. Includes adjustable burn rate and single burn rate wood heaters.

3.2.28 *wood heater empty weight, n*—the weight of the cleaned, dry wood heater with or without dry ash or sand added consistent with the manufacturer’s written instructions, lb (kg).

#### 4. Summary of Test Method<sup>8</sup>

4.1 This test method is used in conjunction with Test Method E2515. The wood heater under evaluation is fueled by cordwood test fuel loads. Test runs employ either a hot-to-hot cycle or a cold-to-hot cycle depending on the burn rate category of the test run. The test fuel pieces must be within the allowable range of specific gravity. The test fuel load weight and composition is determined based on the usable firebox volume of the heater. For low and medium fire test runs, a charcoal bed is established by conducting a full high fire test run. That high fire test run may be an actual test run or may be just for the purpose of establishing the charcoal bed for a low or medium fire test run. The test fuel load is placed on the charcoal bed and given time to ignite before the air control(s) is (are) set to the test run condition.

4.1.1 For the low and medium fire test runs, particulate emission sampling and efficiency measurements begin immediately prior to addition of the test fuel load to the firebox and end when the test run is terminated in accordance with the specifications in the method.

4.1.2 For the high fire test runs, the test run for the purposes of determining emission rate or emission factor begins with a cold (see 8.5.1) empty (see 8.2.1) firebox. Kindling (and crumpled newspaper, if specified) are used to ignite start-up fuel pieces which, in turn, are used to ignite the test fuel load following manufacturer’s written instructions. Particulate emission sampling begins before the kindling is ignited and ends when the test run is terminated in accordance with the specifications in the method.

4.1.3 For low fire, medium fire, and high fire test runs, efficiency is determined on a hot-to-hot cycle and efficiency parameter measurements begin when the test fuel load is added to the firebox and end when the test run is terminated in accordance with the specifications in the method.

4.1.4 For low fire, medium fire, and high fire test runs, average burn rate is determined on a hot-to-hot basis and is based on the weight of the portion of the test fuel load burned during the test run divided by the duration of the test run beginning when the test fuel load is added to the firebox and ending when the test run is terminated. Burn rate for all test runs is adjusted to a dry fuel weight basis.

4.1.5 The total particulate emissions are determined over the test run duration. The particulate emissions rate is then determined from the total particulate emissions divided by the duration of the test run and is reported in grams of particulate per hour. The test run duration for the high fire test for purposes of determining particulate emission rate includes the kindling and start-up fuel period before the test fuel load is added to the firebox. The particulate emission factor lb/lb (g/kg) also may

be determined from the total particulate emissions divided by the dry basis weight of the total fuel weight burned and is reported in pounds of particulate per dry pound of fuel (grams of particulate per dry kilogram of fuel). For high fire test runs, the total test fuel weight when determining emission factor includes any kindling and start-up fuel consumed before the test fuel load is added less any fuel remaining at the end of the test run.

4.1.6 This test method also may be used in conjunction with Annex A1 and CSA B415.1 for determining heat output and efficiency. If heat output and efficiency are determined, particulate emissions per unit of heat output also may be calculated and is reported in pounds of particulate per million Btu of heat output (grams of particulate per megajoule). For low and medium fire test runs, the efficiency, heat output, and particulate emissions per unit of heat output are determined on a hot-to-hot cycle. For high fire test runs, particulate emissions are determined for the entire test run, including the cold start (kindling and start-up) portion. However, the kindling and start-up portions of the test run are excluded from the efficiency and heat output determination. For the determination of particulate emissions per unit of heat output, a different approach must be taken. The hot-to-hot efficiency value is applied to the total fuel burned, including kindling and start-up fuel, to determine the heat output that corresponds to the measured emissions.

4.2 This test method may be used to measure emissions and efficiency from wood heaters with adjustable heat output rates (user-adjustable primary air combustion controls) or “Single Burn Rate” wood heaters (no user adjustable primary combustion air controls). A test series for wood heaters with adjustable primary combustion air controls shall include at least one test run from each of the three burn rate categories: high fire, medium fire, and low fire. For single burn rate wood heaters, a test series shall include at least one test in the high fire category and at least one test in the low fire category. In the case of the low fire test, all references to use of primary combustion air controls, burn duration, and burn rate shall be disregarded since single burn rate heaters have no user-adjustable primary air controls.

4.3 **Warning**—This test method may involve hazardous materials, operations, and equipment.

#### 5. Significance and Use

5.1 This test method is used for determining particulate matter (PM) emission rates and emission factors for wood heaters.

5.2 This method is used in conjunction with Annex A2 for determining particulate matter (PM) emissions for Single Burn Rate heaters.

5.3 Use of this test method in conjunction with Annex A1 and CSA B415.1 allows overall thermal efficiency, carbon monoxide emission rate, and particulate matter per unit of heat output to be determined.

5.4 The fuel load specified in this test method is cordwood that is representative of the fuel actually burned in homes. The intent is that the results from this test method will be more

<sup>8</sup> This method supersedes Test Method E2780 Annex A1.



predictive of in-home performance than other test methods using a lumber crib of uniform dimensions.

## 6. Equipment and Supplies

6.1 *Wood Moisture Meter*—Calibrated electrical resistance meter capable of measuring test fuel moisture content with an accuracy of  $\pm 2\%$  moisture content dry basis. Must meet the calibration requirements specified in 7.1.

6.2 *Test Fuel Scale*—A scale capable of weighing test fuel to within  $\pm 0.01$  lb (0.005 kg). Must meet the calibration requirements specified in 7.3.

6.3 *Platform Scale*—A scale capable of weighing the test wood heater and attached chimney, including the weight of the test fuel, to within  $\pm 0.1$  lb (0.05 kg). Must meet the calibration requirements specified in 7.2.

6.4 *Wood Heater Flue Gas Temperature Measurement Device*—A 0.125-in. (3.2-mm) diameter sheathed, non-isolated junction Type K thermocouple capable of measuring flue gas temperature with an accuracy of  $\pm 4.0$  °F (2.2 °C) or  $\pm 0.75\%$  of the reading, whichever is greater. Must meet calibration requirements specified in 7.4.

6.5 *Wood Heater Surface Temperature Measuring Device*—A temperature sensor capable of measuring surface temperatures with an accuracy of  $\pm 4.0$  °F (2.2 °C) or  $\pm 0.75\%$  of the reading, whichever is greater. Must meet calibration requirements specified in 7.4.

6.6 *Catalytic Combustor Exit Temperature Measuring Device*—A temperature sensor capable of measuring the temperature of the gases exiting the catalytic combustor in a catalyst equipped heater with an accuracy of  $\pm 4.0$  °F (2.2 °C) or  $\pm 0.75\%$  of the reading, whichever is greater. Must meet calibration requirements specified in 7.4.

6.7 *Insulated Solid Pack Chimney*—Chimney used for installation of wood heater in the test facility. Solid pack insulated chimneys shall have a minimum of 1 in. (25 mm) solid pack insulating material surrounding the entire flue and possess a label demonstrating conformance to ANSI/UL-103 Standard for Factory-Built Chimneys for Residential Type and Building Heating Appliances.

## 7. Calibration and Standardization

7.1 *Wood Moisture Meter*—Calibrate in accordance with the manufacturer's instructions before each certification test run. Additional information regarding wood moisture meter calibrations can be found in Practice D7438.

7.2 *Platform Scale*—Perform a multipoint 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 run, audit the scale with the test wood heater in place by weighing at least one calibration weight (NIST 105-1 Class F) that corresponds to between 20 and 80 % of the expected test fuel load weight. If the scale cannot reproduce the value of the calibration weight within 0.1 lb (0.05 kg) or 1 % of the expected test fuel load weight, whichever is greater, recalibrate

the scale before use with at least five calibration weights spanning the operational range of the scale.

7.3 *Test Fuel Scale*—Perform a multipoint calibration (at least five points spanning the operational range) of the test fuel scale before its initial use. The scale manufacturer's calibration results are sufficient for this purpose. Before each certification test run, audit the scale by weighing at least one calibration weight (NIST 105-1 Class F) that corresponds to between 20 and 80 % of either the expected test fuel piece weight or test fuel load weight. If the scale cannot reproduce the value of the calibration weight within 0.01 lb (0.005 kg) or 1 % of the expected test fuel load weight, whichever is greater, recalibrate the scale before use with at least five calibration weights spanning the operational range of the scale.

7.4 *Temperature Sensors*—Temperature measuring equipment shall be calibrated before initial use and at least semi-annually thereafter. Calibrations shall be in compliance with NIST Monograph 175 Temperature-Electromotive Force Reference Functions and Tables for the Letter-Designated Thermocouple Types Based on the ITS-90.

## 8. Procedure

8.1 *Pre-conditioning of the Wood Heater*—The wood heater must be pre-conditioned before a test series begins according to the following steps:

8.1.1 Set up the wood heater in accordance with the manufacturer's written instructions. This includes adding dry sand or dry ash to the bottom of the firebox, if applicable.

8.1.2 The total height of chimney when measured from the floor or top of the platform scale (if the wood heater is on the platform scale) shall be  $15 \pm 1$  ft ( $4.6 \pm 0.3$  m).

8.1.3 Install a flue-gas temperature measurement device at the center of the flue,  $8.0 \pm 0.5$  ft ( $2.44 \pm 0.15$  m) above the floor or top of the platform scale. For catalyst-equipped heaters, install a catalytic combustor exit temperature measurement device at the centroid of the catalytic combustor exit face and within 1 in. (25 mm) downstream of the catalytic combustor exit face. The centroid of catalytic combustor exit is a 2-in. (50-mm) diameter area around the geometric center of the catalytic combustor exit face. For circular shapes, the geometric center is the center of the circle. For rectangular shapes, the geometric center is the intersection of the two diagonal lines from opposite corners.

8.1.4 Operate the wood heater for at least 50 h at a medium combustion air setting using fuel meeting the specifications in 8.4 or with any type of untreated wood with a moisture content between 18 and 28 % dry basis. Untreated wood is wood fuel that has never been chemically treated (including pressure treating, painting, or staining) or that has not been exposed to salt water. The hours of operation do not need to be continuous. The conditioning may be conducted at the manufacturer's facility as long as full documentation for 8.1.5 – 8.1.7 is provided to the laboratory for inclusion in the test report. The manufacturer's test equipment must meet the applicable requirements in Sections 6 and 7.

8.1.5 Record the time, weight, and moisture content for all fuel added.

8.1.6 Record the flue-gas temperature at least once during each hour of operation.

8.1.7 For catalyst-equipped wood heaters, record the hourly catalytic combustor exit temperature.

8.1.8 Allow the wood heater to cool to room temperature and remove all unburned wood, charcoal, ash, or other debris from the firebox.

8.1.9 Clean the chimney using a standard chimney brush appropriately sized for the chimney.

8.2 Install the wood heater in the test facility.

8.2.1 Set up the wood heater in accordance with the manufacturer's written instructions. This includes adding dry sand or dry ash to the bottom of the firebox, if applicable.

8.2.2 Place the wood heater centrally on the platform scale.

8.2.3 The venting shall consist of single wall steel flue pipe extending to  $8.5 \pm 0.5$  ft ( $2.6 \pm 0.1$  m) above the top of the platform scale, and above this level, insulated solid pack type chimney extending to  $15 \pm 1$  ft ( $4.6 \pm 0.3$  m) above the platform scale, and of the size specified in the manufacturer's written instructions. This applies to both freestanding and fireplace insert type wood heaters. Do not install a chimney cap.

8.2.3.1 Other chimney types (for example, solid pack insulated pipe or double wall flue pipe) shall be used in place of the steel flue pipe if the wood heater manufacturer's written appliance specifications require such chimney for home installation. The flue pipe and chimney used for testing shall be documented in the test data and test report.

8.2.4 Locate wood heater surface temperature measuring devices at five locations on the wood heater firebox exterior surface. Position the temperature monitors centrally on the top surface, on two sidewall surfaces, and on the bottom and back surfaces. Position the monitor sensing tip on the firebox exterior surface inside of any heat shield, air circulation walls, or other wall or shield separated from the firebox exterior surface.

8.2.4.1 The wood heater firebox surface temperature sensors may be wired together in a parallel circuit that provides a single reading of the average firebox surface temperature in lieu of recording individual readings. To get a true average temperature, the thermocouples must be the same length or have the same resistance.

8.2.5 Center the flue outlet (chimney) under the dilution tunnel hood. Refer to Test Method E2515 for specific requirements including positioning the flue outlet to meet induced draft and smoke capture requirements.

8.2.6 Install a flue-gas temperature measurement device at the center of the flue,  $8.0 \pm 0.5$  ft ( $2.44 \pm 0.15$  m) above the top of the platform scale.

8.2.7 Photograph or video the completed test installation (including venting) showing front, rear, and side views.

8.3 *Usable Firebox Volume Determination*—Determine the firebox volume, ft<sup>3</sup> (m<sup>3</sup>), using the definitions for firebox height, width, and length in Section 3. Follow the manufacturer's written instructions for where fuel should or should not be placed in the firebox when determining usable firebox volume.

8.4 *Fuel*:

8.4.1 *Test Fuel Load Requirements*:

8.4.1.1 The nominal test fuel load weight shall be determined by multiplying the Usable Firebox Volume (UFV) per 8.3 times the specified nominal load density for the applicable test run (Low, High, or Medium Fire) per 8.5 or 8.6.

8.4.1.2 For the sole purpose of determining the overall composition of the test fuel load, the test fuel load shall be considered to be comprised of two sub-loads. Once determined and assembled, the two sub-loads are combined to form the test fuel load that will be added to the firebox during the test run in accordance with the requirements of 8.5.9.3 or 8.6.5.

8.4.1.3 The core sub-load is comprised of three fuel pieces with a combined weight between 45 and 65 % of the nominal test fuel load weight. The allowable weight range for each core sub-load fuel piece shall be 15 to 25 % of the nominal test fuel load weight. Each of the three core sub-load fuel pieces shall fall within that calculated core fuel piece weight range.

8.4.1.4 For the low fire test and medium fire tests, the remainder fuel sub-load shall be comprised of two or three fuel pieces for heaters with UFVs  $\leq 3.0$  ft<sup>3</sup> (0.08 m<sup>3</sup>) or three or four fuel pieces for heaters with UFVs  $> 3.0$  ft<sup>3</sup> (0.08 m<sup>3</sup>). The total remainder sub-load weight shall be between 35 and 55 % of the nominal test fuel load weight. The allowable weight for each remainder sub-load fuel piece shall be 10 to 30 % of the nominal test fuel load for heaters with UFVs  $\leq 3.0$  ft<sup>3</sup> (0.08 m<sup>3</sup>) and 10 to 20 % of the nominal test fuel load weight for heaters with UFVs  $> 3.0$  ft<sup>3</sup> (0.08 m<sup>3</sup>).

8.4.1.5 For the low and medium fire tests, the smallest fuel piece in the remainder sub-load shall not exceed 67 % of the weight of the largest fuel piece in the remainder sub-load.

8.4.1.6 For the high fire test, the remainder fuel sub-load shall be comprised of up to three fuel pieces for all heaters. The total remainder sub-load weight shall be between 35 and 55 % of the nominal test fuel load weight. The minimum allowable weight for each remainder sub-load fuel piece shall be 10 % of the nominal load weight.

8.4.1.7 The maximum allowable weight for each remainder sub-load fuel piece shall be 55 % of the nominal load weight.

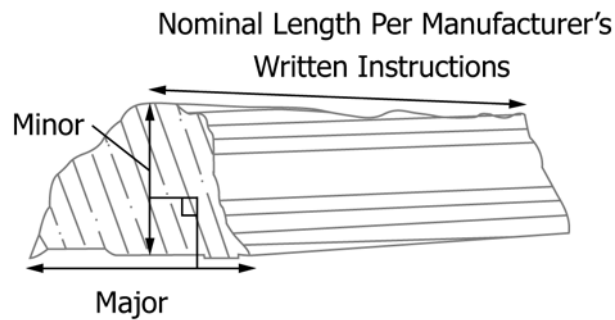
8.4.1.8 Record the total test fuel load weight. The total test fuel load weight (core sub-load plus remainder sub-loads) shall be between 95 and 105 % of the nominal test fuel load weight for all test runs.

8.4.1.9 All test fuel load and piece weight determinations shall be on the as-fired or wet basis.

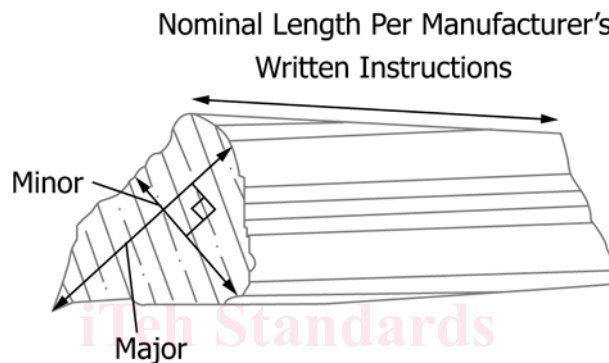
8.4.1.10 The test fuel piece minor dimension shall be  $\geq 40$  % of the major dimension for each piece of test fuel. See Fig. 1A and Fig. 1B. The major dimension is the longest cross-sectional dimension that can be measured on either end of the test fuel piece. The minor dimension is the longest dimension of the test fuel piece measured on a line perpendicular to the major dimension. Dimensional measurements must be made within the perimeter of the ends of the fuel piece. A MS Excel<sup>7</sup> Spreadsheet fuel load calculator is available as an adjunct to this standard.<sup>6</sup>

8.4.2 *Fuel Properties*:

8.4.2.1 *Fuel Species and Properties*—Test fuel load, kindling, and start-up fuel pieces shall be species of cordwood with a specific gravity range of 0.48 to 0.73 on a dry basis



(A)



(B)

FIG. 1 A and 1B Dimensions of Test Fuel Pieces

(oven dry weight/oven dry volume). See Fig. 2 for examples of some fuel species that typically meet the specific gravity requirement. Other fuel species may be used if they meet the specific gravity requirement. Only cordwood pieces that are free of decay, fungus, and loose bark shall be used.

8.4.2.2 *Test Fuel Load Moisture Content*—Using a fuel moisture meter as specified in 6.1 of the test method, determine the fuel moisture content for each test fuel piece used for the test fuel load by averaging at least three fuel moisture meter readings measured parallel to the wood grain for each test fuel piece. One measurement each from two different sides shall be made at approximately 3 in. (75 mm) from opposite ends of the fuel piece. One additional reading shall be made at approximately the center of a third side. Penetration of the moisture meter insulated electrodes for these three readings shall be  $\frac{1}{5}$  to  $\frac{1}{4}$  of the thickness of the fuel piece. For fuel pieces with tightly adhered thick bark (defined as more than  $\frac{1}{8}$  in. (3.2 mm) thick), the thickness of the bark shall be added to the electrode penetration depth or the bark shall be locally removed in the area where the moisture readings are taken. If more than three moisture readings are taken on any test fuel piece, the additional readings shall be dispersed as evenly as practicable among all fuel piece sides and in proportion to the locations of the three required readings. Holes for the moisture meter pins may be pre-drilled to the measurement depth minus at least  $\frac{1}{4}$  in. (6.4 mm). For half-round fuel pieces, the curved

side shall be considered to be comprised of two equal sides and moisture readings taken accordingly. For fuel pieces with geometries that do not directly allow application of the measurement location criteria, measurements should be taken at locations that best meet the intent of this section. The average moisture content for each test fuel piece shall be in the range of 18 to 28 % on a dry basis. The average moisture content of the test fuel load shall be in the range of 19.0 to 25.0 % on a dry basis. Moisture shall not be added to previously dried fuel pieces except by storage under high humidity conditions and temperature up to 100 °F (38 °C). Test fuel load moisture content shall be determined within 4 h of using the fuel for a test.

8.4.2.3 *Start-up Fuel Moisture Content*—Start-up fuel pieces may be split from larger fuel pieces that have had average moisture content determined using the procedure in 8.4.2.2. Moisture content for individual start-up fuel pieces also may be determined using the procedure per 8.4.2.2. Average start-up fuel moisture content shall be in the same allowable range as the test fuel load. Start-up fuel moisture content shall be determined within 4 h of using the fuel for a test.

8.4.2.4 *Kindling Moisture Content Determination*—Kindling that is stored under ambient conditions of  $70 \pm 10$  °F and Relative Humidity of  $50 \pm 10$  % for at least 48 h may be assumed to have a moisture content of 10 % dry basis.