Designation: E2558 – 13

Standard Test Method for Determining Particulate Matter Emissions from Fires in Wood-Burning Fireplaces[1]

This standard is issued under the fixed designation E2558; 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 (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the fueling and operating protocol for determining particulate matter emissions from wood fires in low mass wood-burning fireplaces. The fueling and operating protocol for determining particular matter emissions from masonry or other high mass fireplaces is covered in Annex A1 of this test method.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E631 Terminology of Building Constructions

E2515 Test Method for Determination of Particulate Matter Emissions Collected by a Dilution Tunnel

2.2 *NIST Document:*[3]

Monograph 175 Temperature-Electromotive Force Reference Functions and Tables for the Letter-Designated Thermocouple Types Based on the ITS-90

3. Terminology

3.1 *Definitions*—Terms used in this test method are defined in Terminology E631.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *base of fireplace, n*—the lowest part of the fireplace assembly that would normally be in contact with the floor of the dwelling or structure in which it is installed.

3.2.2 *Douglas fir, n*—untreated, standard, or better grade Douglas fir lumber with agency grade stamp: D. Fir or Douglas Fir.

3.2.3 *firebox, n*—the volume within the fireplace where logs are burned.

3.2.4 *first fuel crib, n*—the first fuel load (including fuel pieces and spacers to create air spaces) placed on the residual fuel from the kindling brands. The specific configuration is described in 9.3.5.1.

3.2.5 *fuel piece, n*—2 × 4 or 4 × 4 wood pieces used to construct fuel cribs and referring to the nominal width and depth dimensions for commonly available dimensional lumber. The actual dimensions are 1½ × 3½ in. (38 × 89 mm) and 3½ × 3½ in. (89 × 89 mm).

3.2.6 *grate, n*—any device included with the fireplace or specified by the fireplace manufacturer for the purpose of elevating the fuel load above the hearth or for constraining fuel pieces from falling outside the intended burning area, or both. This includes basket grates and andirons.

3.2.7 *hearth, n*—the footprint of the fireplace firebox.

3.2.8 *kindling brands, n*—the initial fuel load or loads placed above crumpled newspaper to initiate combustion in the fireplace and to establish a charcoal bed that will become the ignition source for subsequent fuel loads. These are comprised of fuel strips separated by air spaces. The specific configuration is described in 9.3.4.

3.2.9 *low mass fireplace, n*—any fireplace and attached chimney that can be weighed (including the weight of the test fuel) on a platform scale that meets the requirements as specified in 7.3 and 8.2.

3.2.10 *nominal fuel length, n*—the Nominal Fuel Length (NFL) is one of five incremental nominal fuel piece lengths that simulates real-world firewood five piece lengths. These lengths are 16 in. (406 mm), 18 in. (457 mm), 20 in. (508 mm), 22 in. (559 mm), and 24 in. (610 mm). The NFL is used for both the kindling brands and fuel cribs.

[1] 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.

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[2] 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.

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

3.2.11 *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.

3.2.12 *second fuel crib, n*—the second fuel load (including fuel pieces and spacers to create air spaces) placed on the residual fuel from the first fuel crib. The specific configuration is described in 9.3.5.2.

3.2.13 *spacers, n*—wood pieces used to hold individual fuel pieces together when constructing the three fuel cribs. Their function is to provide reproducible fuel crib geometry and air spaces between fuel pieces, as well as to hold the fuel cribs together (with nails).

3.2.14 *standardized fuel retainer, n*—any fireplace that doesn't include or specify a grate as defined in 3.2.6 shall use a standardized fuel retainer during testing. These retainers shall include vertical fuel retainer bars that are made from 0.75 × 0.75 in. (19 × 19 mm) steel square bar or 0.75 in. (19 mm) diameter round steel bar and shall be 8 ± 2 in. (200 ± 50 mm) high. They shall be attached to a steel plate that projects toward the front of the fireplace and shall not interfere with any fireplace function. They shall be spaced so they are 12 ± ½ in. (300 ± 13 mm) apart. Their purpose is to prevent fuel from rolling or falling forward during testing, thus helping to prevent an aborted test. (See Fig. 1.)

3.2.15 *test facility, n*—the area in which the tested fireplace is installed, operated, and sampled for emissions.

3.2.16 *third fuel crib, n*—the third and final fuel load (including fuel pieces and spacers to create air spaces) placed on the residual fuel from the second fuel crib. The specific configuration is described in 9.3.5.3.

4. Summary of Test Method

4.1 This test method is used in conjunction with Test Method E2515. The fireplace under evaluation is fueled with kindling and cribs in a way that simulates fireplace operation in the home. An algorithm that uses the specific configuration of the test fireplace, including hearth and grate dimensions, is used to determine the kindling and fuel crib geometry and dimensions. Kindling brands are placed in the fireplace above crumpled newspaper and ignited. When the kindling brands have burned to a certain point, the first fuel crib is placed on the remains of the kindling. When the first crib is substantially burned, the remaining material is adjusted as needed to form a base for the second crib. This process is repeated again before addition of the third crib. The third crib is allowed to burn until all flaming from volatile material in the fuel ceases, at which point the test is terminated. Burn rate is determined based on the amount of fuel added less the amount remaining at the end of the test divided by the length of test and corrected to a dry fuel basis. Particulate sampling begins at the time of ignition of the newspaper and stops when the test terminates. The total particulate emissions are determined over the test period. The particulate emissions factor is then determined from the total emissions and the total amount of fuel burned and is reported in grams of particulate per dry kilogram of fuel or grams of particulate per hour.

4.2 If the test fireplace includes standard (or offers optional) components that affect particulate emission performance and that have more than one operating position or condition allowed in the owner's manual that accompanies the fireplace, separate emissions tests may be required for each of the various positions or conditions that are allowed in the manual. This might include things like door open and door closed operation, for example. (See 9.4.14 – 9.4.16.)

5. Significance and Use

5.1 This test method is used for determining emission factors and emission rates for low mass wood-burning fireplaces.

5.1.1 The emission factor is useful for determining emission performance during product development.

5.1.2 The emission factor is useful for the air quality regulatory community for determining compliance with emission performance limits.

5.1.3 The emission rate may be useful for the air quality regulatory community for determining impacts on air quality from fireplaces, but must be used with caution as use patterns must be factored into any prediction of atmospheric particulate matter impacts from fireplaces based on results from this method.

5.2 The reporting units are grams of particulate per kilogram of dry fuel and grams of particulate per hour.

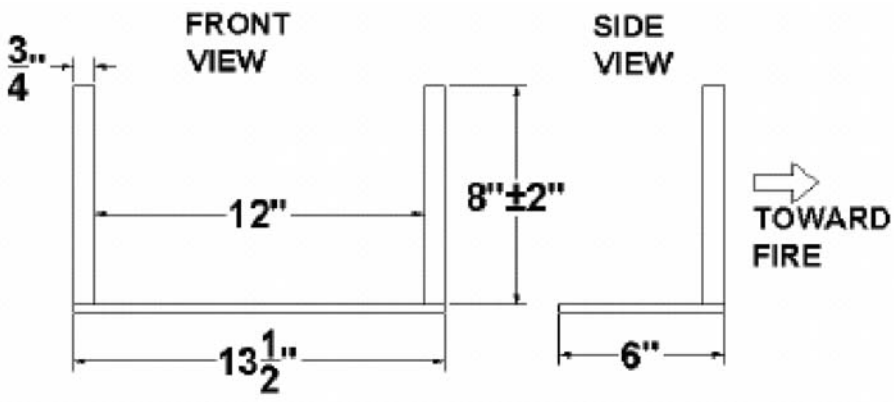

FIG. 1 Example, Standardized Fuel Retainer

5.2.1 Appropriate reporting units for comparing emissions from non-heating appliances: g/kg.

5.2.2 Appropriate reporting units for predicting atmospheric emission impacts only if hours of fireplace use are factored in: g/h.

6. Safety

6.1 *Disclaimer*—This test method may involve hazardous materials, operations, and equipment. This test method may not address all of the safety concerns 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. Equipment and Supplies

7.1 *Wood Moisture Meter*—Calibrated electrical resistance meter capable of measuring test fuel moisture to within 1 % moisture content. Must meet the calibration requirements specified in 8.1.

7.2 *Test Fuel Scale*—A scale capable of weighing test fuel to within 0.01 lb (0.005 kg). Must meet the calibration requirements specified in 8.3.

7.3 *Platform Scale*—A scale capable of weighing the test fireplace and attached chimney, including the weight of the test fuel, to within 0.1 lb (0.05 kg). Must meet the calibration requirements specified in 8.2.

7.4 *Fireplace 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 4.0°F (2.2°C) or 0.75 % of the reading, whichever is greater and meeting the calibration requirements specified in 8.4.

7.5 *Fireplace Temperature Measuring Device*—A temperature sensor capable of measuring firebox surface temperatures with an accuracy of 4.0°F (2.2°C) or 0.75 % of the reading, whichever is greater and meeting the calibration requirements specified in 8.4.

8. Calibration and Standardization

8.1 *Wood Moisture Meter*—Calibrate as in accordance with the manufacturer's instructions before each certification test.

8.2 *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, audit the scale with the test fireplace in place by weighing at least one calibration weight (ASTM Class F) that corresponds to between 20 and 80 % of the expected test fuel charge 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 charge weight, whichever is greater, recalibrate the scale before use with at least five calibration weights spanning the operational range of the scale.

8.3 *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, audit the scale with the wood heater in place by weighing at least one calibration weight (ASTM Class F) that corresponds to between 20 and 80 % of the expected test fuel charge 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 charge weight, whichever is greater, recalibrate the scale before use with at least five calibration weights spanning the operational range of the scale.

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

9. Procedure

9.1 *Preconditioning of the Fireplace*—Prior to testing for emissions, the fireplace to be evaluated must be burned until the weight of the fireplace is stable to within ±0.5 lb (±0.25 kg) but for no less than 10 h for fireplaces without catalytic combustors or no less than 48 h for fireplaces with catalytic combustor(s). This may be done inside or outside the test facility.

9.1.1 Set up the fireplace in accordance with instructions provided by the manufacturer. The total height of chimney when measured from the base of the fireplace shall be 15 ± 1 ft (4.6 ± 0.3 m).

9.1.2 Install a flue-gas temperature measurement device at the center of the flue, 8 ± 0.3 ft (2.4 ± 0.1 m) above the base of the fireplace.

9.1.3 Record the start time, fireplace weight, and flue gas temperature.

9.1.4 Ignite a fire using newspaper and kindling and establish an actively burning fire. Add more fuel as needed to sustain the fire.

NOTE 1—Any type of untreated wood may be used for the preconditioning.

9.1.5 Record the time and weight for all fuel added.

9.1.6 Record the flue-gas temperature at least once during each 30 min of operation.

9.1.7 Periodically allow the fire to burn down completely. While the fireplace is still warm, shovel out all residual fuel, ash and other debris, lift the fireplace off the scale, re-zero the scale and return the fireplace to scale. Record the empty weight of the fireplace. Repeat this process of burning the fireplace and determining the empty weight until the weight becomes stable in accordance to the requirements of 9.1.

9.1.8 When the fireplace weight has stabilized or after at least 10 h of preconditioning fires for fireplaces without catalytic combustors or at least 48 h of preconditioning fires for fireplaces with catalytic combustor(s), whichever is longer, record the ending time, total wood weight of wood burned, and total elapsed time of operation.

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

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

9.2 Install the fireplace in the test facility.

9.2.1 Set up the fireplace in accordance with instructions provided by the manufacturer. Use the chimney type supplied or specified by the manufacturer. The total height of chimney when measured from the base of the fireplace shall be 15 ± 1 ft (4.6 ± 0.3 m). Do not install a chimney cap.

NOTE 2—The chimney that is used for testing should be documented in the test data and test report.

9.2.2 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.

9.2.3 Install a flue-gas temperature measurement device at the center of the flue, 8 ± 0.3 ft (2.4 ± 0.1 m) above the base of the fireplace.

9.3 *Fuel:*

9.3.1 *Fuel Properties:*

9.3.1.1 The fuel is untreated, standard, or better grade Douglas fir lumber.

9.3.1.2 *Fuel Moisture*—The fuel moisture shall be measured using a fuel moisture meter as specified in 7.1. 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). Fuel moisture shall be measured within four hours of using the fuel for a test.

(1) Kindling Loads—The average fuel moisture for each fuel strip used in each of the two specified kindling brands shall be between 6 and 12 % dry basis. Kiln-dried lumber is permitted for the kindling brands. Determine fuel moisture for each fuel strip. One moisture meter reading from each strip, measured parallel to the wood grain is sufficient. If an electrical resistance type fuel moisture meter is used, penetration of insulated electrodes shall be ¼ the thickness of the fuel strips. Average all the readings for all the fuel strips for both kindling brands combined to determine the average fuel moisture for all kindling.

(2) Main Fuel Cribs—The average fuel moisture for each fuel piece used to construct each of the three fuel cribs shall be between 19 and 25 % dry basis. Kiln-dried lumber is not permitted. Kiln-dried lumber is permitted for the spacers. Determine the fuel moisture for each fuel piece (excluding spacers) used for each of the three fuel cribs by averaging at least three fuel moisture meter readings, one from each of three sides, measured parallel to the wood grain. If an electrical resistance type fuel moisture meter is used, penetration of insulated electrodes shall be ¼ the thickness of the fuel piece or ¾ in. (19 mm), whichever is greater.

9.3.1.3 *Fuel Density*—The average fuel density, dry basis, shall be in the range of 27 to 34 lb/ft^3 (0.434 to 0.546 g/cm^3) for the two kindling brands combined and for each of the three individual fuel cribs. Nails and spacer pieces are excluded from the density determinations. Determine the total volume of the fuel pieces that comprise both kindling brands combined and each individual fuel crib. Use the wet basis weight and the arithmetically averaged dry basis moisture content (refer to 9.3.1.2 (*1*) and 9.3.1.2 (*2*)) to determine the dry basis weight for the kindling and for the individual fuel crib pieces. Determine dry basis weight for each fuel crib by summing the dry basis weight of the individual fuel pieces that comprise each crib. Divide the dry basis weight by the volume to determine the density for the combined kindling brands and for each fuel crib.

9.3.1.4 *Nails*—Use uncoated, ungalvanized nails for assembling kindling brands and main fuel loads. The number of nails used should be limited to the minimum number necessary to hold the kindling brands and fuel cribs together.

9.3.1.5 *Weight*—Record the total weight of each kindling brand or main fuel crib after it is assembled using the test fuel scale specified in 7.2. The weighed fuel brands and cribs must be used within 3 h of being weighed.

9.3.2 *Nominal Fuel Length*—The NFL for each fireplace being evaluated is determined based on dimensional parameters of the fireplace firebox or grate, or both.

9.3.2.1 If the fireplace includes a manufacturer supplied or specified grate (see Fig. 2 (A) and (B)), the NFL is:

(1) The longest of the five standard fuel lengths that will fit in or on the grate without interference from any part of the grate structure, or;

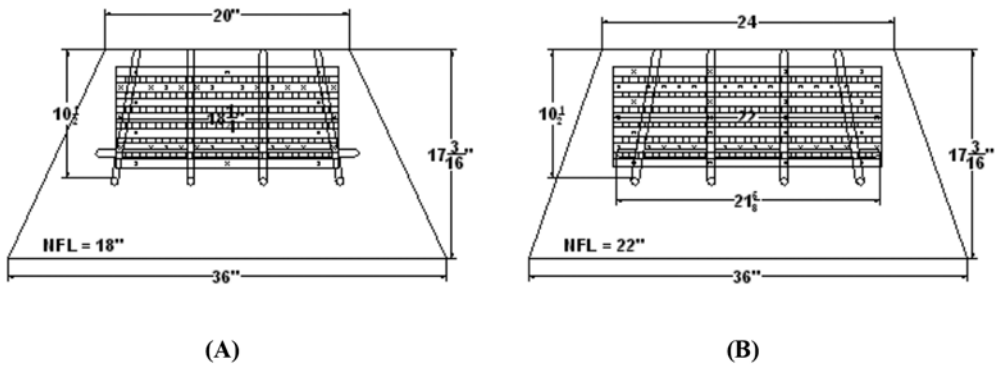

FIG. 2 (A) and (B) NFL Example, Plan Views, Traditional with Grate

(2) If the grate does not include end log retainer bars that limit fuel length, the longest of the five standard fuel lengths that does not extend by more than 2 in. past either end of the longest horizontal grate dimension when the fuel length is centered left-to-right on the grate, or;

(3) If the 2-in. extension of the fuel past the longest grate dimension causes interference with the walls of the firebox, the longest of the standard fuel lengths that can be centered on the grate without interference from the firebox walls, or;

(4) If the manufacturer's written instructions that accompany the fireplace include a specific fuel piece length recommendation for the fireplace user, the recommended length shall be used.

NOTE 3—If the manufacturer's recommended length is not one of the five standard fuel lengths, use the closest standard fuel length that does not exceed the manufacturer's recommended length.

9.3.2.2 If the fireplace has no grate supplied or specified by the manufacturer, the NFL is determined as follows:

(1) If the manufacturer's written instructions that accompany the fireplace provide no specific information regarding where fuel may or may not be placed in the firebox, the longest fuel length that will fit without interference from the side walls of the firebox, while still allowing the front edge of the first kindling crib to be no closer to the front of the fireplace opening than ⅓ the depth of the fireplace or 6 in., whichever is less. (See Fig. 3 (A) and (B)), or

(2) If the manufacturer's written instructions that accompany the fireplace provide specific information regarding where fuel may or may not be placed in the firebox, the NFL is the longest fuel length that will fit without interference from the side walls of the firebox, while still allowing the front edge of the first kindling crib to be within the area of the firebox where fuel is allowed to be placed per the manufacturer's written instructions. (See Fig. 3 (B)), or,

(3) If the manufacturer's written instructions that accompany the fireplace include a specific fuel piece length recommendation for the fireplace user, the recommended length shall be used.

NOTE 4—If the manufacturer's recommended length is not one of the five standard fuel lengths, use the closest standard fuel length that does not exceed the manufacturer's recommended length.

(4) Standardized fuel retainers shall be used for any fireplace that does not have a grate.

9.3.2.3 Dimensional tolerance for the NFL is 1/16 in. (±1.5 mm).

9.3.2.4 If the fireplace firebox has height restrictions that will cause interference when loading test fuel cribs, the NFL is longest NFL that provides a minimum of 6 in. of vertical clearance to the top of the firebox from the hearth or loading area for the fuel (or from the grate or the top of the log retainers on the grate if a grate is provided or specified) over the full length of the NFL when the NFL is centered on the hearth or grate. See Fig. 4.

9.3.3 *Newspaper:*

9.3.3.1 Loosely crumpled balls of full sheets of non-color ink newspaper are used to ignite the kindling loads. The number of balls is dependent on the NFL. The intent is to ensure rapid and even ignition of the kindling brands. The following guideline (Table 1) is given:

TABLE 1 Guideline for Newspaper Used for Igniting Kindling

NFL		Newspaper
in.	mm	# of Sheets
16	406	4
18	457	5
20	508	6
22	559	7
24	610	8

9.3.4 *Kindling Loads*—There are two kindling brands that are used to establish an initial charcoal bed and to ignite the

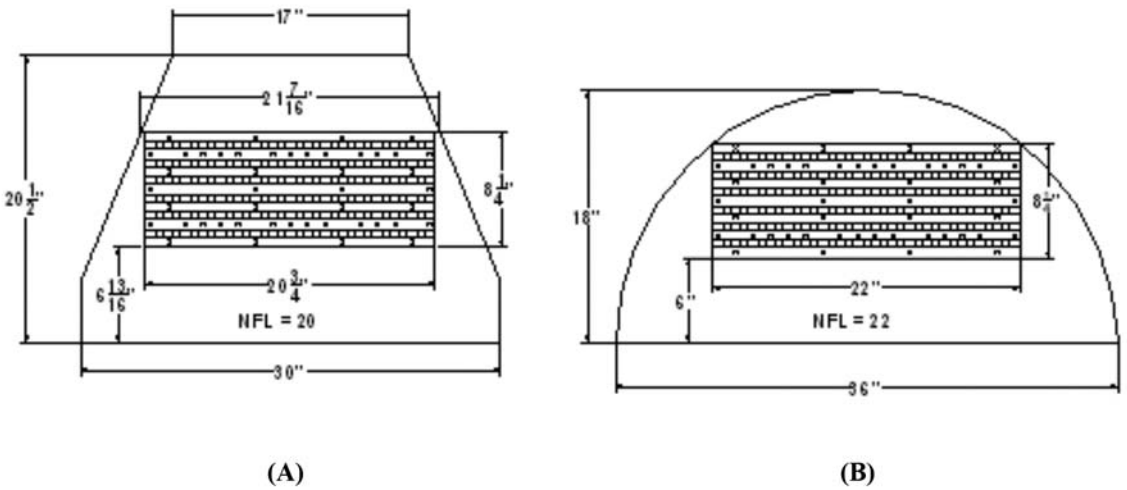

FIG. 3 (A) and (B) NFL Example, Plan Views, Fireplaces without Grates

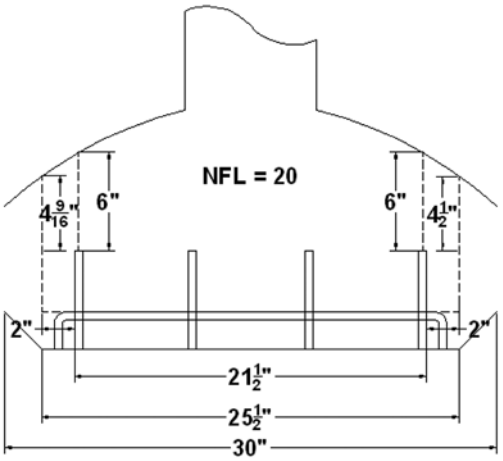

FIG. 4 NFL Example, Front View, Fireplace with Firebox Height Interference

first fuel crib. The kindling brands are comprised of Douglas fir pieces that meet the specifications of 9.3.1.

9.3.4.1 *First Kindling Brand:*

(1) For fireplaces that include a grate or specify that a grate must be used, the first kindling brand is comprised of two layers of ¾ × ¾ in. (19 × 19 mm). The strips are spaced ½ in. (12.7 mm) apart and nailed together using 18 gauge or smaller nails no longer than 1⅜ in. (35 mm). The two layers are perpendicular to each other. (See Fig. 5 and Fig. 7.)

(a) The bottom layer is comprised of strips that are 8¼ in. (210 mm) long. The number of strips is dependent on the NFL as determined in Table 3. (See Table 2.)

(b) The top layer is comprised of seven strips. The top layer length (TLL) is determined by the NFL. (See Table 2.)

(2) For fireplaces that do not include a grate or do not specify a grate that must be used, the kindling brands and fuel loads are burned directly on the fireplace hearth and the first kindling brand is comprised of two layers of ¾ in. × ¾ in. (19 mm × 19 mm) strips constructed in accordance with 9.3.4.1 (*1*) but with the addition of two spacer pieces that attached to the underside of the bottom layer of the brand. The spacers are comprised of 1½ in. × 1½ in. (38 mm × 38 mm) pieces. The spacers are 8¼ in. (210 mm) long and positioned at each end of the brand and parallel to the pieces that comprise the bottom layer of the brand. (See Fig. 6 and Fig. 8.)

9.3.4.2 *Second Kindling Brand*—The second kindling brand is comprised of two layers. The fuel pieces are nailed together using 18 gauge or smaller nails no longer than 1⅜ in. (35 mm). The two layers are perpendicular to each other. (See Fig. 9.)

(1) The bottom layer is comprised of 1½ × 1½ in. (38 × 38 mm) pieces or a combination of 1½ × 1½ in. (38 × 38 mm) and ¾ × 1½ in. (19 × 38 mm) pieces spaced 1⅜ in. (35 mm) apart. Each piece is 8 ¼ in. (210 mm) long. The number and position of each strip is determined by the NFL. (See Fig. 9 and Fig. 10 and Table 3.)

(2) The top layer is comprised of four ¾ × ¾ in. (19 × 19 mm) strips. The outer strips are located at the ends of the

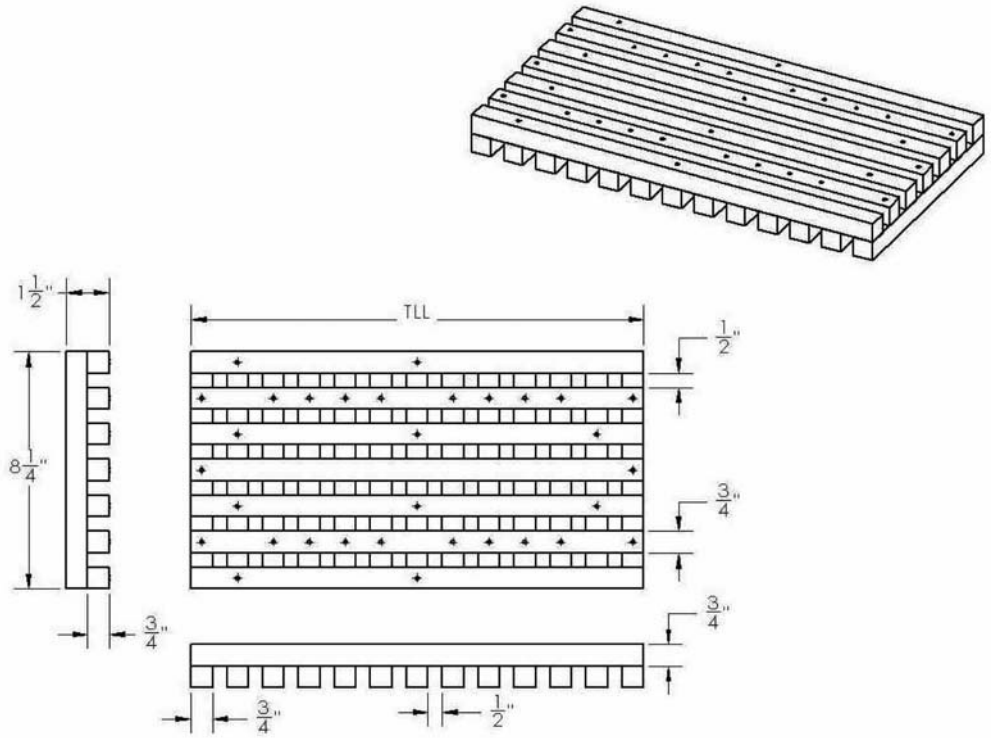

FIG. 5 Kindling Brand 1 (With Grate)

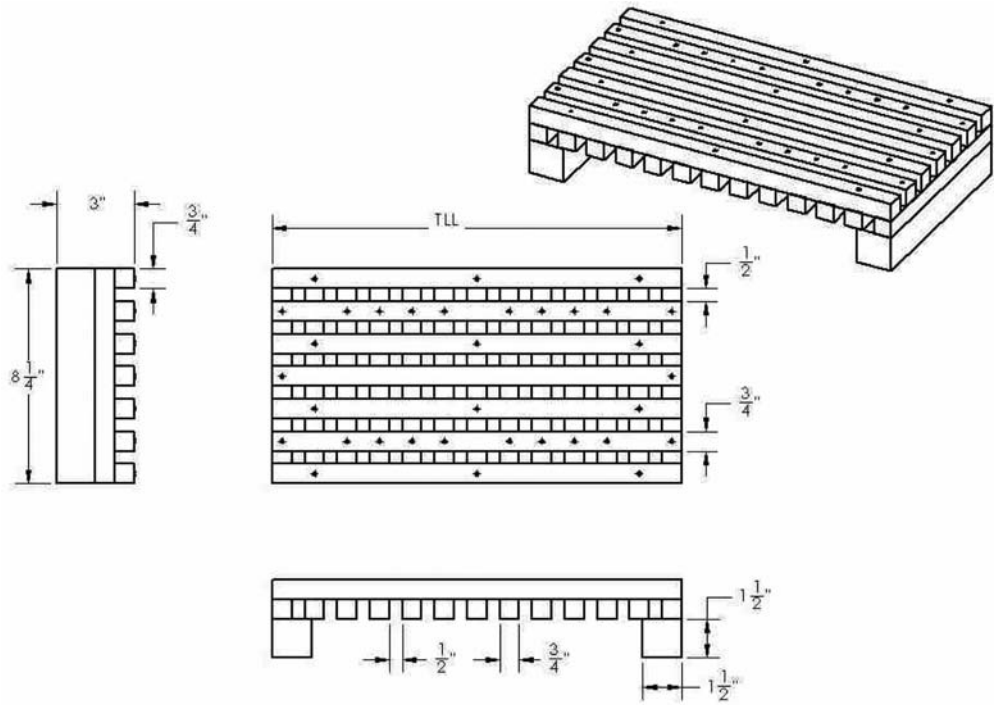

FIG. 6 Kindling Brand 1 (No Grate)

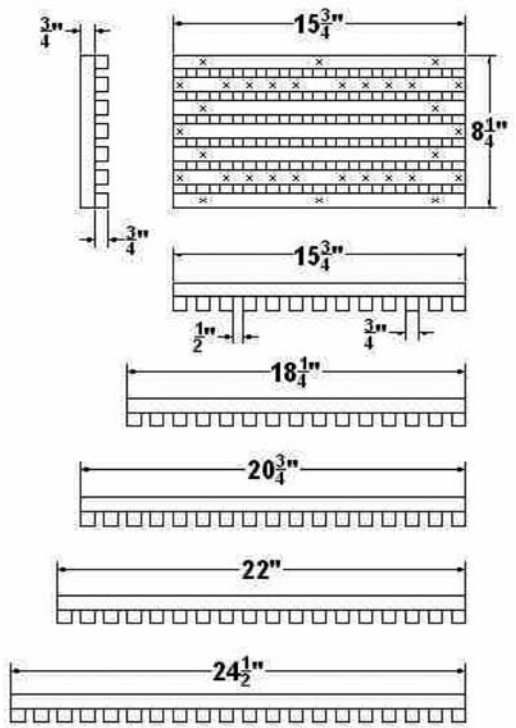

FIG. 7 Kindling Brand 1 (With Grate)

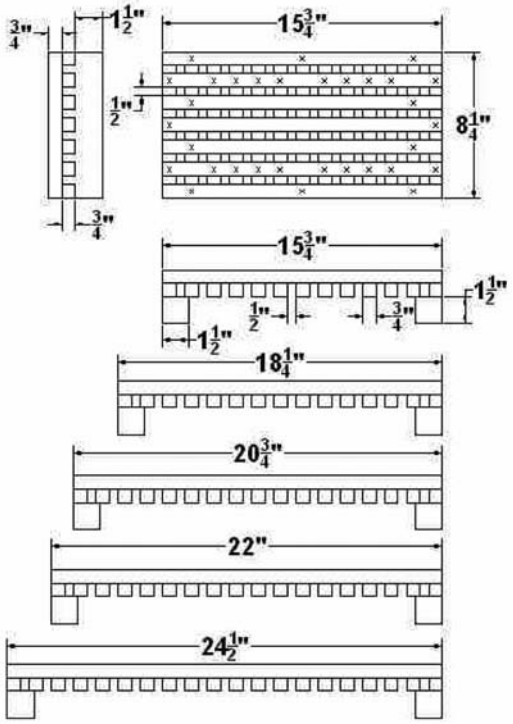

FIG. 8 Kindling Brand 1 (No Grate)

lower layer pieces and the remaining two strips are spaced 1½ in. (38 mm) from the first two. The TLL is determined by the NFL. (See Fig. 9, Fig. 10, and Table 3.)

9.3.5 *Main Fuel Loads*—There are three main fuel cribs that are added to the fire as described in 9.4. The cribs are comprised of dimensional lumber assembled in specific patterns with specific air spaces between the pieces. The dimensional lumber pieces are air-dried Douglas fir that meet the specifications of 9.3.1. The fuel spacer pieces are Douglas fir that meet the specifications of 9.3.1. All pieces are nailed together. Fuel spacer pieces are attached to the dimensional lumber pieces using 18 gauge or smaller nails no longer than 1⅜ in. (35 mm).

TABLE 2 Kindling Brand 1

NFL		Lower Layer	Top Layer Length	
in.	mm	# of Strips	in.	mm
16	406	13	15¾	400
18	457	15	18¼	464
20	508	17	20¾	527
22	559	18	22	559
24	610	20	24½	622

TABLE 3 Kindling Brand 2

NFL		Lower Layer	Lower Layer	Top Layer Length	
in.	mm	# of 2 × 2	# of 1 × 2	in.	mm
16	406	6	0	15⅞	403
18	457	6	1	18	457
20	508	6	2	20⅛	511
22	559	8	0	21⅝	549
24	610	8	0	24½	591

9.3.5.1 *First Fuel Crib*—The first fuel crib is comprised of one fuel piece of 4 × 4 dimensional lumber and two fuel pieces of 2 × 4 dimensional lumber plus six spacers. The length of each fuel piece is the NFL as determined in 9.3.2. The 2 × 4 fuel pieces face the front of the fireplace and are offset from each other by ⅛ in. (3 mm). The crib is assembled using four ¾ × 1½ in. (19 × 38 mm) spacers and two ½ × 1½ in. (12.7 × 38 mm) spacers. (See Fig. 11 for the specific details of construction.)

9.3.5.2 *Second Fuel Crib*—The second fuel crib is comprised of two fuel pieces of 4 × 4 dimensional lumber and one fuel piece of 2 × 4 dimensional lumber plus two spacers. The length of each fuel piece is the NFL as determined in 9.3.2. The 2 × 4 fuel piece and one 4 × 4 fuel piece are nailed together with three 8-penny common nails to form a nominal 4 × 6 piece. The nails are centered on the width of the 3½-in. (89-mm) face of the 2 × 4, with one nail at the center of the NFL and the other two spaced in 4 in. (100 mm) from each end. The crib is assembled using two ¾ × 1½ in. (19 × 38 mm) spacers so that the fuel pieces are rotated 45° from horizontal. The 4 × 4 faces the front of the fireplace. (See Fig. 12 for the specific details of construction.)

9.3.5.3 *Third Fuel Crib*—The third fuel crib is comprised of two fuel pieces of 2 × 4 dimensional lumber plus spacers. The length of each fuel piece is the NFL as determined in 9.3.2. The crib is assembled using six ½ × 1½ in. (12.7 × 38 mm) spacers. (See Fig. 13 for the specific details of construction.)

9.4 *Operation:*

9.4.1 Prior to beginning a test, measure the temperature of the fireplace. Use a surface temperature probe held against the center of the back wall of the firebox until a constant temperature is obtained. The fireplace temperature must be within the allowable test facility temperature range specified in Test Method E2515.

9.4.2 Within 10 min prior to starting the emissions test run, record the indicated scale weight of the empty fireplace/chimney assembly. If the test will be conducted using a standardized fuel retainer, include the weight of the fuel retainer in the empty fireplace weight. Note that after obtaining the empty starting weight of the fireplace/chimney assembly, tare the platform scale to obtain a zero empty starting weight if that function is available on your scale.

9.4.3 *Newspaper and Kindling (See Fig. 14):*

9.4.3.1 Record the weight of and then place the appropriate number of crumpled newspaper balls as shown in 9.3.3 in the fireplace, such that they will be evenly distributed under the kindling brands.

9.4.3.2 Record the weight of and then place the first kindling brand above the newspaper balls. The short strips of fuel should be on the bottom, closest to the fireplace hearth.

(1) Locate the first kindling brand on the grate or on the hearth in accordance with the manufacturer's written instructions that are supplied with the fireplace, or if no written instructions are provided, see below.

(2) If the fireplace has a grate, center the first kindling brand on the grate, both front-to-back and left-to-right.

(3) If the fireplace does not have a grate, place the first kindling brand so that it is centered left-to-right and is as far back in the fireplace as possible. Without compressing the newspaper balls anymore than absolutely needed, nestle the first kindling brand so that it is as level as possible on the newspaper balls.

9.4.3.3 Record the weight of and then place the second kindling brand on top of the first. The short fuel pieces should be on the bottom, closest to the first kindling brand. Center the second kindling brand over the first, both front-to-back and left-to-right.

9.4.4 For fireplaces without grates, place the standardized fuel retainer so that the back surfaces of the vertical fuel retainer bars are within ½ in. (13 mm) of the front of the deepest of the three main fuel cribs (typically, this will be the second fuel crib). Center the standardized fuel retainer from left to right.

9.4.5 When all requirements for starting the emissions test are met in accordance with Test Method E2515, record the start time, record the indicated scale weight of the fireplace including the combined weight of newspaper and first and second kindling brands or, if the scale has been tared, record the combined weight of the newspaper and first and second kindling brands directly, start the sampling equipment, and then ignite the newspaper balls. A propane gas torch has been found to be a good device for obtaining rapid and even ignition of the newspaper. Quickly work your way from one side to the other to insure even ignition. All newspaper must be ignited within 30 s from starting the sampling equipment.

9.4.6 When the indicated scale weight is between 20 and 15 % of the combined weight (wet) of the newspaper, first and second kindling brands, record the time and add the first fuel crib in accordance with the following procedure. (See Fig. 15.)

NOTE 5—When determining the indicated scale weight range that fuel loads should be added or for determining when fuel adjustments are allowed in accordance with 9.4, round the calculated weight range values to the nearest 0.1 lb (0.05 kg) that is still within the calculated weight range. For example, if the kindling and newspaper weigh 5.8 lb (2.65 kg), the 15 to 20 % calculated allowable weight range for adding the first fuel crib in accordance with 9.4.6 would equal 0.87 lb (0.40 kg) to 1.16 lb (0.53 kg). The indicated weights on the scale would round to 0.9 lb (0.40 kg) to 1.1 lb 90.50 kg) in order to be within the allowable calculated range.

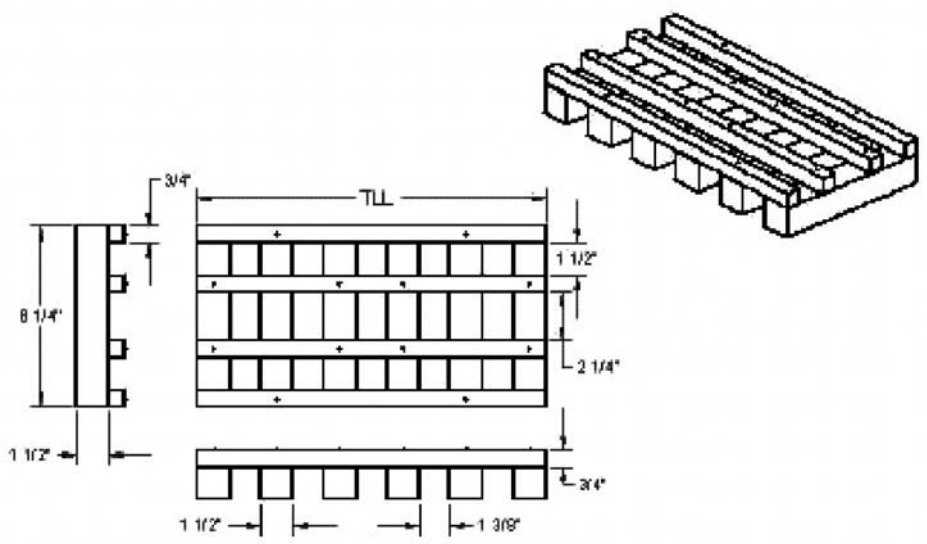

FIG. 9 Kindling Brand 2

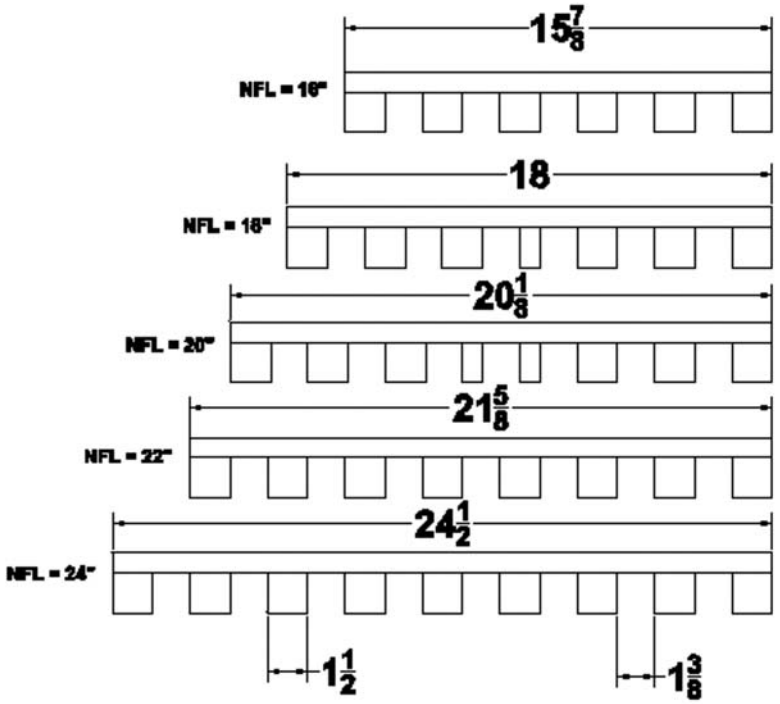

FIG. 10 Kindling Brand 2—Front View For Each NFL

9.4.6.1 Using a poker, gently agitate the remains of the kindling brands to cause burning coals and fuel pieces to break apart and create a bed under the grate (if used) or on the hearth (if there is no grate). Poking should last no more than 60 s.

9.4.6.2 Level the remaining fuel to provide an even base for the first fuel crib.

9.4.6.3 Place the first fuel crib, with the 4 × 4 toward the rear of the firebox, on the poked and leveled kindling fuel bed being sure to center it left-to-right on the grate (if used) or on the kindling fuel bed itself (if there is no grate).

9.4.6.4 Follow the manufacturer's written instructions for fuel placement that are included with the fireplace. In the absence of specific written instructions regarding the placement of fuel on the grate or hearth, push the crib to the rear of the grate and against the rear wall of the firebox, if possible. The spacers on the crib will prevent the 4 × 4 from actually contacting the rear firebox wall. If there is no grate, push the crib against the rear wall of the firebox or as far back as possible. Nestle the crib down and into the kindling fuel bed to ensure good ignition.

9.4.6.5 Record the time and the combined weight of the residual fuel (coals) from the kindling plus the first crib.

9.4.6.6 *Poking*—One fuel adjustment (poking) is allowed to keep the first fuel crib burning in an aesthetically pleasing

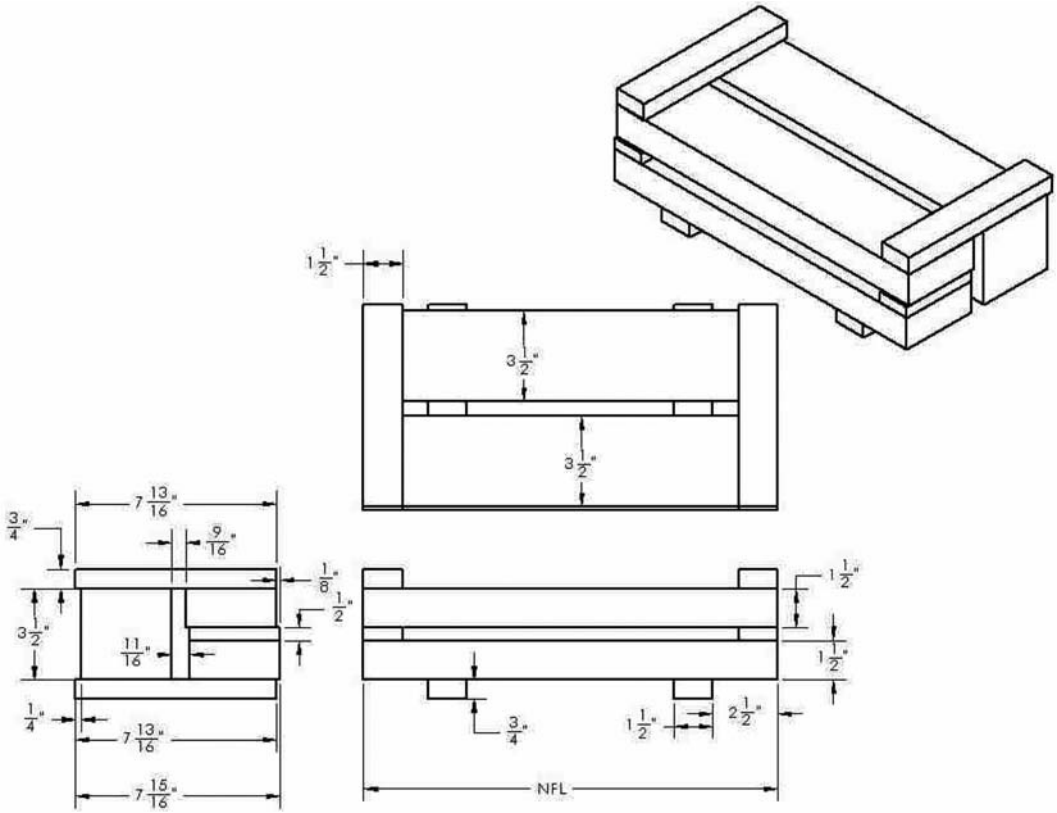

FIG. 11 First Fuel Crib

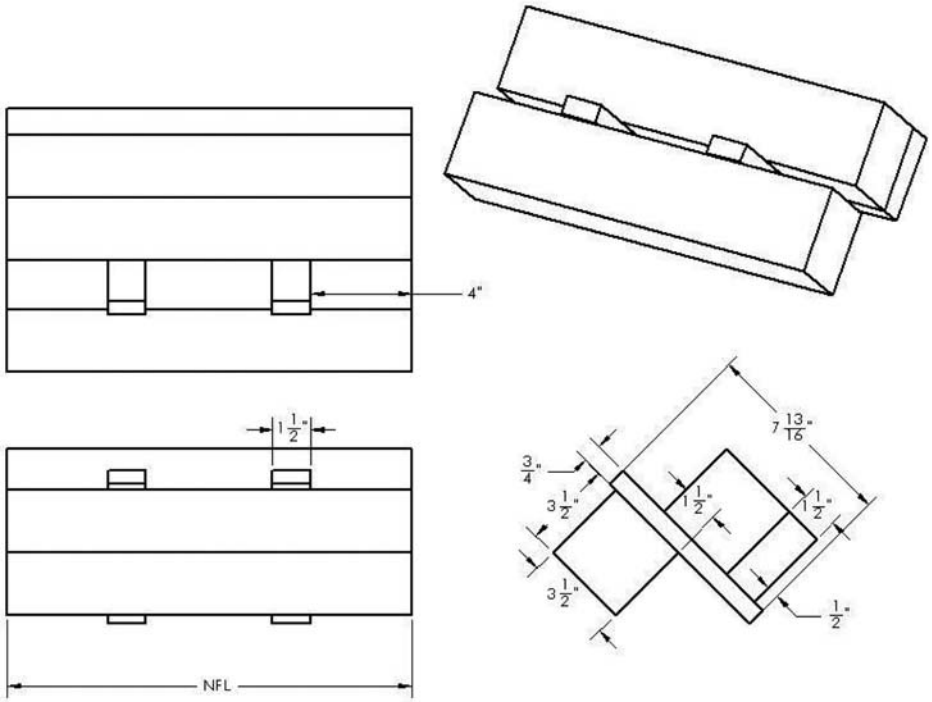

FIG. 12 Second Fuel Crib

manner. Although "aesthetically pleasing" requires the judgment of the test technician, the intent is to maintain flames and even burning across the fuel crib. The poking can occur only in the period of the test when the indicated scale weight (wet) is equal to or less than 50 % of the weight (wet) of the first fuel crib, and the poking should last no more than 60 s. Record the time, weight (wet), and duration of the fuel adjustment. If the spacers on the first fuel crib burn through and the fuel crib falls

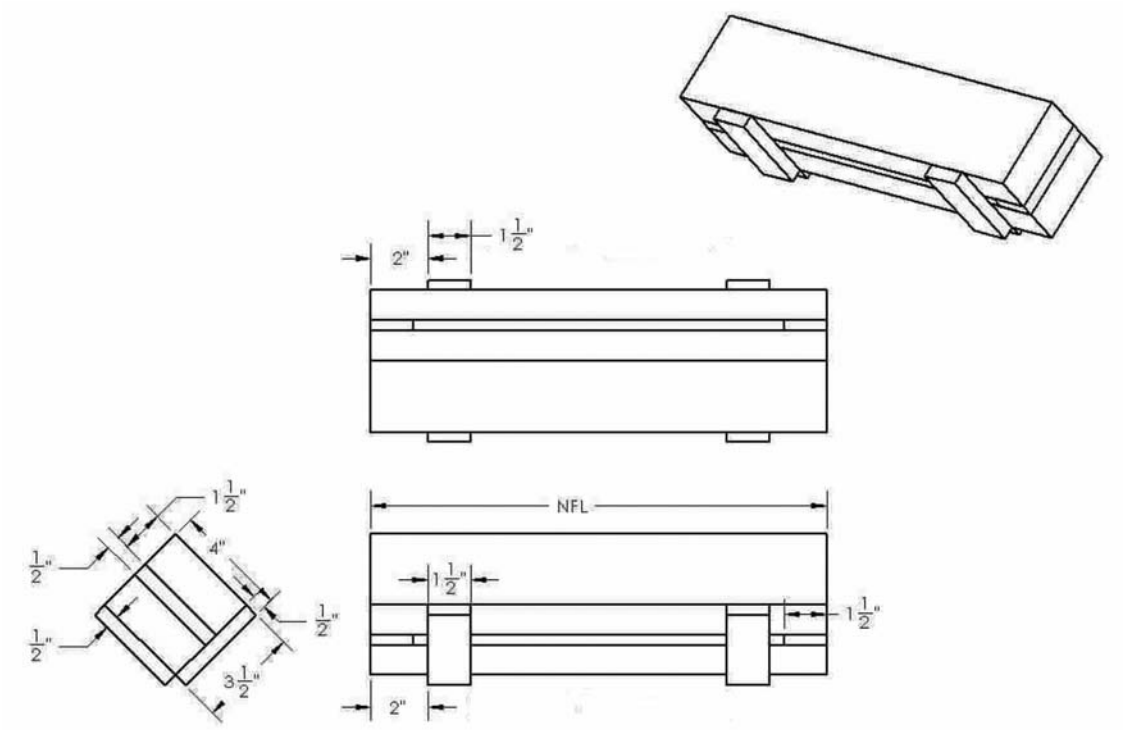

FIG. 13 Third Fuel Crib

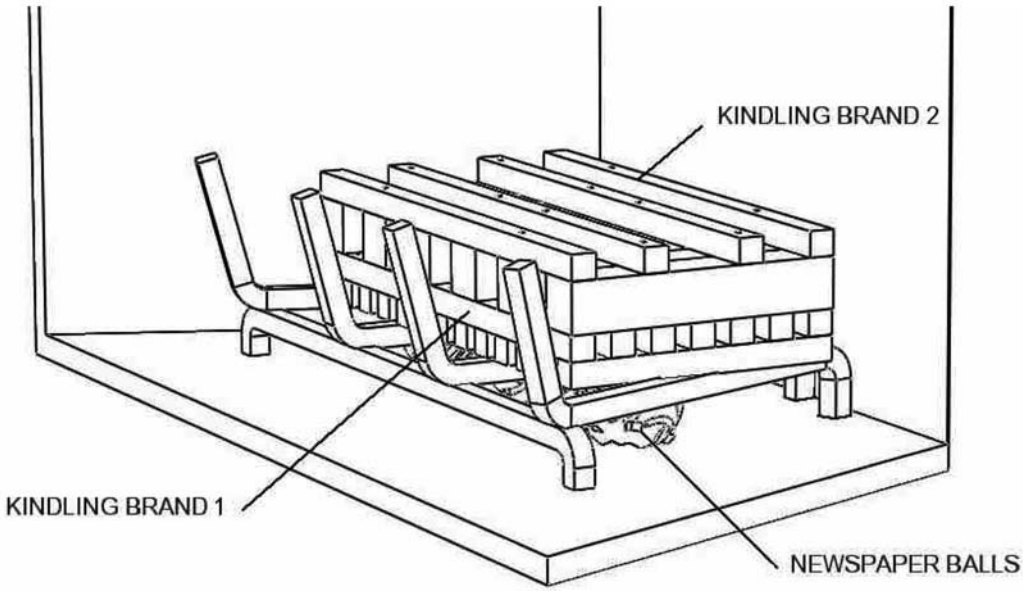

FIG. 14 Newspaper and Kindling (Fireplace with Grate)

apart in such a way that combustion of the crib is adversely impacted (such as the front 2 × 4s falling forward and away from the general fire mass), a fuel adjustment may be made before 50 % of the weight (wet) of the first crib is burned. This fuel adjustment is limited to moving the separated fuel pieces back to their approximate original locations in the crib and should last no longer than 60 s. Record the time, weight (wet), and duration of the fuel adjustment.

9.4.7 When the indicated scale weight is between 25 % and 20 % of the weight (wet) of the first fuel crib, record the time, weight (wet), and add the second fuel crib using the following procedure. (See Fig. 16.)

9.4.7.1 Using a poker, breakdown and adjust the remnants of the first fuel crib as necessary to facilitate loading of the second fuel crib. Poking should last no more than 60 s. Record the time, weight (wet), and the duration of the fuel adjustment.

9.4.7.2 The remains of the 4 × 4 should be pulled to the center of the grate (if a grate is used) or to the center of the remaining mass of fuel (if no grate is used). This forms the base for nesting the second fuel crib.

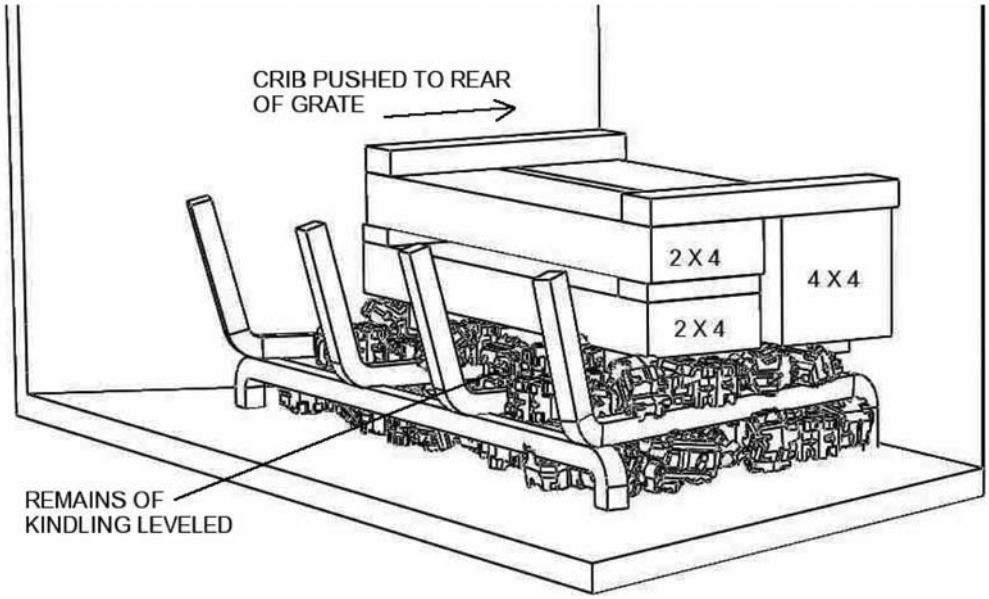

FIG. 15 First Fuel Crib

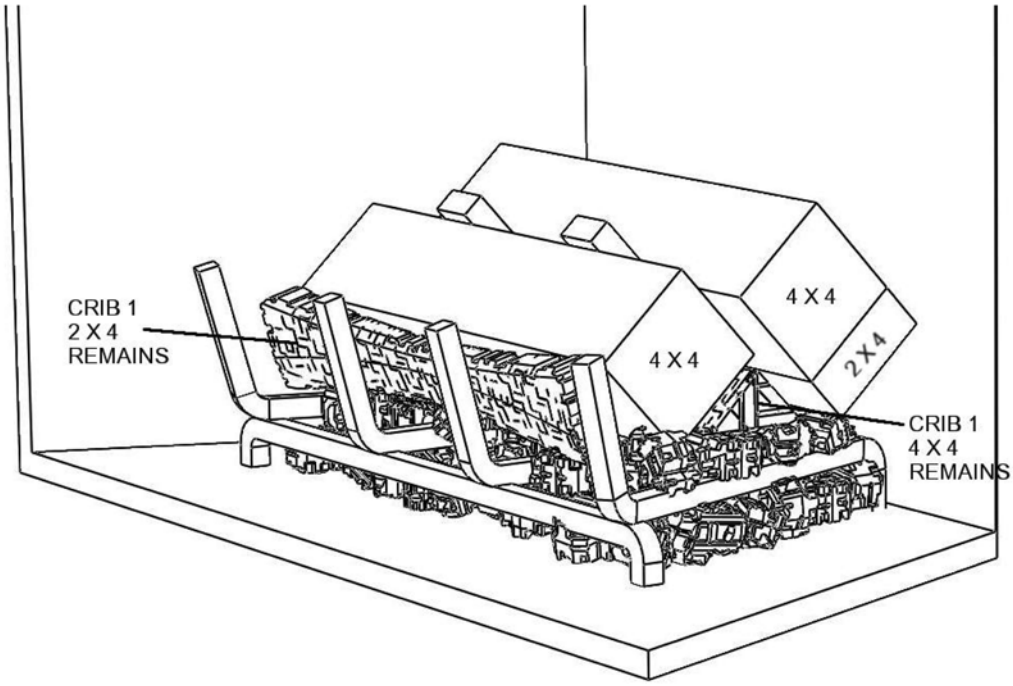

FIG. 16 Second Fuel Crib

9.4.7.3 If solid material remains from the front 2 × 4s, pull that material toward the front of the grate (if a grate is used) or toward the front of the remaining fuel mass (if no grate is used) so that it does not interfere with placement of the second fuel crib and so that it will continue to burn and stimulate ignition of the second fuel crib.

9.4.7.4 Place the second fuel crib on the poked and rearranged fuel base so that the crib is centered front-to-back and left-to-right on the grate (if a grate is used) or on the remaining fuel mass (if no grate is used). Nestle the crib down and into remnant fuel bed to insure good ignition.

9.4.7.5 Record the time and the combined weight of the residual fuel from the first crib plus the second crib.

(1) Poking—One fuel adjustment (poking) is allowed to keep the second fuel crib burning in an aesthetically pleasing manner. Although "aesthetically pleasing" requires the judgment of the test technician, the intent is to maintain flames and even burning across the fuel crib. The poking can occur only in the period of the test when the indicated scale weight (wet) is equal to or less than 50 % of the weight (wet) of the second fuel crib, and the poking should last no more than 60 s. Record the time, weight (wet), and duration of the fuel adjustment. If

the spacers on the second fuel crib burn through and the fuel crib falls apart in such a way that combustion of the crib is adversely impacted (such as the front 4 × 4 falling forward and away from the general fire mass), a fuel adjustment may be made before 50 % of the weight (wet) of the second crib is burned. This fuel adjustment is limited to moving the separated fuel pieces back to their approximate original locations in the crib and should last no longer than 60 s. Record the time, weight (wet), and duration of the fuel adjustment.

9.4.8 When the indicated scale weight (wet) is between 45 and 40 % of the weight (wet) of the second fuel crib, record the time, weight (wet), and add the third (and final) fuel crib using the following procedure. See Fig. 17.

9.4.8.1 Using a poker, break down and adjust the remnants of the second fuel crib as necessary to facilitate loading of the third fuel crib. Poking should last no more than 60 s. Record the time, weight, and duration of the fuel adjustment.

9.4.8.2 The remains of the second fuel crib form a cradle for the third fuel crib, and this cradle should be maintained while poking.

9.4.9 Place the third fuel crib in the remnant fuel bed cradle and center the crib from left to right. Nestle the crib down and into remnant fuel bed to ensure good ignition.

9.4.10 Record the time and the combined weight of the residual fuel from the second crib plus the third crib.

9.4.11 *Poking*—For the third fuel crib, poking is allowed at more than one point during the burning period.

9.4.11.1 One fuel adjustment (poking) is allowed in the period when the indicated scale weight (wet) is between 60 % and 40 % of the weight (wet) of the third fuel crib to keep the third fuel crib burning in an aesthetically pleasing manner. Although "aesthetically pleasing" requires the judgment of the test technician, the intent is to maintain flames and even burning across the fuel crib. The poking should last no more than 60 s. Record the time, weight (wet), and duration of the fuel adjustment.

9.4.11.2 When the indicated scale weight (wet) is less than or equal to 40 % of weight (wet) of the third fuel crib, the remaining fuel should be poked and rearranged as needed to keep any remaining raw wood burning. The intent is to consume all raw wood by the end of the test. Record the time, weight (wet), and duration of each fuel adjustment.

9.4.12 *End of Test Determination*—The test ends when all yellow flaming or visible smoke, or both, (indicative of raw wood combustion) has ceased for a period of 5 min after repeated poking. Only ash, dead charcoal, glowing charcoal and charcoal with blue flames, or combination thereof, should remain.

9.4.13 At the end of the test, record the time and all other parameters as required by Test Method E2515 and shut off the emissions measurement equipment. In addition:

(1) Record the indicated scale weight of the fireplace at the end of the test.

(2) Shovel out all remaining fuel (coals), ash, and nails.

(3) If needed in order to obtain a stable final empty weight, allow the fireplace to cool down, with the door(s) open (if applicable) until the flue gas temperature per 7.4 and 9.2.1 is less than or equal to 90ºF (32°C) or for two hours, whichever occurs first.

(4) Record the indicated empty weight of the fireplace.

(5) The difference is the weight of unburned fuel.

NOTE 6—The weight of the nails is considered insignificant and is ignored.

9.4.14 If the fireplace includes a front door or doors, a separate emissions test shall be conducted for each door

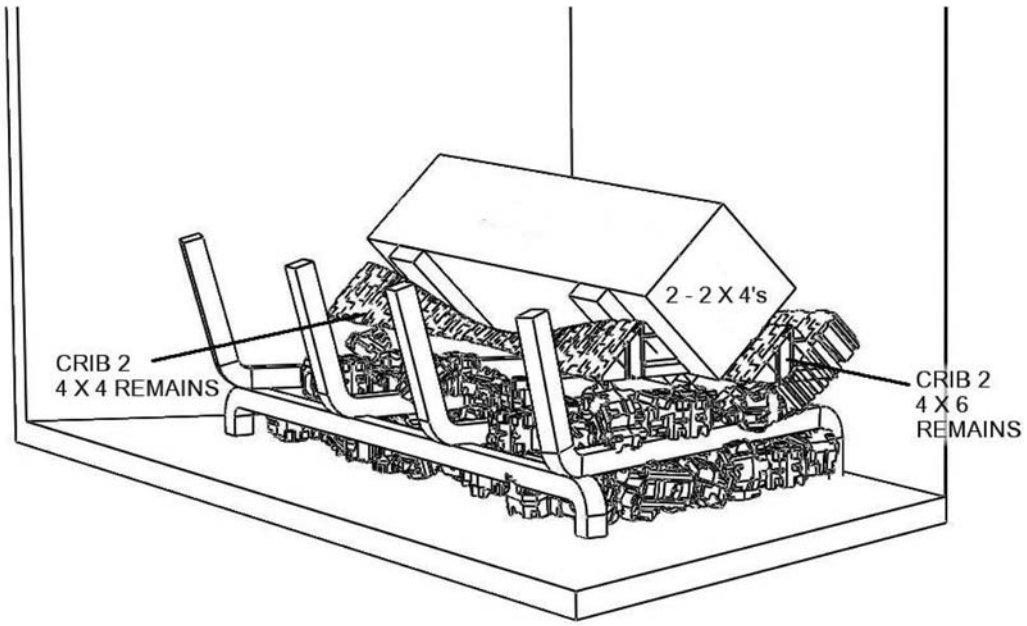

FIG. 17 Third Fuel Crib

position that is allowed in the owner's manual that accompanies the fireplace. In the absence of any instructions, separate emissions tests shall be conducted with the door or doors fully open and fully closed.

9.4.15 If the fireplace includes a manually adjustable combustion air control (or air controls), or other manually adjustable components that affect particulate emission performance, they shall be set in accordance with the instructions in the owner's manual that is supplied with the fireplace. In the absence of any instructions, separate emissions tests shall be conducted with the air control or controls or other manually adjustable components set at their extreme positions (fully open and fully closed, for example).

9.4.16 If the fireplace includes a convection air blower or blowers as standard equipment or as optional equipment, all emission tests shall be conducted with the blower or blowers set at the maximum blower air flow setting.

10. Data Analysis and Calculations

10.1 Carry out calculations, retaining at least one extra significant figure beyond that of the acquired data. Round off figures after the final calculation. Other forms of the equations may be used as long as they give equivalent results.

10.2 *Nomenclature:*

$$M_{K1,2db} = (M_{K1,2wb})(100/(100+FM_{K1,2})) \quad (1)$$

where:

$FM_{K1,2}$ = average fuel moisture of kindling brands 1 and 2, % dry basis;
$M_{K1,2wb}$ = weight of fuel pieces comprising kindling brands 1 and 2 combined, excluding nails, wet basis, lb (kg); and
$M_{K1,2db}$ = weight of kindling brand 1 and 2 combined, excluding nails, dry basis, lb (kg).

$$M_{Sdb} = (M_{Swb})(100/(100+FM_{K1,2})) \quad (2)$$

where:

M_{Swb} = weight of all spacers used to construct fuel cribs 1, 2 and 3, excluding nails, wet basis, lb (kg); and
M_{Sdb} = weight of all spacers used to construct fuel cribs 1, 2 and 3, excluding nails, dry basis, lb (kg).

$$M_{Cidb} = \sum(M_{CiPnwb})(100/(100+FM_{CiPn})) \quad (3)$$

where:

M_{CiPnwb} = weight of each fuel piece n in fuel crib i, excluding nails and spacers, wet basis, lb (kg);
M_{Cidb} = weight of fuel crib i, excluding nails and spacers, dry basis, lb (kg);
FM_{CiPn} = average fuel moisture of fuel piece n in fuel crib i, % dry basis;
i = fuel crib 1, 2, or 3; and
n = fuel piece 1, 2, or 3 as applicable.

$$D_{K1,2db} = M_{K1,2db}/V_{K1,2} \quad (4)$$

where:

$D_{K1,2db}$ = average fuel density of kindling brands 1 and 2 combined, dry basis lb/ft^3 (g/cm^3); and
$V_{K1,2}$ = combined volume of all fuel pieces comprising kindling brands 1 and 2, ft^3 (cm^3).

$$D_{Cidb} = M_{Cidb}/V_{Ci} \quad (5)$$

where:

D_{Cidb} = density of fuel crib i;
V_{Ci} = volume of fuel crib i, cm$^{ft^3}$ (3); and
i = fuel crib 1, 2, or 3.

$$M_{FTAdb} = M_{K1,2db} + M_{Sdb} + \sum M_{Cidb} \quad (6)$$

where:

M_{FTAdb} = total weight of fuel added, excluding nails, dry basis, lb (kg).

$$M_{FTBdb} = M_{FTAdb} - (M_{FPet} - M_{FPef}) \quad (7)$$

where:

M_{FPef} = empty weight of fireplace and chimney assembly including grate or log retainer after end of test run, lb (kg);
M_{FPet} = weight of fireplace and chimney assembly including grate or log retainer and residual fuel, ash, and nails at end of test run, lb (kg); and
M_{FTBdb} = total weight of fuel burned, dry basis, lb (kg).

$$EF = E_T/M_{FTBdb} \quad (8)$$

where:

E_T = total particulate emissions, g (as measured by Test Method E2515); and
EF = emission factor, grams of particulate/dry kg fuel burned.

$$BR = 60(M_{FTBdb}\,\theta) \quad (9)$$

where:

θ = total sampling time, min; and
BR = burn rate, dry kg/h.

$$ER = 60(E_T/\theta) \quad (10)$$

where:

ER = emission rate, grams of particulate/h of fireplace operation.

10.3 *Tare Weight Loss:*

10.3.1 If the tare weight difference of the fireplace at the beginning of the test in accordance with 9.4.2 and at the end of the test in accordance with 9.4.13 (*3*) is greater than 5 % of the total fuel added in accordance with Eq 6, the test run shall be invalid.

$$\text{If } |M_{FPes} - M_{FPef}| > 0.05\,(M_{FTBdb}), \text{ the test run is invalid.} \quad (11)$$

where:

M_{FPes} = empty weight of fireplace and chimney assembly including grate or log retainer before start of test run, lb (kg).

11. Precision and Bias

11.1 *Precision*—It is not possible to specify the precision of the procedure in Test Method E2515 for measuring fireplace emissions because the appliance operation and fueling protocols and the appliances themselves produce variable amounts of emissions and, therefore, the results cannot be used to determine reproducibility or repeatability of this measurement method.

11.2 *Bias*—No information can be presented on the bias of the procedure in Test Method E2515 for measuring fireplace emissions because no material having an accepted reference value is available.

12. Keywords

12.1 emissions; fireplaces; low-mass fireplace; particulate; particulate matter; wood-burning

ANNEX

(Mandatory Information)

A1. MASONRY FIREPLACE FUELING AND OPERATION

A1.1 Scope

A1.1.1 This annex to the test method covers the fueling and operating protocol for determining particulate matter emissions from wood fires in masonry or other high mass fireplaces.

A1.2 Terminology

A1.2.1 *Definitions of Terms Specific to This Annex:*

A1.2.1.1 *masonry or high mass fireplace*—any fireplace with a mass after completion of construction or assembly that prohibits the use of a platform scale that meets the requirements of 7.3 to determine when fuel loads are to be added.

A1.2.1.2 *oxygen recovery level*—The flue gas oxygen concentration that is equal to the lowest observed or calculated flue gas oxygen concentration during combustion of the referenced fuel load (or kindling load) plus the specified percentage difference between the lowest observed concentration and an assumed room air oxygen concentration of 20.9 %.

NOTE A1.1—As an alternative to measuring the flue gas oxygen concentration, the flue gas carbon dioxide and carbon monoxide concentrations may be measured and flue gas oxygen calculated using the following equation:

$$\text{Calculated Oxygen Concentration (\%)} = 20.9\ \% - (\text{Observed Carbon Dioxide \%} + 1/2\ \text{Observed Carbon Monoxide \%}) \quad \text{(A1.1)}$$

A1.3 Equipment and Supplies

A1.3.1 *Flue Gas Sampling System*—The flue gas sampling system consists of the following components:

A1.3.1.1 *Flue Gas Oxygen Analyzer*—Calibrated oxygen analyzer capable of measuring the flue gas oxygen concentration in the range of 0 to 20.9 % and meeting the following minimum specifications:

(1) Resolution: ±1.0 % full scale,
(2) Accuracy: ±1.0 % full scale,
(3) Repeatability: ±0.5 % full scale,
(4) Zero drift: ±1.0 % full scale/24 h ± 5°C,
(5) Span drift: ±1.0 % full scale/24 h ± 5°C, and
(6) Response time (electrical): <2 s.

The flue gas oxygen analyzer must meet the calibration requirements specified in A1.4.

A1.3.1.2 *Carbon Dioxide and Carbon Monoxide Analyzer(s)*—Calibrated analyzer(s) capable of measuring the flue gas carbon dioxide concentration in the range of 0 to 20 % and the flue gas carbon monoxide concentration in the range of 0 to 2 % and meeting the same minimum performance specifications as specified in A1.3.1.1 (1) through (6). The flue gas carbon dioxide and carbon monoxide analyzer(s) must meet the calibration requirements specified in A1.4).

A1.3.1.3 *Flue Gas Sample Probe*—Seamless 304 stainless steel tubing or borosilicate glass with an internal diameter capable of allowing a flow rate that enables the gas sampling train to meet the response time specifications in A1.3.1.1 *(6)*. The probe must be of adequate length to reach the center of the fireplace chimney.

A1.3.1.4 *Flue Gas Sample Conditioning Train*—A flue gas sample conditioning train is recommended for protection of the flue gas analyzer(s). This train typically consists of a particulate filter and a means for removing moisture from the sample stream to a dew point of 32°F (0°C) or less.

A1.3.1.5 *Flue Gas Sample Pump System*—The flue gas sample pump system draws the sample from the fireplace flue under vacuum and pressurizes the sample for delivery to the flue gas analyzer(s). The pump and other components should be nonreactive to the flue gas sample.

A1.3.2 *Flue Gas Sampling System Response Time*—The time required for a flue gas analyzer to display a concentration equal to 95 % of actual flue gas concentration for the flue gas component or components being measured when a step change in measured flue gas component concentration occurs.

A1.4 Calibration and Standardization

A1.4.1 The flue gas analyzer(s) must be calibrated before each test run using NIST traceable calibration gases. The calibration gases must include nitrogen that is at least 99.99 % pure as a zero gas, a high-range span gas with a measured flue gas component concentration in the range of 80 to 100 % of the full scale span of the analyzer (balance nitrogen) and a midrange span gas with a measured flue gas component concentration in the range of 40 to 60 % of the full scale span of the analyzer (balance nitrogen). If an oxygen analyzer is

used, room air may be used as the high-range span gas. If carbon dioxide and carbon monoxide analyzers are used, the full scale and mid-range span gases may be a combination of the required ranges of carbon dioxide and carbon monoxide with the balance nitrogen.

A1.4.2 After the analyzer(s) zero and span settings are adjusted for the zero and high-range span gas concentrations using the analyzer manufacturer's recommended calibration procedures and standard laboratory practices, introduce the midrange span gas and allow the analyzer(s) to reach a stable reading. The concentration displayed for the midrange span gas must be equal to the known concentration ±1 % of the full scale span of the analyzer. In the case of an oxygen analyzer with a 0 to 25 % measurement range (span), the midrange reading must be within ±0.25 % of the known oxygen concentration in the midrange span gas. In the case of a carbon dioxide analyzer with a 0 to 20 % measurement range (span), the midrange reading must be within ±0.20 % of the known carbon dioxide concentration in the midrange span gas. In the case of a carbon monoxide analyzer with a 0 to 2 % measurement range (span), the midrange reading must be within ±0.02 % of the known carbon monoxide concentration in the midrange span gas. If this requirement is not met, the analyzer(s) can not be considered to be linear over its measurement range. The analyzer must either be adjusted to be linear following the analyzer manufacturer's instructions or a NIST traceable multipoint analyzer calibration curve that spans the operating range of the analyzer must be used.

A1.4.3 Before each test run, conduct a leak test of the flue gas sampling system to insure that there are no leaks upstream (vacuum side) of the flue gas sample pump.

A1.4.4 With the flue gas sample flow to the flue gas analyzer(s) set to the flow rate recommended by the analyzer manufacturer, use a rubber stopper or other sealing means to plug the end of flue gas sample probe. Observe the sample flow rate to the analyzer by watching the sample flow meter until no measurable flow is observed. If a measurable flow is observed, the leak test is failed. Find and repair the leak source and repeat the leak test until no measurable flow is observed. Other equivalent leak test procedures may be used to determine that there are no measurable leaks that will impact the flue gas analyzer(s) readings.

A1.4.5 Conduct a flue gas sampling system response time check by introducing a sample gas with a known flue gas component concentration at the flue gas sample probe inlet and allowing the analyzer reading to stabilize. Introduce a second sample gas with a different known concentration and determine the time required to reach 95 % of the known concentration on the analyzer display (recorder or data acquisition system, if used). The time required to reach 95 % of the known concentration in the sample measured from the time the sample is introduced to the sample probe must be less than two minutes. If the system response time is greater than two minutes, reconfigure the flue gas sampling system or adjust the sample flow rate until the system response time is less than two minutes.

A1.5 Procedure

A1.5.1 *Preconditioning of the Fireplace*—Prior to testing for emissions, the fireplace to be evaluated must be burned for no less than 10 h for fireplaces without catalytic combustors or no less than 48 h for fireplaces with catalytic combustor(s). This may be done inside or outside the test facility.

A1.5.1.1 Set up the fireplace in accordance with instructions provided by the manufacturer. The total height of chimney when measured from the base of the fireplace shall be 15 ± 1 ft (4.6 ± 0.3 m).

A1.5.1.2 Install a flue-gas temperature measurement device at the center of the flue, 8 ± 0.3 ft (2.4 ± 0.1 m) above the floor base of the fireplace.

A1.5.1.3 Record the start time and flue gas temperature.

A1.5.1.4 Ignite a fire using newspaper and kindling and establish an actively burning fire. Add more fuel as needed to sustain the fire.

NOTE A1.2—Any type of untreated wood may be used for the preconditioning.

A1.5.1.5 Record the time and weight for all fuel added.

A1.5.1.6 Record the flue-gas temperature at least once during each 30 min of operation.

A1.5.1.7 Record the ending time, total wood weight of wood burned, and total elapsed time of operation.

A1.5.1.8 When the preconditioning fire is completed, allow the fireplace to cool to room temperature and remove all unburned wood, charcoal, ash, or other debris from the firebox.

A1.5.1.9 Clean the chimney using a standard chimney brush appropriately sized for the chimney.

A1.5.2 Install the fireplace in the test facility. Installation of the fireplace in the test facility must be done in accordance with the requirements of 9.2 except:

A1.5.2.1 Install the flue gas sampling system that meets the requirements in A1.3.1 with the inlet to the flue gas sample probe in the center of the flue and 8 ft. (2.4 m) above the fireplace hearth or 4 ft. (1.2 m) above the smoke chamber (whichever is greater).

A1.5.3 *Fuel*—The fuel used shall meet the requirements and specifications in 9.3. When that section references the manufacturer of the fireplace, the term "manufacturer" may be interpreted to include masons or installers.

A1.5.4 *Operation*—The operation of the fireplace will be in accordance with 9.4 except a flue gas oxygen recovery algorithm is used instead of remaining fuel weight to determine when the fuel cribs may be loaded or fuel adjustments made.

A1.5.4.1 The 35 % oxygen recovery level used throughout the fueling section of this annex is defined as the observed or calculated flue gas oxygen concentration that is equal to the lowest observed or calculated flue gas oxygen concentration during the combustion of the referenced fuel load (or kindling load) plus 35 % of the difference between the lowest observed or calculated concentration and an assumed room air oxygen concentration of 20.9 %.

(1) Example—Lowest observed or calculated flue gas oxygen value during combustion of the kindling load or given fuel load = 18.1 %. Difference between 20.9 % and

18.1 % = 2.8 %. 35 % of 2.8 % = 0.98 %. This rounds to 1.0 %. 18.1 % + 1.0 % = 19.1 %. This is the 35 % oxygen recovery value.

A1.5.4.2 When all requirements for starting the emissions test are met in accordance with E2515, record the start time, record the combined weight of the newspaper and first and second kindling brands, start the sampling equipment, including the flue gas sampling system, and then ignite the newspaper balls. A propane gas torch has been found to be a good device for obtaining rapid and even ignition of the newspaper. Quickly work your way from one side to the other to insure even ignition. All newspaper must be ignited within 30 s from starting the sampling equipment. Flue gas oxygen readings or calculated values should be recorded at least once per minute. A chart recorder or data acquisition system that allows visual tracking of the oxygen (or carbon dioxide and carbon monoxide) concentration(s) has been found to be useful in helping to determine the minimum flue gas oxygen concentration observed during the combustion of the kindling or main fuel loads.

A1.5.4.3 After the observed (or calculated) oxygen level in the flue gas during the kindling fire has reached the 35 % oxygen recovery level as defined in A1.2.1.2 and A1.5.4.1, record the time, the observed or calculated flue gas oxygen level, and then add the first fuel crib following the procedure in 9.4.6.1 – 9.4.6.4.

(1) Record the time and the observed or calculated flue gas oxygen level immediately after the first crib is added.

(2) Poking—One fuel adjustment (poking) is allowed to keep the first fuel crib burning in an aesthetically pleasing manner. Although "aesthetically pleasing" requires the judgment of the test technician, the intent is to maintain flames and even burning across the fuel crib. The first fuel crib may be adjusted anytime after the observed or calculated flue gas oxygen concentration reaches the 35 % oxygen recovery level as defined in A1.2.1.2 and A1.5.4.4 and is no longer burning in an aesthetically pleasing manner. The poking should last no more than 60 s. Record the time, flue gas oxygen level and the duration of the fuel adjustment.

(a) Exception—If the spacers on the first fuel crib burn through and the fuel crib falls apart in such way that combustion of the crib is adversely impacted (such as the front 2 × 4s falling forward and away from the general fire mass), a fuel adjustment may be made before the oxygen recovery level has reached 35 %. This fuel adjustment is limited to moving the separated fuel pieces back to their approximate original locations in the crib and should last no longer than 60 s. Record the time, observed or calculated flue gas oxygen level, and the duration of the fuel adjustment.

A1.5.4.4 After the observed or calculated oxygen level in the flue gas during the combustion of the first fuel crib reaches the 35 % oxygen recovery level as defined in A1.2.1.2 and A1.5.4.1, record the time, observed or calculated flue gas oxygen level, and then add the second fuel crib following the procedure in 9.4.7.1 – 9.4.7.4.

(1) Record the time and observed or calculated flue gas oxygen level immediately after the second crib is added.

(2) Poking—One fuel adjustment (poking) is allowed to keep the second fuel crib burning in an aesthetically pleasing manner. Although "aesthetically pleasing" requires the judgment of the test technician, the intent is to maintain flames and even burning across the fuel crib. The second fuel crib may be adjusted anytime after the observed or calculated flue gas oxygen concentration reaches the 35 % oxygen recovery level as defined in A1.2.1.2 and A1.5.4.1 and is no longer burning in an aesthetically pleasing manner. The poking should last no more than 60 s. Record the time, observed or calculated flue gas oxygen level and the duration of the fuel adjustment.

(a) Exception—If the spacers on the second fuel crib burn through and the fuel crib falls apart in such way that combustion of the crib is adversely impacted (such as the front 4 × 4 falling forward and away from the general fire mass), a fuel adjustment may be made before the oxygen recovery level has reached 35 %. This fuel adjustment is limited to moving the separated fuel pieces back to their approximate original locations in the crib and should last no longer than 60 s. Record the time, observed or calculated flue gas oxygen level, and the duration of the fuel adjustment.

A1.5.4.5 After the observed or calculated oxygen level in the flue gas during the combustion of the second fuel crib reaches the 35 % oxygen recovery level as defined in A1.2.1.2 and A1.5.4.1, record the time, observed or calculated flue gas oxygen level, and then add the third fuel crib following the procedure in 9.4.8.1 – 9.4.9.

(1) Record the time and the observed or calculated flue gas oxygen level immediately after the third crib is added.

(2) Poking—For the third fuel crib, poking is allowed at more than one point during the burning period.

(a) One fuel adjustment (poking) is allowed in the period before the observed or calculated oxygen level in the flue gas during combustion of the third fuel crib has reached the 35 % oxygen recovery level to keep the third fuel crib burning in an aesthetically pleasing manner. Although "aesthetically pleasing" requires the judgment of the test technician, the intent is to maintain flames and even burning across the fuel crib. The poking should last no more than 60 s. Record the time, observed or calculated flue gas oxygen level, and the duration of the fuel adjustment.

(b) After the observed or calculated oxygen level in the flue gas during the combustion of the third fuel crib reaches the 35 % oxygen recovery level as defined in A1.2.1.2 and A1.5.4.1, the remaining fuel should be poked and rearranged as needed to keep any remaining raw wood burning. The intent is to consume all raw wood by the end of the test. Record the time, observed or calculated flue gas oxygen level, and the duration of each fuel adjustment.

A1.5.4.6 *End of Test Determination*—Refer to 9.4.12.

A1.5.4.7 At the end of the test, record the time and all other parameters as required by E2515 and shut off the emissions measurement equipment. In addition:

(1) Shovel out and weigh all remaining fuel (coals), ash, and nails.