Designation: E2886/E2886M – 14

An American National Standard

Standard Test Method for Evaluating the Ability of Exterior Vents to Resist the Entry of Embers and Direct Flame Impingement[1]

This standard is issued under the fixed designation E2886/E2886M; 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 fire-test-response standard prescribes two individual methods to evaluate the ability of a gable end, crawl space (foundation) and other vents that mount on a vertical wall or in the under-eave area to resist the entry through the vent opening of embers and flame. The ability of such vents to completely exclude entry of flames or embers is not evaluated. Roof ridge and off-ridge (field) vents are excluded from this standard. Acceptance criteria are not provided in this standard.

NOTE 1—Test Method E2912 records information relevant to evaluate completely excluding the entry of flames through the venting device.

1.2 Ember entry and flame penetration are evaluated separately using different test procedures. A commentary and summary of the development of the ember test apparatus are given in Appendix X1.

1.3 These laboratory tests are used to evaluate the response of vents when subjected to ember and flame exposures under controlled conditions.

1.4 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems has the potential to result in non-conformance with the standard.

1.5 Unless otherwise specified, the tolerance for dimensions in figures and text in this document shall be ±5 %.

1.6 This test method does not address interior fire spread.

1.7 *The standard is used to measure and describe the response of materials, products or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire hazard or fire risk assessments of the materials, products or assemblies and other cladding materials under actual fire conditions.*

1.8 *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.*

1.9 *Fire testing is inherently hazardous. Adequate safeguards for personnel and property shall be employed in conducting these tests.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1929 Test Method for Determining Ignition Temperature of Plastics

E108 Test Methods for Fire Tests of Roof Coverings

E176 Terminology of Fire Standards

E2257 Test Method for Room Fire Test of Wall and Ceiling Materials and Assemblies

E2707 Test Method for Determining Fire Penetration of Exterior Wall Assemblies Using a Direct Flame Impingement Exposure

E2912 Test Method for Fire Test of Non-Mechanical Fire Dampers Used in Vented Construction

2.2 *Other Documents:*[3]

SFM 12-7A-1, Exterior Wall Siding and Sheathing, California Office of the State Fire Marshal, Sacramento, CA

SFM 12-7A-3, Under Eave, California Office of the State Fire Marshal, Sacramento, CA

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method refer to Terminology E176, Test Method E108, and Test Method E2912.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *ember, n*—small burning or glowing pieces of vegetation or other cellulosic-based material.

3.2.2 *flaming combustion, n*—ignition of combustible material that results in flaming combustion.

[1] This test method is under the jurisdiction of ASTM Committee E05 on Fire Standards and is the direct responsibility of Subcommittee E05.14 on External Fire Exposures.

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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: http://osfm.fire.ca.gov/codedevelopment/wildfireprotectionbuildingconstruction.php

3.2.3 *smoldering combustion, n*—ignition of combustible material where a transition to flaming combustion does not occur but a charred area indicating locations where embers landed can be observed.

3.2.4 *sustained flaming, n*—existence of flame on or over the surface of the vent for continuous periods of at least 4 s.

3.2.5 *unexposed side, n*—the face of the vent not directly exposed to the fire in the Flame Intrusion Test.

3.2.6 *vent, n*—a device or assembly placed in an exterior opening of a building (located in an eave, gable, wall, or foundation) that allows for aeration (free exchange of air).

4. Summary of Test Method

4.1 This test method contains two procedures to assess the ability of the vent to limit the entry of embers and flame penetration.

4.2 *Ember Intrusion Test*—This test method provides for a direct ember exposure to vents. The apparatus allows for embers to fall vertically and impinge on the vent mounted horizontally on ledges within the test chamber. An induction fan located at the bottom of the apparatus pulls the air stream through the vent, allowing any embers that pass through the vent to impinge on a combustible target material.

4.2.1 Observations are made for the occurrence of flaming combustion of the combustible target material during the time that embers are being generated and passing through the vent.

4.2.2 This test method utilizes a vertical air flow apparatus for the ember test.

4.3 *Flame Intrusion Test*—This test method provides for the evaluation of direct flame impingement on a vent mounted in a test assembly described in Test Method E2912.

4.3.1 The flame source is directed into the test assembly and directly impinges the vent that is mounted in either a vertical or horizontal position as described in Test Method E2912.

4.3.2 This test method employs a gas burner described in Test Method E2912 to produce flames that contact the vent.

4.3.3 The fuel flow rate from the burner shall produce a heat release rate of 300 ± 10 kW as described in Test Method E2912.

4.3.4 This test method includes an Integrity Test as described in Test Method E2912 to ascertain the presence of sustained flaming. The Integrity Test includes the following:

NOTE 2—Integrity is defined in Test Method E2912.

4.3.4.1 Visual observations are made for the presence and duration of any flame penetration through the vent.

4.3.4.2 An Ignition Test Procedure as described in Test Method E2912 is used to ascertain flaming combustion.

4.3.5 This test method includes an optional Insulation Test as described in Test Method E2912. The optional Insulation Test includes surface thermocouples to measure the temperature on the unexposed side of the vent.

5. Significance and Use

5.1 This test method evaluates the ability of exterior vents that mount vertically or horizontally to resist the entry of embers and flame penetration through the vent.

NOTE 3—A comparison study between the vertical air flow apparatus and a horizontal air flow apparatus, developed at the National Institute of Standards and Technology (NIST), has been conducted. A summary of the results of that comparison study are presented in Section X1.3 of the Appendix.

5.2 *Flame Intrusion Test*—Refer to the Significant and Use Section in Test Method E2912 for information related to the direct flame impingement on the vent.

6. Apparatus

6.1 *Apparatus for the Ember Intrusion Test:*

6.1.1 Diagrams of the ember intrusion apparatus are shown in Figs. 1-5. The apparatus consists of an ember generation chamber, a gas burner, a drive unit with controls, a flame chamber, a test cabinet and an exhaust fan.

6.1.2 *Ember Generation Chamber (Circular Tumbler):*

6.1.2.1 The circular tumbler shall be fabricated from 13 mm [0.5 in.] by 1.5 mm [0.059 in.] flattened expanded metal wrapped around four 6 mm [0.25 in.] diameter bracing rods that are equally spaced around the perimeter and connected on each end to 203 mm [8 in.] diameter, 8 mm [0.3125 in.] thick steel end disc plates. The end disc plates shall be 457 mm [18 in.] apart, forming a cylinder that is 203 mm [8 in.] in diameter and 457 mm [18 in.] in length.

6.1.2.2 The circular tumbler shall have a hinged door also made of the 13 mm [0.5 in.] by 1.5 mm [0.059 in.] flattened expanded steel, approximately 140 mm by 89 mm [5.5 in. by 3.5 in.] arched to match the curve of the tumbler and located in the center of the tumbler between one end plate and the other. The orientation of the access door shall be such that the 89 mm [3.5 in.] dimension is measured along the circumference of the cylinder. The hinges of the access door shall be located along the 140 mm [5.5 in.] dimension of the door.

6.1.2.3 A 25.4 mm (+0 mm / –0.1 mm) [1 in. (+0 in./ –0.004 in.)] diameter cold rolled steel bar shall be connected to the center of each of the 203 mm [8 in.] round plates of the tumbler. These bars shall act as an axle. Each bar shall be 76 mm [3 in.] in length and shall be welded on one end to the outside centers of each plate. The centerline of the bars shall match the centerline of the tumbler. Both bars shall pass through their respective 25.4 mm (+0.1 mm / –0 mm) [1 in.(+ 0.004 in. / –0 in.)] (inside diameter) bearing pillow block which shall be mounted to the frame with two 6 mm, 10 threads per cm [M6×1] by 32 mm length [0.25 in. – 20 by 1.25 in.] machine bolts each. The bearings shall be located 13 mm [0.5 in.] from the 203 mm [8 in.] round end plates. A 20-tooth ISO 08B roller chain sprocket with 25.4 mm [+0.1 mm / –0 mm] inside bore diameter [20-tooth by ANSI #40 roller chain sprocket with 1-in. inside diameter] shall be affixed on the axle shaft on the side of the drive assembly.

6.1.2.4 While in operation, the tumbler shall be shielded with a hinged hood. The hood shall be a two piece clam shell style that overlaps at the top by 25 mm [1 in.]. The hood shall be formed using 0.8 mm [0.031 in.] sheet metal with 19 mm [0.75 in.] wide flat bar reinforcing at the perimeter. The flat bar stock shall be attached to the sheet metal hood with pop rivets. When closed the hood shall be arched to have a diameter of 254 mm [10 in.]. Each of the two pieces that make up the hood shall be 495 mm [19.5 in.] wide.

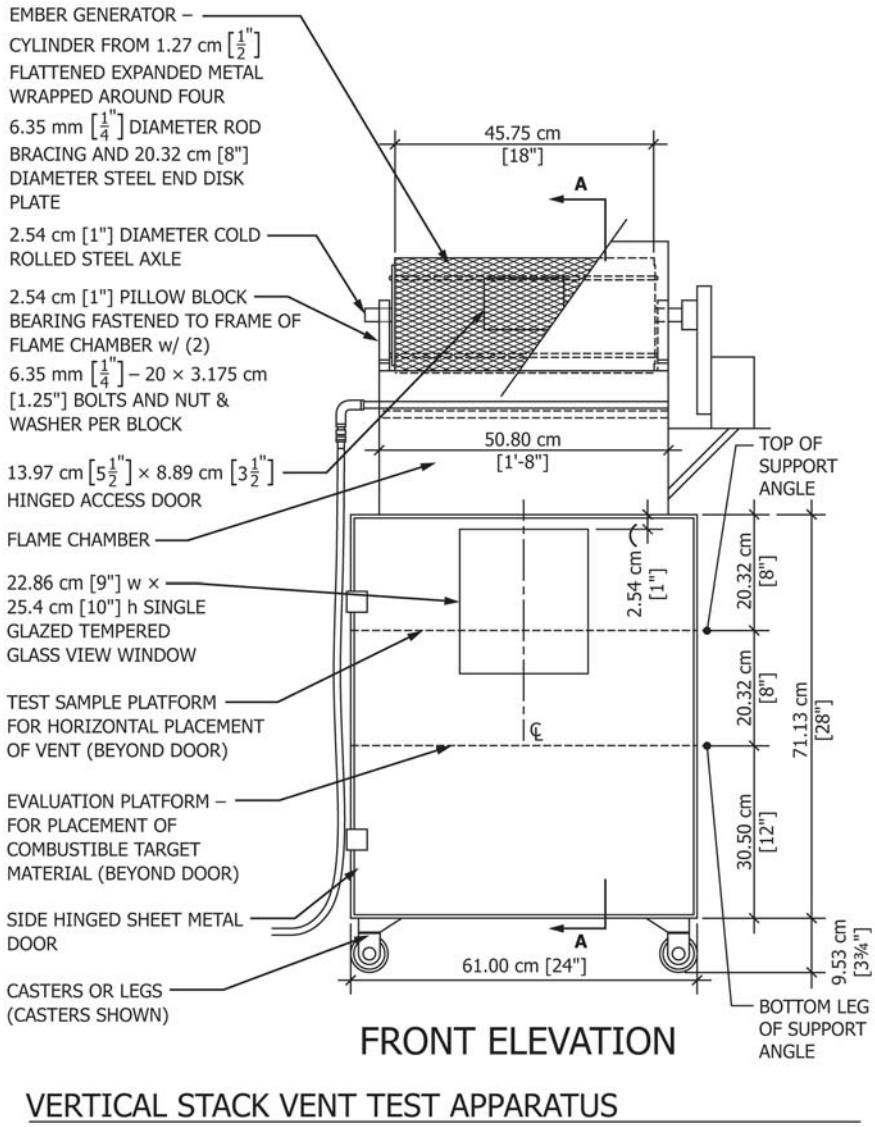


FIG. 1 Ember Apparatus, Front View

6.1.3 The drive unit shall consist of a motor, gear box, chain and sprockets and controls.

6.1.3.1 The motor shall be a ¼ HP National Electrical Manufacturers Association (NEMA) 56C C-face mount single phase AC motor, 1725 rpm, and shall be mounted to a metal cantilevered shelf. The metal shelf shall be made from a 5 mm [0.1875 in.] plate, 305 mm [12 in.] wide and 184 mm [7.25 in.] deep with metal knee braces tack welded to the left side of the flame chamber.

6.1.3.2 The gear box shall be a 0.35 HP maximum, NEMA 56C C-face input, left hand output by 22.2 mm [0.875 in.] round shaft, 60:1 ratio and shall be mounted to the same shelf as the motor.

6.1.3.3 The drive chain and sprockets shall be International Organization for Standardization (ISO) 08B (#40) roller chain, ISO 08B (4020) BS 22.2 mm [0.875 in.] gear box sprocket and ISO 08B (4020 BS 25 mm [1 in.]) sprocket. The drive chain shall be guarded with sheet metal or expanded steel for operational safety.

6.1.3.4 When activated, the circular tumbler shall rotate at 30 rev/min.

6.1.4 The controls shall have three switches: one for the fan, one for the drive motor, and one for the fan and drive motor together.

6.1.5 The flame chamber shall be centered directly below the tumbler. The flame chamber shall be constructed with a framework of 19 by 19 mm [0.75 by 0.75 in.] steel angle and skinned with 2 mm [0.078 in.] sheet metal panels on four sides. The top and bottom of the box shall be open to allow the embers to flow through. The chamber shall be 228 mm [9 in.] deep, 508 mm [20 in.] wide and 254 mm [10 in.] tall.

6.1.5.1 The burner shall consist of a 13 mm [0.5 in.] round black iron gas pipe with fifteen 2.4 mm [0.09375 in.] round holes equally spaced at 19 mm [0.75 in.] in a straight pipe. The pipe shall run horizontally, parallel with the tumbler. The distance between the bottom of the tumbler and the center of the gas pipe shall be 57 mm [2.25 in.]. The first hole in the pipe shall be located 95 mm [3.75 in.] from the left wall of the flame

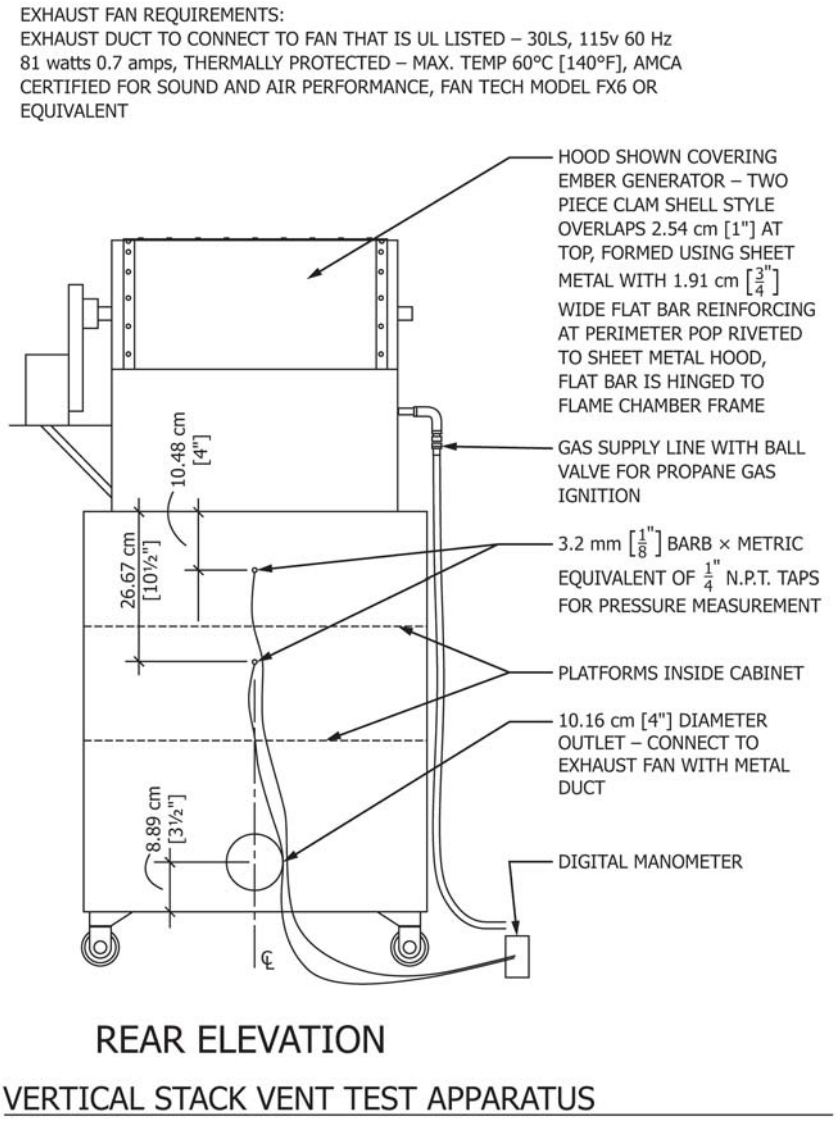


FIG. 2 Ember Apparatus, Rear View

chamber. The last hole shall be located 362 mm [14.25 in.] from the left wall of the flame chamber.

6.1.5.2 The burner pipe shall be connected to the left and right side of the flame chamber, exiting on the left where it shall be attached to a gas supply line with ball valve.

6.1.6 *Test Cabinet:*

6.1.6.1 The test cabinet shall be a rectangular steel box, 381 mm [15 in.] deep, 610 mm [24 in.] wide and 711 mm [28 in.] tall. It shall be centered below the flame chamber and shall rest on four casters or legs that are 95 mm [3.75 in.] tall. The test cabinet shall have an opening in the top, through to the flame chamber, which is 190 mm [7.5 in.] deep and 457 mm [18 in.] wide positioned so that it is centered from left-to-right and from front-to-back in the top of the test cabinet. The test cabinet shall have an interior framework of welded 32 by 32 mm [1.25 by 1.25 in.] angle iron and skinned with 2 mm [0.078 in.] sheet metal panels.

6.1.6.2 The front side of the test cabinet shall consist of a left-hinged 2 mm [0.078 in.] door with a glazed tempered-glass view window, and two latches on the right side to hold the door securely closed during testing. The door shall be framed out with 32 by 32 mm [1.25 by 1.25 in.] by 3 mm [0.125 in.] thick angle iron or equivalent material.

6.1.6.3 The view window shall be 229 mm [9 in.] wide and 254 mm [10 in.] high. The window shall be centered left-to-right and the top of the window shall be 25 mm [1 in.] from the top of the door it is mounted in.

6.1.7 Two shelves shall be mounted inside the test chamber.

6.1.7.1 *Upper Shelf:*

(1) The upper shelf shall serve as a platform for the vent and shall be located 203 mm [8 in.] from the top of the chamber.

6.1.7.2 The upper shelf shall have a ledge on four sides made of 25 mm by 25 mm [1 in. by 1 in.] by 3 mm [0.125 in.] steel angle welded to the interior cabinet walls. A piece of gypsum board, nominal 13 mm [0.5 in.] thick, shall be cut to size to fit on top of the angle iron frame. The gypsum board

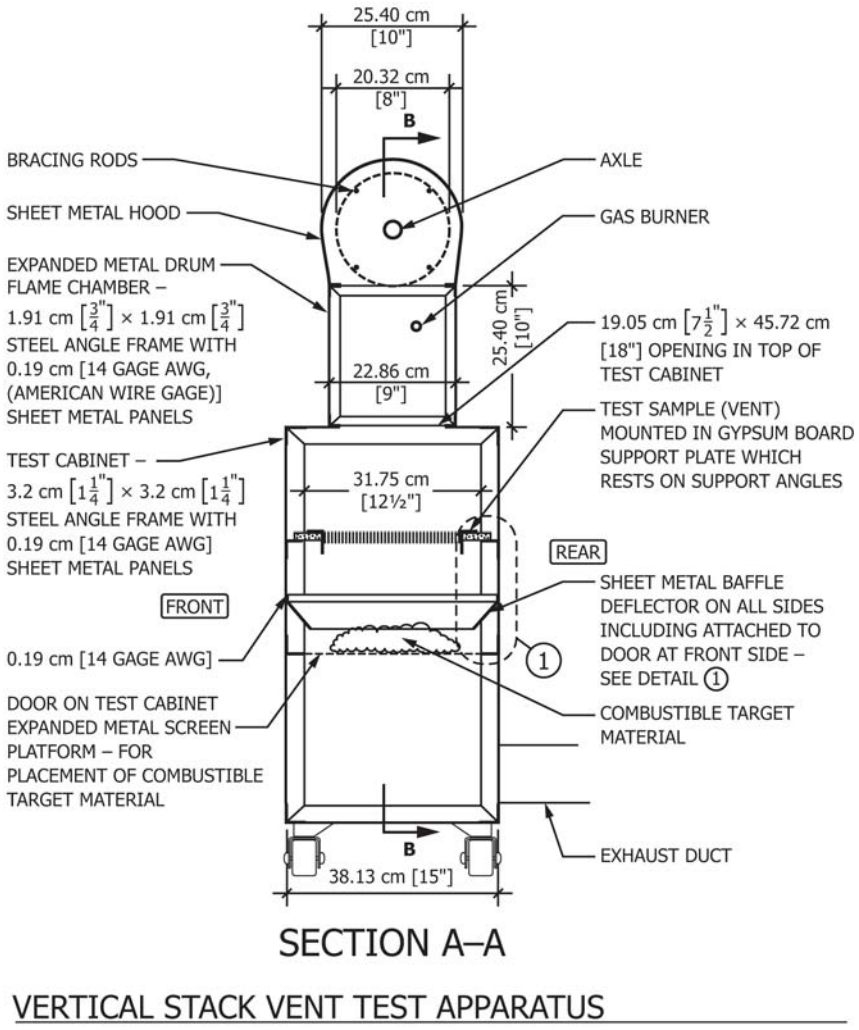


FIG. 3 Ember Apparatus, Section A-A, Side View

shall be cut appropriately to center the vent under the tumbler. The edges between the vent and gypsum board shall be sealed.

6.1.7.3 The gypsum board section shall be scored in the 305 mm [12 in.] depth direction, approximately 13 mm [0.5 in.] from the edge, to allow for folding of the section, and facilitate insertion and removal of the vent in the apparatus.

6.1.8 *Lower Shelf:*

6.1.8.1 The lower shelf shall be located 406 mm [16 in.] from the top of the chamber. The shelf shall have a ledge on four sides made of 25 by 25 mm [1 by 1 in.] by 3 mm [0.125 in.] thick steel angle welded to the interior cabinet walls. A piece of 13 mm [0.5 in.] by 1.5 mm [0.059 in.] flattened expanded metal screen shall rest on the ledge of the angle iron and be tack welded to it.

6.1.8.2 The lower shelf shall be used to support the combustible test media that will be used to evaluate vent performance.

6.1.9 The test cabinet shall have sheet metal baffle deflectors attached on all four interior cabinet walls, including the back side of the door. These baffles shall be located between the upper and lower shelf.

6.1.9.1 The baffles are designed to funnel test embers away from the edge of the combustible target media without resulting in an accumulation of embers along the outside edge.

6.1.9.2 The baffles shall be fabricated from 76 mm [3 in.] strips of 1 mm [0.051 in.] sheet metal that is tack welded or bolted to the interior cabinet walls and door.

6.1.9.3 The baffles shall have a 19 mm [0.75 in.] tab as an attachment point and bent to angle inward at 45 degrees from another 57 mm [2.25 in.].

6.1.10 There shall be a 102 mm [4 in.] round hole in the back wall of the cabinet, centered from side-to-side and located 89 mm [3.5 in.] from the bottom of the cabinet. The steel edge around the hole shall be used to attach a metal collar.

6.1.10.1 A 915 mm [3 ft] section of sheet metal ducting shall be attached to the outlet collar at one end and to the exhaust fan at the other end.

6.1.10.2 The exhaust fan shall be a 30LS, 115 VAC, 60 Hz, 81 W, 0.7 A thermally-protected [maximum temperature 140°F] fan. The fan shall be used to draw air through the apparatus.

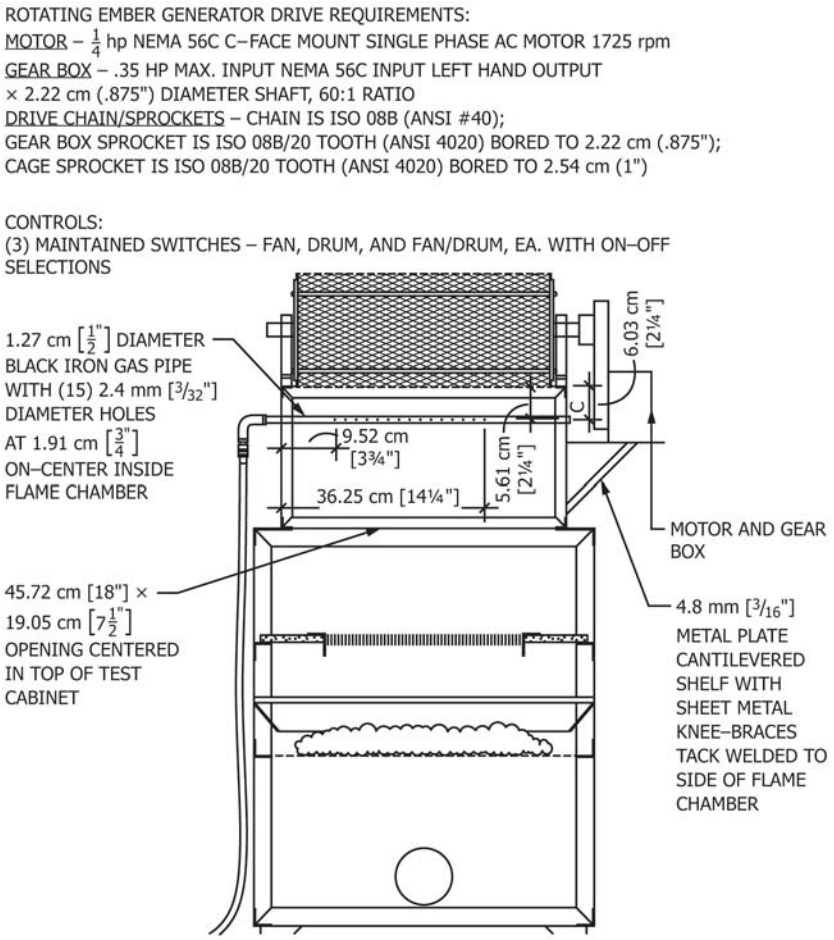


FIG. 4 Ember Apparatus, Internal Baffle Deflector Detail

6.1.10.3 The fan shall have variable speed control adjustment and the control shall be adjusted such that with a 6 mm [0.25 in.] screen mesh with 0.64 mm [0.025 in.] wire, covering the entire upper shelf, and the prescribed expanded steel covering the lower shelf, the wind velocity shall have an average speed of 0.9 m/s [2.0 mph].

(1) Velocity shall be measured 38 mm [1.5 in.] above the upper shelf.

6.1.11 Three thermocouples (Type K, 18 B&S gauge (1 mm [0.04 in.])) shall be positioned at a height of 25 mm [1 in.] directly over and along the center line of the width of the vent. One thermocouple shall be placed above the center of the vent. The remaining two thermocouples shall be placed on each side of the center thermocouple at distance halfway between the center thermocouple and the outer edge of the vent. Temperature readings shall be taken at 1-s intervals over the entire length of the test.

6.2 *Apparatus for the Flame Intrusion Test:*

6.2.1 *Fire Source*—Refer to the Apparatus Section and "Fig. 1 Gas Burner Exposure Fire Source" in Test Method E2912 for the burner and fuel source needed to produce the fire source and conduct the Flame Intrusion Test on the vent.

NOTE 4—The burner and its output were selected to produce a sudden direct flame impingement on the test specimen that is constant. The burner configuration and its output were based upon those prescribed in Test Method E2257. The distance between the test specimen and the fire source (gas burner) was set to address variables typically seen in building occupation that contribute to sudden direct flaming. Two of many possible examples are: *(1)* Exterior vents located near storage areas where combustibles are stacked such as wood piles, *(2)* Exterior vents in contact with landscaping (vegetation or forestation, or both). In many cases, these combustibles are just inches from the vent, which is open to allow airflow, and are subject to a sudden direct flame impingement.

6.2.2 *Test Assembly*—Refer to the Apparatus Section in Test Method E2912 for the test bench (as shown in Figs. 2-9, inclusive, in Test Method E2912).

6.2.3 *Cotton Pads and Applicator Frame*—Refer to the Apparatus Section and the Annex in Test Method E2912 for the type of cotton pads and applicator frame (as shown in Figs. A1.1 and A1.2 in Test Method E2912).

6.2.4 *Unexposed Surface Thermocouples*—Refer to the Apparatus Section in Test Method E2912 for the type of optional unexposed surface thermocouples.

6.2.5 *Thermocouple Pads*—Refer to the Apparatus Section in Test Method E2912 for the type of optional thermocouples pads.

6.2.6 *Other Detection and Observation Devices*—A video camera is permitted to document the presence and duration of any flame penetration through the vent. When desired, refer to the Apparatus Section in Test Method E2912 for other thermal detection devices that are permitted.

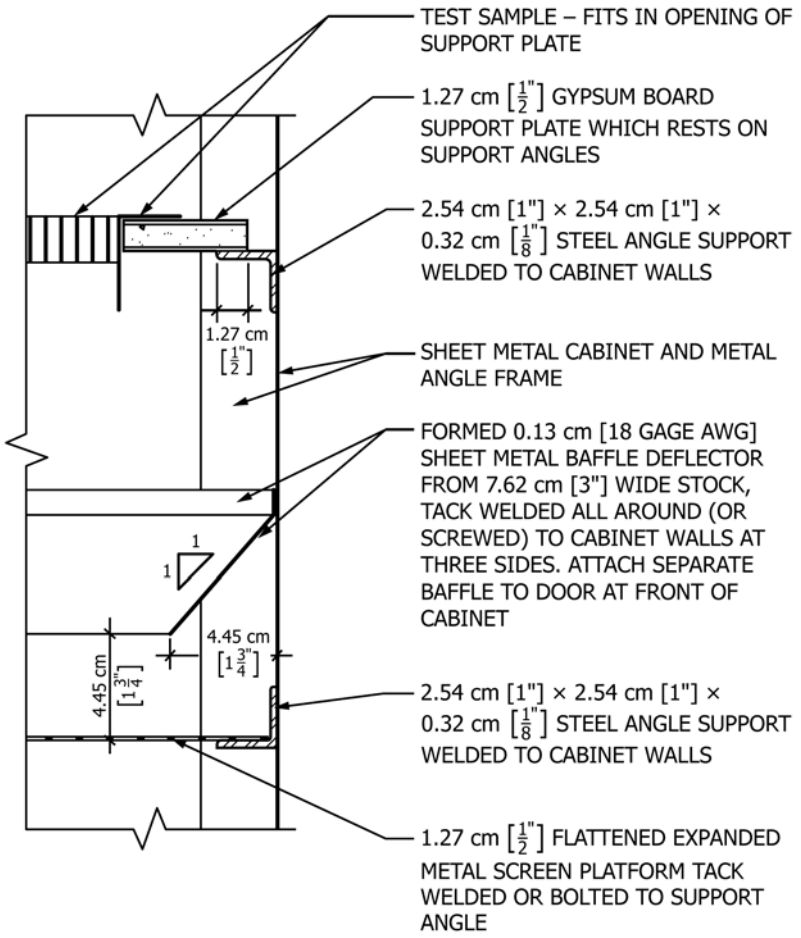


FIG. 5 Baffle Deflector Detail, Section 1

6.2.7 *Time Measurement*—Refer to the Apparatus Section in Test Method E2912 for the type of time measurement devices.

7. Test Specimen

7.1 The test specimen is the vent. The test specimen shall be representative of the vent as used in practice. Document a detailed description of the vent with respect to materials, components, workmanship, and details. The same model number (type) of vent shall be used in both the Ember Intrusion Test and Flame Intrusion Test.

7.2 *Ember Intrusion Test:*

7.2.1 *Test Specimen Size*—Some vents are larger than what the test apparatus will accommodate. When necessary, the vent shall be reduced in length or width while maintaining the same design features in order to fit into the ember test apparatus. Document the dimensions of the test specimen tested. Photograph the vent used in the Ember Intrusion Test.

NOTE 5—The maximum sized vent that the test chamber will accommodate is 330 by 533 mm [13 by 21 in.].

7.2.2 *Test Specimen Installation*—Document the installation of the vent and all materials used.

7.3 *Flame Intrusion Test:*

7.3.1 *Test Specimen Splices*—Refer to and follow the Test Specimen and Test Assembly Section requirements in Test Method E2912 related to splices.

7.3.2 *Test Specimen Size*—Refer to and follow the Test Specimen and Test Assembly Section requirements in Test Method E2912 related to size.

7.3.3 *Test Specimen Installation*—Refer to and follow the Test Specimen and Test Assembly Section requirements in Test Method E2912 related to installation.

7.3.4 *Horizontal Test Specimens*—Refer to and follow the Test Specimen and Test Assembly Section requirements in Test

Method E2912 related to horizontal test specimens (as shown in Figs. 10, 11 and 12 in Test Method E2912).

7.3.5 *Vertical Test Specimens*—Refer to and follow the Test Specimen and Test Assembly Section requirements in Test Method E2912 related to vertical test specimens (as shown in Figs. 13, 14 and 15 in Test Method E2912).

8. Specification, Conditioning, and Preparation

8.1 *Ember Intrusion Test:*

8.1.1 *Ember Raw Material:*

8.1.1.1 Standard Class C brands, as described in Test Methods E108 (Section 10.3.3) shall be used as the starting materials for generating embers.

8.1.1.2 Prior to the test, the Class C brands shall be conditioned in an oven maintained at 40 to 49°C [105 to 120°F] for a minimum of 24 h.

8.1.2 *Combustible Target Material:*

8.1.2.1 A 305 by 457 mm [12 by 18 in.] section of 100 % cotton shall be used as the combustible target material.

8.1.2.2 The thickness of the cotton material shall be not less than 10 mm [0.4 in.] and not greater than 20 mm [0.8 in.]. The thickness shall be measured after placing a rigid, uniformly-loaded board, having the same dimensions as the cotton batt, on top of the cotton. The total weight of the rigid board and any additional loading shall be 910 ± 10 g.

8.1.2.3 The cotton shall be new and consist of soft cotton fibers. The density of the cotton material, on an oven-dry basis, shall be between 20 and 25 kg/m^3.

8.1.2.4 Prior to the test, the 100 % cotton material shall be conditioned in an oven maintained at 105 ± 5°C [220 ± 9°F] for a minimum of 4 h.

8.1.2.5 The conditioned cotton shall be used in the test within 15 min after removal from the heated oven.

NOTE 6—There are a number of suppliers of 100 % roll cotton and many of these are sold in nominal 12 in. widths. The total length of the roll varies, but is usually sufficient to obtain seven to nine cut-to-length pieces.

8.2 *Flame Intrusion Test:*

8.2.1 *Preparation of Apparatus*—Refer to and follow the Preparation of Apparatus Section requirements in Test Method E2912 related to the Fire Test Apparatus and optional Unexposed Surface Thermocouple Placement.

8.2.2 *Test Assembly Conditioning*—The following combination creates the test assembly for the Flame Intrusion Test. The test specimen (vent) is installed into a non-combustible frame with an opening representing the vented construction such as an eave, gable, wall, or foundation. Refer to and follow the Test Assembly Conditioning Section requirements in Test Method E2912 related to the test assembly.

9. Test Procedure

9.1 *Ember Intrusion Test:*

9.1.1 Insert test vent into the precut slot in the upper horizontal shelf in test cabinet of the apparatus. The vent shall be installed according to the manufacturer's instructions. Photograph installation of the vent and installed condition.

9.1.2 Load ten Class C brands into the tumbler. All Class C brands shall be positioned in the tumbler on edge and spaced 3 mm [0.125 in.] apart.

9.1.3 Insert a 305 by 457 mm [12 by 18 in.] piece of 100 % cotton material into a 305 by 457 mm [12 in. by 18 in.] open-bottom tray centered on the flattened expanded metal screen on the lower shelf.

NOTE 7—The open-bottom tray can be fabricated using 38 mm [1.5 in.] sheet metal angle flashing material, cut and bent at the corners, and fastened with aluminum tape. Use of the tray facilitates consistent placement of the cotton in the test apparatus.

9.1.4 Load ten 22 mm [0.875 in.] steel nuts into the tumbler. Close and latch the tumbler door.

9.1.5 Start recording temperatures of the three thermocouples. Continue recording temperature every second until the test is concluded.

9.1.6 Ignite the gas burner and direct the flame such that it extends approximately 50 mm [2 in.] into the tumbler, and impinges on all Class C brands. The flame contact exposure shall last for 3 min.

NOTE 8—A nominal propane gas flow delivery rate of 5 L/min is sufficient to accomplish appropriate flame impingement on the brands.

9.1.7 The test cabinet door shall remain open during the 3-min ignition period of the Class C brands.

9.1.8 At the end of the 3-min ignition period for the Class C brands:

9.1.8.1 Turn off the gas burner.

9.1.8.2 Close the door to the test cabinet.

9.1.8.3 Close the solid metal hood to cover the tumbler.

9.1.8.4 Turn on the tumbler.

9.1.8.5 Turn on the exhaust fan.

9.1.8.6 Run the tumbler until it is devoid of all portions (that is, the embers) generated by the tumbling Class C brands.

NOTE 9—The ember exposure time resulting from the tumbled Class C brands should be approximately 3 min (see Appendix X1.4).

9.1.8.7 Observation and notes shall be made regarding ignition of cotton material. The time at which flaming ignition occurs shall be noted.

(1) If flaming ignition does not occur, the cotton material shall be examined at the conclusion of the test. Locations where embers landed, as evidenced by a carbonaceous char area associated with smoldering combustion, shall be noted.

9.1.8.8 Tests shall be run in triplicate, with each test using a different sample of the vent product being tested.

9.1.8.9 Sufficient time shall be allowed in between tests to permit the apparatus to return to ambient temperatures before beginning a subsequent test.

9.2 *Flame Intrusion Test:*

9.2.1 Refer to and follow the Test Procedure Section requirements in Test Method E2912 related to conducting the Flame Intrusion Test (as shown in Figs. 16-23, inclusive, in Test Method E2912).

9.2.1.1 Refer to and follow the Integrity Section requirements in Test Method E2912. Employ the Ignition Test Procedure in the Annex of Test Method E2912 a minimum of three times during the 10-min Flame Intrusion Test. At a minimum, use the Ignition Test Procedure at the following standard times: 30 s, 5 min, and 9 min 30 s after the start of the Flame Intrusion Test. Record the times of additional Ignition Test Procedures during the 10-min Flame Intrusion Test. When

the Flame Intrusion Test is continued past the initial 10 min, use additional Ignition Test Procedures and record the times of their use.

NOTE 10—The 10-min exposure specified in this test standard is the same as that specified in Test Method E2707.

9.2.1.2 When optional unexposed surface thermocouples are employed, refer to and follow the Insulation Test Section requirements in Test Method E2912.

9.2.2 Flame Intrusion Tests shall be run in triplicate with a different vent (test specimen) of the same model number (type) used for each test.

10. Report

10.1 The report shall include the following:

10.1.1 Name and address of the testing laboratory,

10.1.2 Name and address of the test sponsor,

10.1.3 Description of the vent tested, including, if applicable, activation temperature(s) of any of the vent component(s),

10.1.4 Number of vents tested for each test (Ember Intrusion Test and Flame Intrusion Test),

10.1.5 Details of the test apparatus calibration,

10.1.6 Date of test, identification number, and date of report.

10.1.7 *Ember Intrusion Test Results:*

10.1.7.1 State whether the 100 % cotton material experienced flaming ignition and, if applicable, the time interval required for flaming ignition to occur.

10.1.7.2 In the case where flaming ignition does not occur, state whether there was evidence of locations where embers landed, as indicated by carbonaceous char areas that would be associated with smoldering combustion.

10.1.7.3 A record of the temperatures inside the test chamber during the entire test.

10.1.7.4 A record of the maximum temperature reached during the test by any of the three thermocouples.

10.1.7.5 A photographic record of installed vent and cotton target material.

10.1.8 *Flame Intrusion Test Results:*

10.1.8.1 State whether flaming ignition occurred during the Integrity Test portion of the Flame Intrusion Test. When flaming ignition occurred, report the time of that incidence.

10.1.8.2 Report the time and duration of flame penetration through the vent observed or recorded during the Flame Intrusion Test.

10.1.8.3 When requested, report the temperatures on the unexposed side of the vent during the entire optional Insulation Test of the Flame Intrusion Test.

NOTE 11—Information regarding ignition temperature of wood is provided in Appendix X1.7.

10.1.8.4 When requested, the maximum temperature reached during the test by any one of the unexposed surface thermocouples during the entire optional Insulation Test of the Flame Intrusion Test.

10.1.8.5 When requested, the maximum average temperature reached during the test by all of the unexposed surface thermocouples during the entire optional Insulation Test of the Flame Intrusion Test.

10.1.8.6 A photographic record of installed vent and unexposed side during test.

11. Precision and Bias

11.1 *Ember Intrusion Test*—No information is presented about either the precision or bias for Ember Intrusion Test because the test result is non-quantitative.

11.2 *Flame Intrusion Test*—Refer to the Precision and Bias Section in Test Method E2912.

12. Keywords

12.1 attic; crawl space; eave; foundation; gable; soffit; vent

APPENDIX

(Nonmandatory Information)

X1. COMMENTARY

X1.1 *Introduction*—Post-fire surveys of structures (destroyed, damaged and saved) after recent wildfires have shown that ember and direct flame contact have resulted in ignitions of buildings in wildfire prone areas. The procedures outlined here have been developed to provide a standard method to evaluate the ability of under-eave soffit, gable end attic or crawl space vents to resist the intrusion of embers and resist the intrusion of flames from a direct flame contact exposure.

X1.1.1 Potential wildfire exposures for vents on buildings include embers and direct flame contact. If defensible space has been created around a building, and ignition resistant or noncombustible materials have been used in constructing the building, it is possible that a given vent would only be exposed to embers. Therefore, this standard provides separate procedures for ember and flame exposures. A vent must be able to resist an ember exposure separately and not rely on an initial exposure to flames to resist the ember exposure.

X1.1.2 Vents have traditionally been incorporated into the design of buildings to moderate moisture levels and, in the case of attics, temperatures in these enclosed, unconditioned spaces. Ember and flame contact exposures to a building during wildfires present a conflicting design issue – vents providing the moisture management function for these unconditioned spaces versus providing an entry area for wildfire generated embers and flame. This standard test procedure will provide a

method to evaluate the performance of vents under simulated ember and flame exposures. Traditional procedures can be used to evaluate the air flow characteristics of these vents.

X1.1.3 Post-fire surveys in recent wildland fires have shown that a major cause of building loss has been a result of ember ignitions. Maranghides and Mell (**1**)[4] reported that approximately two out of three building ignitions in the 2007 Witch Fire involved embers. A report on the 2006 Angora Fire (**2**) also indicated embers were an important cause of home ignitions. Leonard and Blanchi (**3**) reported that embers are the major cause of ignition. In the same report, Leonard and Blanchi reported that approximately 50 % of the homes destroyed in the 2003 Australian Capital Territory bushfire had inadequate vent protection, in this case defined as vent openings without screen mesh. Reports from the Texas Forest Service(**45**) also attribute building loss or damage to open vents or vents with minimal screening.

X1.2 *Development of the Ember Test Apparatus*:

X1.2.1 The ember intrusion apparatus specified for use in this test procedure was designed by members of the ASTM E.05.14.06, Exterior Fire Subcommittee, Vent Task Group. Embers generated in the upper section of this apparatus result from ignition of standard Class C brands (referenced in Test Methods E108), with subsequent agitation in a steel mesh-covered tumbler. Embers are generated when Class C brands impact each other, as well as with the steel nuts loaded into the tumbler, and steel bars located on the inside perimeter of the circular tumbler.

X1.2.2 During the development of the ember test (Part A) procedure, a different ember 'starting materials' have been evaluated. These have included Class C brands, Class C brands that were cut into quarter sections, and wood pellets used in pellet stoves. All of these materials generated embers in a similar manner. The wood pellets were eliminated because they are densified, and were not considered to represent typical woody biomass. Performance differences were not observed between Class C and quartered Class C brands, and therefore further processing from Class C into quartered Class C was not considered necessary.

X1.2.3 In the early stages of apparatus development, both vertical and horizontal flow devices were considered, as well as including forced air flow that "pushed" and "pulled" air through the device. Even though a horizontal flow device better simulates actual in-service conditions, a vertical flow device was considered to be more severe because of the ease with which embers are directed at the vents. Therefore, this approach was pursued.

X1.2.4 Preliminary efforts in developing the apparatus utilized a fan to push embers at the vent (positive pressure on the entering air side of the vent). Using this approach, the generated embers were not directed to the vent. Therefore, subsequent development utilized negative pressure on the entering air side of the vent (that is, air was pulled through the vent). The current standard utilizes this process.

X1.2.5 A K6 series inline centrifugal fan was used in the standard development work. Rating information for this fan included: 115 V, nominal rev/min: 2680, maximum watts: 84, and maximum amps: 0.74.

X1.3 *Coordinated Testing, Horizontal Flow and Vertical Flow Apparatus*:

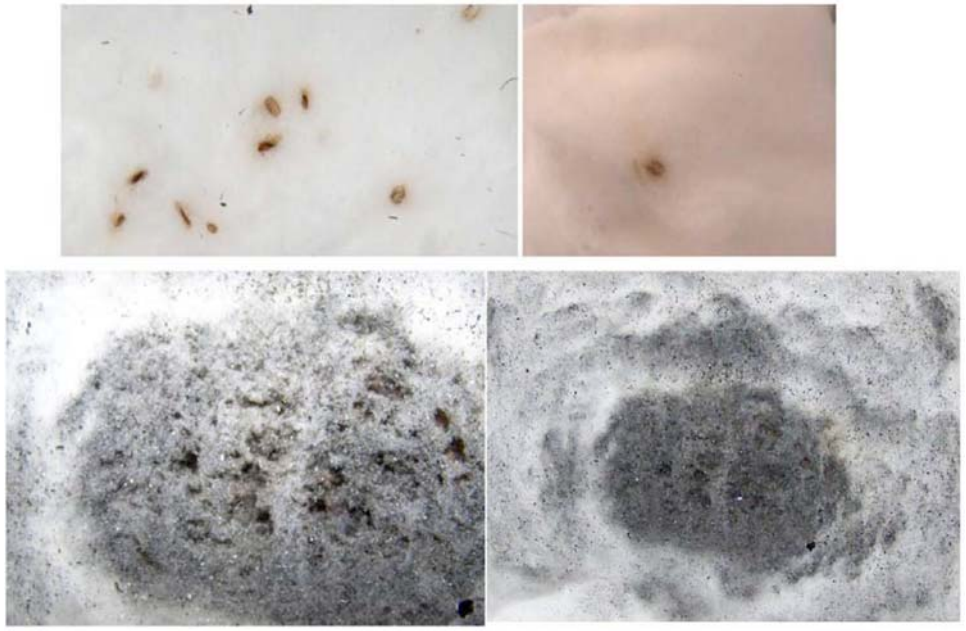
X1.3.1 During the fall of 2009, testing with the intent of comparing relative performance of a full scale and a reduced scale (horizontal flow) wind tunnel tests and the vertical flow apparatus took place. The full scale wind tunnel testing was conducted in Japan (full scale) and the reduced scale (horizontal flow) wind tunnel test was conducted at NIST, Gaithersburg, MD. Testing with the vertical flow apparatus was conducted at the University of California Richmond Field Station. The wind tunnel testing was reported by Manzello et al.(**6**) A summary of the vertical flow apparatus testing and summary comparison is given below.

X1.3.2 The tests evaluated performance of the horizontal and vertical flow devices by comparing results obtained using a variety of standard screen mesh sizes and combustible target materials. Tests were conducted using the following mesh (openings per inch) screen sizes: 4, 8, 10, 14, 16, and 20. Four combustible target materials were included: 100 % cotton material, shredded paper, and an oriented strand board (OSB)-to-lumber assembly, with and without shredded paper at the 90° joint. Three replications were run on each combustible target material for each screen size. Screens were obtained by the same supplier, and the combustible target materials were shared.

X1.3.3 Materials used to generate embers were different for each device. Norway spruce mulch was used for tests conducted in the full size wind tunnel. Douglas-fir rectangular blocks, 7.9 by 7.9 by 12.7 mm [0.33 by 0.33 by 0.5 in.] were used for tests conducted in the reduced scale wind tunnel. Standard Class C brands prepared from ponderosa pine were used for tests conducted in the vertical flow apparatus described in this standard. The dimension of Class C brands are 38 by 38 by 20 mm [1.5 by 1.5 by 0.78 in.], and are fully described in Test Methods E108.

X1.3.4 Combustibility ratings were different for the horizontal flow tests compared to the vertical flow tests. For the horizontal flow tests, the ignitibility of the combustible target materials were rated as either "no ignition" (NI), "smoldering ignition" (SI) or "flaming ignition" (FI). For the vertical flow tests, the ignitibility of the combustible target materials was rated as either "flaming ignition" (FI) or "no (flaming) ignition" (NI). Each vertical flow test was run long enough to allow for any observed smoldering combustion in a target combustion material to either transition to flaming (FI) or self-extinguish (NI). Fig. X1.1 shows cotton samples from the horizontal full scale test and vertical flow apparatus test. The results of testing, by apparatus, are shown in Tables X1.1-X1.3. A summary of all results is given in Table X1.4.

[4] The boldface numbers in parentheses refer to a list of references at the end of this standard.



NOTE 1—The upper two photographs were from cotton material exposed to embers that passed though a 4 mesh [¼ in.] screen during a horizontal flow apparatus test (Figure 9, Manzello et al.(**6**)). The bottom two photographs were from cotton material exposed to embers that passed through a 16 mesh [1/16 in.] screen during a vertical drop apparatus test. As indicated in Table X1.4, the condition in the upper photographs was rated "SI" and those in the lower photographs were rated "NI". Photographs on the left were from the upper (exposed) surface of the cotton target material and those on the right were from the lower (bottom) surface of the cotton target material.

FIG. X1.1 Samples of Cotton Target Materials after Exposure to Embers During Exposure Tests

TABLE X1.1 Summary of the Horizontal Flow Full Scale Tests

Mesh Size	Combustible Target Material			
	Paper	Cotton	OSB-Lumber Joint	OSB-Lumber Joint with Paper
4 [5.7 mm]	SI to FI	SI	SI	SI to FI (paper) SI (OSB)
8 [2.74 mm]	SI to FI	SI	SI	SI to FI (paper) SI (OSB)
10 [2.0 mm]	SI to FI	SI	NI	SI to FI (paper) SI (OSB)
14 [1.6 mm]	SI	SI	NI	SI (paper) SI (OSB)
16 [1.4 mm]	SI	SI	NI	NI
20 [1.0 mm]	NI (two tests) SI (one test)	SI (two tests) NI (one test)	NI	NI

TABLE X1.2 Summary of the Horizontal Flow Reduced Scale Tests

Mesh Size	Combustible Target Material			
	Paper	Cotton	OSB-Lumber Joint	OSB-Lumber Joint with Paper
4 [5.7 mm]	SI to FI	SI to FI	SI	SI to FI (paper) SI (OSB)
8 [2.74 mm]	SI to FI	SI	SI	SI to FI (paper) SI (OSB)
10 [2.0 mm]	SI to FI	SI	NI	SI to FI (paper) SI (OSB)
14 [1.6 mm]	SI	SI	NI	SI to FI (paper) SI (OSB)
16 [1.4 mm]	SI	SI	NI	NI
20 [1.0 mm]	NI	SI	NI	NI

TABLE X1.3 Summary of the Vertical Flow Apparatus Tests

Mesh Size	Combustible Target Material			
	Paper	Cotton	OSB-Lumber Joint	OSB-Lumber Joint with Paper
4 [5.7 mm]	FI	FI	NI	NI
8 [2.74 mm]	FI	FI	NI	NI
10 [2.0 mm]	FI	FI	NI	NI
14 [1.6 mm]	FI	NI	NI	NI
16 [1.4 mm]	FI	NI	NI	NI
20 [1.0 mm]	FI	NI	NI	NI

TABLE X1.4 Summary of the Horizontal and Vertical Test Results

Mesh Size, Openings/in. [mm]	Apparatus	Combustible Target Material			
		Paper	Cotton	OSB-Lumber Joint, No Paper at Joint	OSB-Lumber Joint, Paper at Joint
4 [5.7]	Full Scale	SI to FI	SI	SI	SI to FI (paper) / SI (OSB)
	Reduced Scale	SI to FI	SI to FI	SI	SI to FI (paper) / SI (OSB)
	Vertical	FI	FI	NI	NI
8 [2.7]	Full Scale	SI to FI	SI	SI	SI to FI (paper) / SI (OSB)
	Reduced Scale	SI to FI	SI	SI	SI to FI (paper) / SI (OSB)
	Vertical	FI	FI	NI	NI
10 [2.0]	Full Scale	SI to FI	SI	NI	SI to FI (paper) / SI (OSB)
	Reduced Scale	SI to FI	SI	NI	SI to FI (paper) / SI (OSB)
	Vertical	FI	FI	NI	NI
14 [1.6]	Full Scale	FI	SI	NI	SI (paper and OSB)
	Reduced Scale	SI	SI	NI	SI to FI (paper) / SI (OSB)
	Vertical	FI	NI	NI	NI
16 [1.4]	Full Scale	SI	SI	NI	NI
	Reduced Scale	SI	SI	NI	NI
	Vertical	FI	NI	NI	NI
20 [1.0]	Full Scale	NI (two tests) SI (one test)	SI (two tests) NI (one test)	NI	NI
	Reduced Scale	NI	SI	NI	NI
	Vertical	FI	NI	NI	NI

X1.3.5 As a result of air being pulled through the combustible materials, the cotton and shredded paper materials reached flaming ignition (FI) at finer mesh screen sizes with the vertical flow test chamber, compared to the horizontal flow devices. Although smoldering combustion (the SI designation in the horizontal flow tests) was observed in OSB-lumber joint with shredded paper, this only occurred with coarser mesh sizes. The OSB-lumber joint clearly blocks air flow in the vertical flow test chamber, and therefore is not sensitive in evaluating this configuration.

X1.3.6 Preheating of the cotton target material was not measured. The door of the apparatus remained open during the time that the 3-min flame contact ignition exposure for the Class C brands. During this time the induction fan was turned off. After the 3-min ignition exposure, the gas flame was turned off, the apparatus door was closed, and the induction fan was turned on to pull air through the apparatus.

X1.4 *Duration of Ember Exposure*—The ember exposure duration during wildfire can be longer than the 3-min exposure used in this standard. Testing conducted using 8 and 16 mesh screening during the development of this standard indicated that:

(1) reducing the agitation (accomplished by limiting the number of nuts in the chamber) increased the duration of exposure,

(2) using relatively larger pieces of raw material (for example, nominal 50 by 50 by 50 mm [2 by 2 by 2 in.]) cubes increased the duration of exposure,

(3) increasing the amount of material in the chamber could result in ignition of the cotton target material when 16 mesh screening was used, indicating the relative severity of this procedure, and

(4) agitation resulted in a higher number of embers impacting the test vent.

X1.4.1 Using a combination of Class C brands and the larger cube material (nominal 50 by 50 by 50 mm [2 by 2 by 2 in.]), and fewer steel nuts to agitate the burning wood, an exposure duration of 6 min was achieved. The results with these extended duration tests were the same as with the tumbler loading arrangement specified in this standard (that is, FI for 8 mesh screening and NI for 16 mesh screening).

X1.4.2 Depending on raw material loading scenario and amount of agitation, longer periods were possible. The 6-min time interval reported here was selected based on feedback from the task group where the question posed was whether the same result would occur if exposure time were doubled (so, from 3 to 6 min).

X1.4.3 Most of the development of this test method was based on raw material loading and agitation that resulted in the 3-min exposure. The additional testing that indicated similar results at a 6- and 3-min exposure indicated that there wasn't an overriding reason to extend the duration of exposure.

X1.5 *Velocity Measurements in the Vertical Flow Apparatus*:

X1.5.1 Velocity was measured with a 3.2 mm [0.125 in.] and 1.5 mm [0.0625 in.] mesh screen installed in the upper shelf. An anemometer was located 38 mm [1.5 in.] and 89 mm [3.5 in.] above the lower shelf and 38 mm [1.5 in.] above the upper shelf. Results of the velocity measurements are given in Tables X1.5-X1.7. This data can be used to calibrate different vertical flow chambers.

X1.6 *Pressure Ports (if used)*:

X1.6.1 The test cabinet can be equipped with pressure ports in order to evaluate the pressure between the upper and lower chambers. If pressure drop measurements are desired, install two 3.2 mm [0.125 in.] taps for pressure measurement. These taps should be located in the back wall of the cabinet, both centered from side to side. The upper port should be located 105 mm [4 in.] from the top of the cabinet. The lower port should be located 266 mm [10.5 in.] from the top of the cabinet.

X1.6.2 The taps should be threaded 0.25 in. N.P.T. (no metric equivalent). The taps would be attached with appropriate sized plastic tubing to a digital manometer.

X1.7 *Flame Intrusion Test*:

X1.7.1 Ignition temperature on the non-fire side of the vent: Until wood has ignited, a sizable velocity is not helpful towards ignition, but after initial glowing ignition is achieved, a modest velocity does help convert glowing to flaming. For relatively low speed air movement (a convective velocity that naturally exists when purposive blowing is not being done), the *Ignition Handbook*(7) indicated a best-estimate ignition temperature of 250°C. When considering situations where a directed velocity is applied, the *Ignition Handbook* (p. 952) reported that ignition was achieved at 292°C and not achieved at 210°C. The arithmetic mean of these is 251°C. This is a conservative strategy, since if you expose wood at higher heat flux values than is needed for the minimum for ignition, the ignition temperature rises, not falls.

X1.7.2 The ignition temperature of wood reported with Test Method D1929 is 260ºC. The test duration in D1929 is 10 min, the same exposure time used in this standard.

NOTE X1.1—The purpose of this section is to provide information regarding ignition temperature of wood to enable Authority Having Jurisdiction to evaluate and interpret the temperature readings provided in the report.

X1.7.3 The test procedure from Test Method E2912 subjects the vent, whether in a vertical or horizontal orientation, to direct flame impingement. Whether the vent is used in an eave, gable end, wall, or foundation, the fire source during the Flame Intrusion Test is located at approximately the same distance to standardize exposure. Using the test procedure from Test Method E2912, the external effects (such as air flow) on the performance of the vent are minimized. The following calculations are presented to demonstrate the potential variables affecting the fire exposure on the vent, which are negated using the test procedure from Test Method E2912.

X1.7.4 Vents may be installed in parts of buildings including eaves, gables, walls, and foundations used for air transfer and to allow ventilation of structures without ductwork. Vents can be located adjacent to combustible construction or materials, or both. Resistance to flame, radiation, and hot gases may be concerns when direct flame impingement is a credible risk, or when limited penetration of flames is required by the authority having jurisdiction, or both. This test method provides procedures that enable an assessment of this direct flame impingement on vents.

X1.7.5 Except for Test Method E2912, there are currently no published test methods (nationally or internationally) that

TABLE X1.5 Velocity Measurements Using 1.5 mm [0.06 in.] Mesh Screen

Location	Velocity	
	Maximum, m/s [mph]	Average, m/s [mph]
38 mm [1.5 in.] above upper shelf	1.1 [2.4]	0.9 [2.0]
38 mm [1.5 in.] above lower shelf	0.7 [1.6]	0.6 [1.3]

TABLE X1.6 Velocity Measurements Using 3.2 mm [0.125 in.] Mesh Screen

Location	Velocity	
	Maximum, m/s [mph]	Average, m/s [mph]
38 mm [1.5 in.] above upper shelf	1.1 [2.5]	0.9 [2.0]
38 mm [1.5 in.] above lower shelf	0.8 [1.8]	0.7 [1.6]

TABLE X1.7 Velocity Measurements Using 6 mm [0.25 in.] Mesh Screen

Location	Velocity	
	Maximum, m/s [mph]	Average, m/s [mph]
38 mm [1.5 in.] above upper shelf	1.1 [2.5]	0.9 [2.0]
38 mm [1.5 in.] above lower shelf	0.9 [2.0]	0.8 [1.8]

address the application of sudden direct flame impingement on vents used in vented construction. In the European Union (EU), CEN (European Committee for Standardization), some countries have used large scale tests with 5MW fire exposures to assess vent reactions to sudden direct flame impingement as part of the entire building construction. Standard time-temperature curves used to control gas-fired furnaces do not ensure a sudden direct flame impingement on the vent, which this test method is designed to do. A post flashover condition, the spontaneous combustion of materials, ignition of a highly combustible material acting as the source of the fire or the location of materials can create a fire scenario resulting in a sudden direct flame impingement.

X1.7.6 Test Method E2912 uses a test box to mount vents in a vertical orientation to be assessed using a similar flame impingement exposure as the horizontal orientation of vents. Through a "trial and error" method, the slots on the top of the box were sized and positioned to develop a constant and steady flame impingement on the vent positioned in the square 500-mm opening as is done in the horizontal orientation. The design of the test box is intended to produce a simple reproducible device to subject the vent to a credible sudden direct flame impingement. The pressure within the test box is slightly positive based on the convective heat flow as in most real life fire scenarios. Positive pressure is a more severe condition than negative pressure when assessing insulation and integrity of vents.

X1.7.7 The optional temperature information acquired during the Flame Intrusion Test using the Insulation Test in Test Method E2912 may be helpful in fire modeling and performance-based fire safety design as this temperature is discussed in "Unexposed-Face Temperature Criteria in Fire Resistance Tests: A Reappraisal."(**8**) An excerpt from the Conclusions states, "Thus, the findings indicate that if the hot surface temperature is kept below 400ºC [752°F], ignition will not occur due to thermal transmission across fire-resistive barriers for any goods which may be permissibly stored in normal buildings. Since other criteria of fire resistance tests do not incorporate an explicit, added-on safety factor, for consistency this should also not be done in this case. Expressed as a criterion, failure due to thermal transmission may be presumed to occur when a temperature of 400ºC [752°F] is exceeded. This is a fixed value and not a "temperature rise" value. To obtain the latter, it is appropriate to subtract 20ºC [68°F], thus the temperature rise criterion becomes 380ºC [684°F]. There does not seem to be any technical justification for having a criterion for a single-point rise any higher than the value that corresponds to the lowest relevant hot-surface ignition temperature. Thus, the single-point criterion should also be a temperature rise of 380ºC [684°F]".

X1.7.8 The intent of using Test Method E2912 test procedures for the Flame Intrusion Test is to provide a more uniform direct flame impingement (fire exposure) whether testing a vent in a horizontal application, such as an eave condition, and a vent in a vertical application such as would occur in wall, gable, and foundation conditions.

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