



# Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source<sup>1</sup>

This standard is issued under the fixed designation E 162; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

~~1.1 This fire-test-response standard, to be used for research and development purposes, covers standard describes the measurement of surface flammability of materials. It is not intended for use as a basis of ratings for building code purposes.~~

~~1.2 This standard should be used purposes (see Appendix X1).~~

~~1.3 This standard measures and describes the response of materials, products, or assemblies to heat and flame under controlled conditions and should conditions, but does not be used to describe by itself incorporate all factors required for fire hazard or appraise the fire hazard or fire-risk fire risk assessment of the materials, products, or assemblies under actual fire conditions.~~

~~1.4 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.~~

~~1.5 The values stated in inch-pound units are to~~

~~1.6 Fire testing of products and materials is inherently hazardous, and adequate safeguards for personnel and property shall be regarded as the standard. The values employed in parentheses are for conducting these tests. This test method may involve hazardous materials, operations, and equipment. Specific information about hazard is given in Section 7.~~

~~NOTE 1—There is no similar or equivalent ISO standard.~~

## 2. Referenced Documents

2.1 *ASTM Standards:*

D 3675 Test Method for Surface Flammability of Flexible Cellular Materials Using a Radiant Heat Energy Source<sup>2</sup>

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee E05 on Fire Standards and is the direct responsibility of Subcommittee E05.22 on Surface Burning. Current edition approved Jan. April 10, 2002. Published April July 2002. Originally published as E 162 – 60 T. Last previous edition E 162 – 98<sup>ε1</sup>–E 162 – 02.

E 84 Test Method for Surface Burning Characteristics of Building Materials<sup>3</sup>

E 176 Terminology Relating to Fire Standards<sup>3</sup>

E 1546 Guide for Development of Fire Hazard Assessment Standards<sup>3</sup>

2.2 ISO Standards<sup>4</sup>

ISO 13943 Fire Safety—Vocabulary

### 3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to the terminology contained in Terminology E 176 and ISO 13943. In case of conflict, the definitions given in Terminology E 176 shall prevail.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *radiant panel index,  $I_{rs}$ ,  $n$* —the radiant panel index is the product of the flame spread factor,  $F_s$ , and the heat evolution factor,  $Q$ .

3.2.2 *flashing,  $n$* —flame fronts of 3 seconds or less in duration.

3.2.2.1 *Discussion*—All flame fronts, however temporary, are to be taken into account.

### 4. Summary of Test Method

4.1 This test method of measuring surface flammability of materials employs a radiant heat source consisting of a 12 by 18-in. (305 by 457-mm) panel, in front of which an inclined 6 by 18-in. (152 by 457 mm) specimen of the material is placed. The orientation of the specimen is such that ignition is forced near its upper edge and the flame front progresses downward.

4.2 A factor derived from the rate of progress of the flame front and another derived from the rate of heat liberated by the material under test are combined to provide a radiant panel index.

### 5. Significance and Use

5.1 This test method provides a laboratory test procedure for measuring and comparing the surface flammability of materials when exposed to a prescribed level of radiant heat energy. It is intended for use in measurements on the surface flammability of materials whose surfaces may be exposed to fire. The test is made on specimens of conducted using small-size (6 by 18 in. (150 by 460 mm)) specimens that are representative, to the extent possible, of the material or assembly being evaluated. The test is intended for research (Example: in terms of their thickness, layering, and development only any potential substrate.)

5.2 The rate at which flames will travel along surfaces depends upon the physical and thermal properties of the material, its method of product or assembly under test, the specimen mounting method and orientation, the type and level of fire or heat exposure, the availability of air, and properties of the surrounding enclosure.<sup>5</sup>

5.3 In this procedure, the specimens are subjected to one or more specific sets of laboratory fire test conditions. If different test conditions are substituted or the end-use conditions are changed, it is not always possible by or from this test to predict changes in the fire-test-response characteristics measured. Therefore, the results are valid only for the fire test exposure conditions described in this procedure.

5.4 If the test results obtained by this test method are to be considered as part of an overall assessment of fire hazard in a building or structure, then the example criteria, concepts and procedures incorporated into Guide E 1546 shall be taken into consideration.

### 6. Apparatus

6.1 The apparatus shall be essentially as shown in Figs. 1 and 2 and shall include the following:

6.1.1 *Radiant Panel with Air and Gas Supply*—The radiant panel shall consist of a porous refractory material vertically mounted in a cast iron frame, exposing a radiating surface of 12 by 18 in. (305 by 460 457 mm) and shall be capable of operating at temperatures up to 1500°F (815°C). The panel shall be equipped (see Fig. 2) with a venturi-type aspirator for mixing gas and air at approximately atmospheric pressure; a centrifugal blower, or equivalent, to provide 100 ft<sup>3</sup>/min (50 L/s) air at a pressure of 2.8 in. of water (700 Pa); an air filter to prevent dust from obstructing the panel pores; a pressure regulator and a control and shut-off valve for the gas supply.

<sup>2</sup> Annual Book of ASTM Standards, Vol 04.07, 08.02.

<sup>3</sup> Robertson, A. F., "Surface Flammability Measurements by the Radiant Panel Method," *Symposium on Fire Test Methods*,

<sup>3</sup> Annual Book of ASTM-*STP-344 Standards*, ASTM, 1962, pp. 33-46.

Robertson, A. F., Gross, D., and Loftus, J., "A Method for Measuring Surface Flammability of Materials Using a Radiant Energy Source," *Proceedings*, ASTM, Vol 56, 1956, pp. 1437-1453.

Gross, D. and Loftus, J. J., "Surface Flame Propagation on Cellulosic Materials Exposed to Thermal Radiation," *Journal of Research*, NBS, Vol 67C, 1963, pp. 251-258.

Magee, R. S. and McAlevy III, R. F., "The Mechanism of Flame Spread," *Journal of Fire and Flammability*, Vol 2, 1971, pp. 271-297, 04.07.

<sup>4</sup> Available from International Standardization Organization, P.O. Box 56, CH-1211, Geneva 20, Switzerland.

<sup>5</sup> Robertson, A. F., "Surface Flammability Measurements by the Radiant Panel Method," *Symposium on Fire Test Methods*, ASTM STP 344, ASTM, 1962, pp. 33-46.

Robertson, A. F., Gross, D., and Loftus, J., "A Method for Measuring Surface Flammability of Materials Using a Radiant Energy Source," *Proceedings*, ASTM, Vol 56, 1956, pp. 1437-1453.

Gross, D. and Loftus, J. J., "Surface Flame Propagation on Cellulosic Materials Exposed to Thermal Radiation," *Journal of Research*, NBS, Vol 67C, 1963, pp. 251-258.

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FIG. 1 Radiant Panel Flame Spread Test Equipment

6.1.2 *Specimen Holder*—The specimen holder shall conform in shape and dimension to Fig. 3 and be constructed from heat-resistant chromium steel. Observation marks shall be filed on the surface of the specimen holder to correspond with 3-in. (76-mm) interval lines on the specimen.

6.1.3 *Framework for Support of the Specimen Holder*—The framework shall have two transverse rods of stainless steel, each  $\frac{1}{2}$   $0.50 \pm 0.13$  in. ( $13 \pm 3.3$  mm) in diameter, with a stop to center the specimen holder directly in front of the radiant panel. The support and bracing members ~~should~~ shall be constructed from metal stock. Since the angle of the specimen and its position with respect to the panel are critical, the framework dimensions specifying these conditions shall be within  $\frac{1}{8}$   $0.125$  in. (3.2 mm) of the values given in Fig. 2.

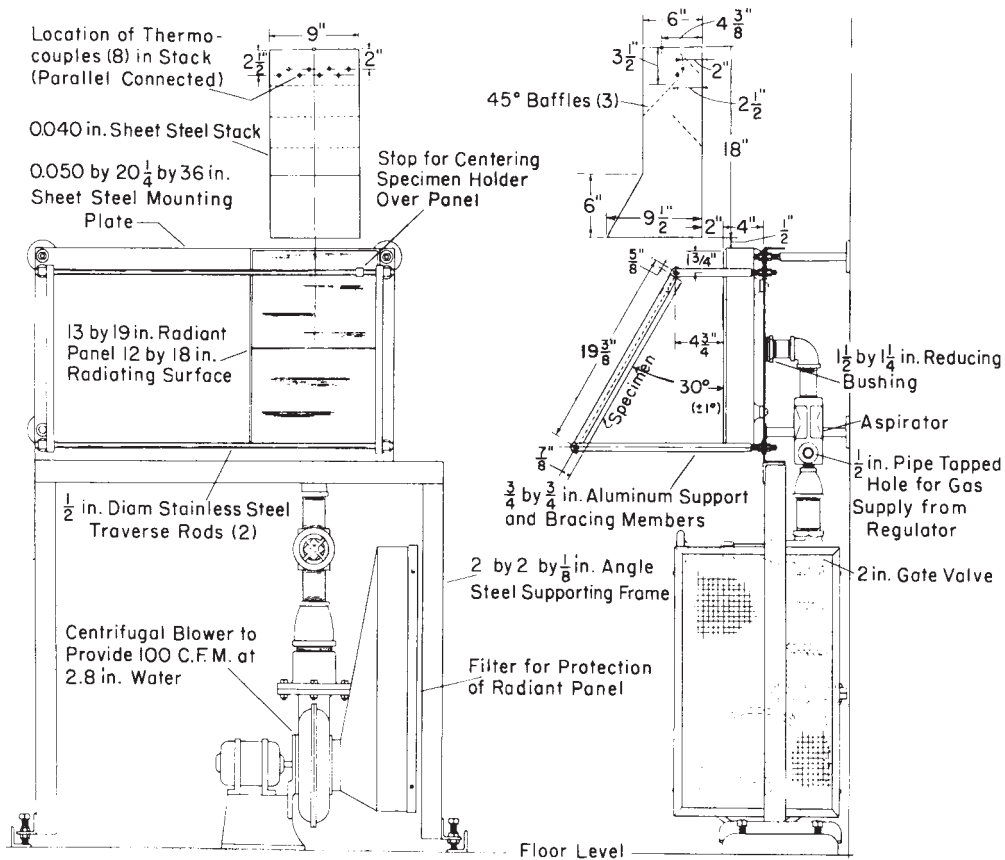
6.1.4 *Pilot Burner*—The pilot burner shall be a length of stainless steel tubing approximately 8 to 9 in. (203 to 229 mm) long with ~~nominally~~  $0.125$  in. (3.2 mm) inside diameter by  ~~$\frac{3}{16}$  in.~~ nominally 0.19 in. (4.8 mm) outside diameter. ~~The~~ As an option, to prolong the service life of the pilot burner, the part of the burner that is exposed to radiant energy may can be protected with a porcelain tube  $\frac{13}{64}$  in. (5.16 nominally 0.20 in. (5.2 mm) inside diameter by  $\frac{9}{32}$  in. (6.84 nominally 0.28 in. (7.14 mm) outside diameter. The burner shall be mounted horizontally and at a slight angle to the intersection of the horizontal plane of the burner with the plane of the specimen. The burner shall also be capable of being moved out of position when not in use. The pilot shall provide a 2 to 3 in. (51 to 76-mm) flame of acetylene gas premixed with air in an aspirating type fitting. Acetylene has been found satisfactory for this purpose. The position of the burner tip is shall be such that the pilot flame will shall contact or shall be within  $\frac{1}{2}$  0.5 in. (12.7 mm) of contacting the top center area upper central surface of the specimen.

6.1.5 *Stack*—The stack shall be made from nominally 0.040 in. (1.0 mm) sheet steel with shape and dimensions as shown in Fig. 2. The position of the stack with respect to the specimen and radiant heat panel shall also comply with the requirements of Fig. 2.

6.1.6 *Thermocouples*—Eight thermocouples of equal resistance and connected in parallel shall be mounted in the stack and supported with porcelain insulators as indicated in Fig. 2 and Fig. 4. ~~Each junction~~ The thermocouples shall be formed by fusing Chromel-Alumel Type K, shielded against high heat with insulation resisting up to 2170° F (1200° C), and with wire gauges in the end range of a twisted pair of Chromel and Alumel wires of 0.020 in. (0.5 mm) diameter. 0.014 – 0.020 in. (0.36 – 0.51 mm; 30 AWG-24 AWG) diameter. The mean stack thermocouple temperature rise for unit heat input rate of the calibration burner shall be determined periodically for the specific test apparatus, using the procedure in A1.2.

6.1.7 *Data Collection System*—For collecting test data, use one of the following:

6.1.7.1 *Automatic Potentiometer Recorder*—An automatic potentiometer recorder in the range from 100 to 1000° F (38 to 538° C) shall be installed to record the temperature variation of the stack thermocouples as described in 6.1.6. ~~The recorder should give a continuous~~ 6.1.6.



Metric Equivalents

| in.   | mm   | in.                   | mm               |
|-------|------|-----------------------|------------------|
| 0.040 | 1.0  | 6                     | 152              |
| 1/2   | 12.7 | 9 1/2                 | 241              |
| 5/8   | 16.0 | 18                    | 457              |
| 7/8   | 22.2 | 19 3/8                | 492              |
| 1 3/4 | 44   | 3/4 by 3/4            | 19.2 by 19.2     |
| 2     | 51   | 1 1/2 by 1 1/4        | 38 by 32         |
| 2 1/2 | 64   | 12 by 18              | 305 by 457       |
| 2.8   | 71   | 13 by 19              | 330 by 483       |
| 4     | 102  | 2 by 2 by 1/8         | 51 by 51 by 3.2  |
| 4 3/8 | 111  | 0.050 by 20 1/4 by 36 | 13 by 514 by 914 |
| 4 3/4 | 121  |                       |                  |

100 ft<sup>3</sup>/min = 47.21 L/s

FIG. 2 Details of Construction of Test Equipment

6.1.7.2 *Computer Data Collection System*—The data acquisition system shall have the capability to record the temperature output from the thermopile. The data acquisition system shall have an accuracy of 0.01% of the maximum temperature to be measured.

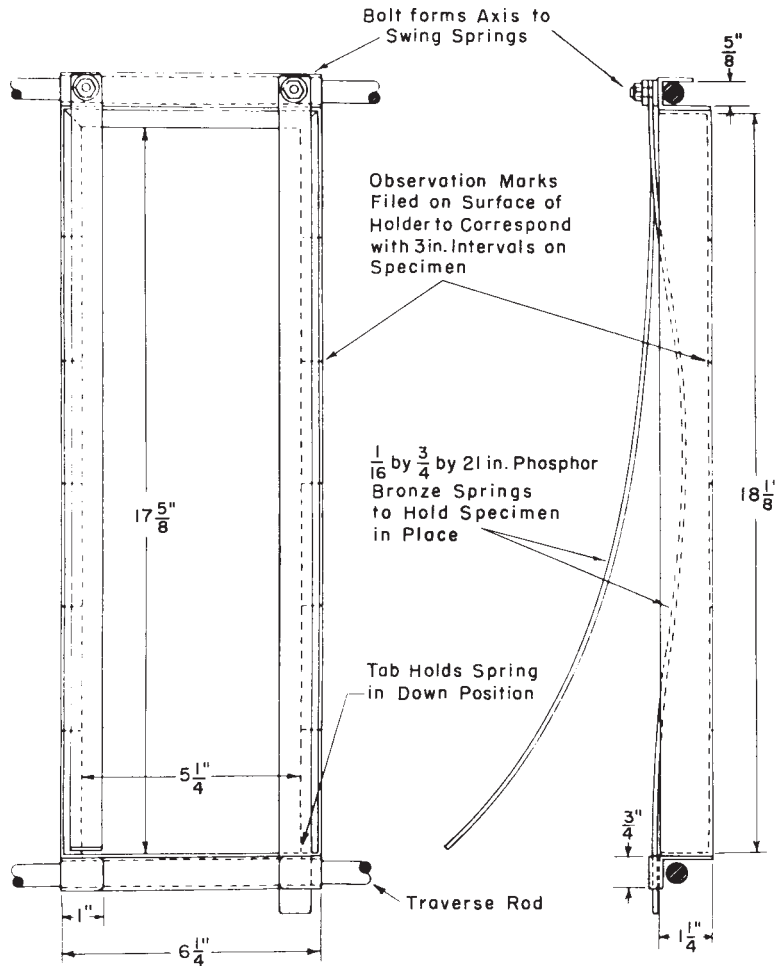
6.1.7.3 *Whichever system is used, it shall be capable of recording, or printing, data at time intervals least every 5 s for a minimum of not more than 15 s-1 h. For cases where preliminary tests indicate rapid flame spread, a system shall be used capable of acquiring data fast enough to ensure adequate results (see 12.6).*

6.1.8 *Hood*—A hood with exhaust blower placed over the stack is required. The blower should produce a velocity of 100 ft/min (0.5 m/s) (30.5 m)/min at the top of the stack with the radiant panel not operating, or approximately 250 ft/min (1.3 m/s) with the radiant panel at operating temperature. The velocity through the stack is not critical for flame-spread measurements provided a stack thermocouple temperature calibration is performed (see Annex 6.1.6 and A1.2) for the established test conditions. The hood surfaces ~~should~~ shall clear the top and sides of the stack by a minimum of 10 in. (254 mm) and 7 1/2 in. (191 mm) respectively.

6.1.9 *Radiation Pyrometer*—The radiation pyrometer for standardizing the thermal output of the panel shall be suitable for viewing a circular area 10 in. (254 mm) in diameter at a range of about 4 ft (1.2 m). It shall be calibrated over the operating black body temperature range in accordance with the procedure described in the Annex A1.

6.1.9.1 *Monitor and record the millivolt output of the radiation pyrometer with the data collection systems described in 6.1.7.*

6.1.10 *Portable Potentiometer*—The electrical output of the radiation pyrometer shall be monitored by means of a



Metric Equivalents

| in.            | mm   | in.                                   | mm               |
|----------------|------|---------------------------------------|------------------|
| $\frac{3}{4}$  | 19.0 | $6\frac{1}{4}$                        | 159              |
| 1              | 25   | $17\frac{5}{8}$                       | 433              |
| $1\frac{1}{4}$ | 32   | $18\frac{1}{8}$                       | 460              |
| 3              | 76   | $\frac{1}{16}$ by $\frac{3}{4}$ by 21 | 1.6 by 19 by 533 |
| $5\frac{1}{4}$ | 133  |                                       |                  |

FIG. 3 Specimen Holder

potentiometer provided with a millivolt range suitable for use with the radiation pyrometer described in 6.1.9.

6.1.11—Timer—The timer shall be calibrated to read to 0.01 min to record the time of events during the test.

## 7. Hazards

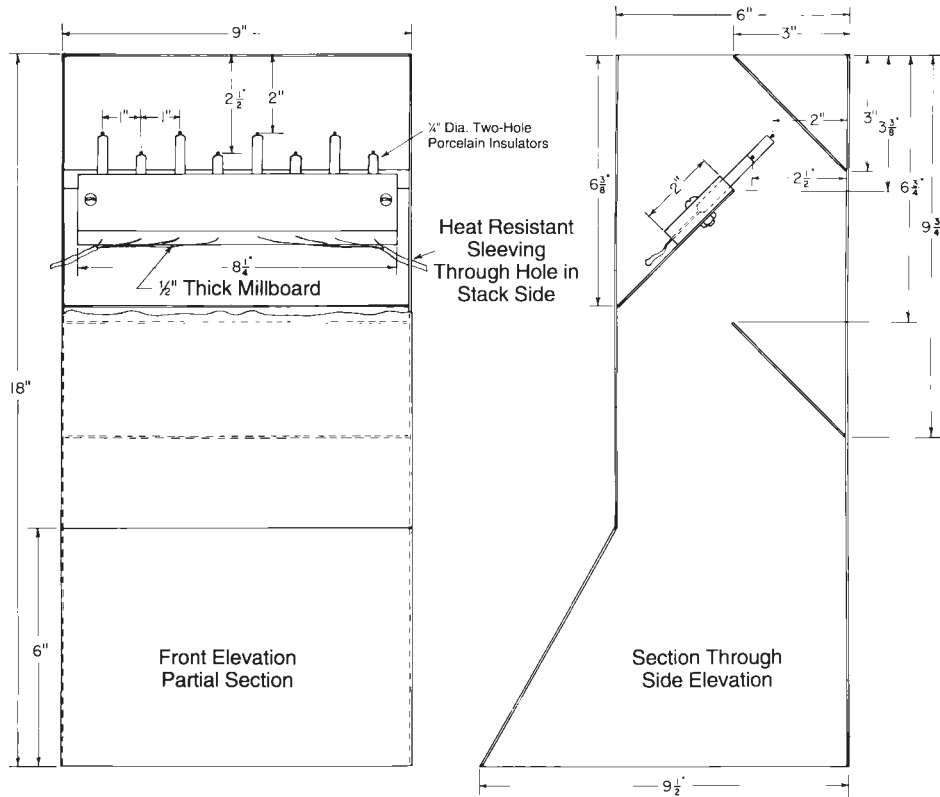
7.1 Safeguards shall be installed in the panel fuel supply system to guard against a gas air fuel explosion in the test chamber. Potential safeguards include, but are not limited to, one or more of the following: a gas feed cut-off activated when the air supply fails; a flame sensor directed at the panel surface that stops fuel flow when the panel flame goes out; and a heat detector mounted in contact with the radiant panel plenum that is activated when the panel temperature exceeds safe limits. Manual reset is a requirement of any safeguard system used.

7.2 The exhaust system must be so designed and operated that the laboratory environment is protected from smoke and gas. The operator shall be instructed on ways to minimize exposure to combustion products by following sound safety and industrial hygiene practices. For example, ensure that the exhaust system is working properly and wear appropriate clothing including gloves, safety glasses, and breathing apparatus (when hazardous fumes are expected).

7.3 During this test, very high heat fluxes and high temperatures are generated that are capable of igniting some clothing following even brief exposures. Precautions shall be taken to avoid ignitions of this type.

## 8. Test Specimens

8.1 The test specimen shall be 6 by 18 in. (150 by 460 mm) by the sheet thickness, where this is less than 1 in. (25.4 mm).



Metric Equivalents

| in.   | mm   | in.   | mm  | in.   | mm  |
|-------|------|-------|-----|-------|-----|
| 1/4   | 6.4  | 3     | 76  | 9     | 229 |
| 1/2   | 12.7 | 3 3/8 | 86  | 9 1/2 | 241 |
| 1     | 25   | 6     | 152 | 9 3/4 | 248 |
| 2     | 51   | 6 3/4 | 171 | 18    | 457 |
| 2 1/2 | 64   | 8 1/4 | 210 |       |     |

FIG. 4 Thermocouple Mounting Arrangement

Materials supplied in greater at a thickness greater than 1 in. (25.4 mm) shall be cut to 1 in. (25.4 mm) for testing. At the request of the sponsor, it is possible to test materials may be tested in thickness greater than 1 in. (25.4 mm); thickness by using an oversized specimen holder will then be needed. holder.

8.2 Materials intended to be applied to a substrate shall be tested on that substrate.

8.3 For comparison tests, or where the intended application of a finish material is not specified, the finish material shall be prepared for test in accordance with 8.4-8.7.

8.4 Sheet materials that are opaque to infrared radiation and greater than 1/16-in. (1.6-mm) thickness are not applied to a base.

8.5 Opaque sheet materials up to 1/16-in. (1.6-mm) thickness, and liquid films such as paints, etc. intended for application to combustible base materials, shall be applied to 1/4-in. (6.4-mm) thick tempered hardboard using recommended application procedures. The hardboard shall have a mean flame-spread index of 130 to 160 based upon a minimum of four tests performed in accordance with this method.

8.6 Liquid films and other materials for application to a noncombustible base shall be applied to the smooth surface of 1/4-in. (6.4-mm) thick inorganic reinforced cement board, using specified spreading rate requirements, or, in the absence of requirements, a minimum-coating thickness of 0.030 in. (0.76 mm).

NOTE 12—Wherever inorganic reinforced cement board is specified, the material shall be nominal 1/4 in. (6.3 mm) thick, high density (110 ± 5 lb/ft<sup>3</sup> (1762 ± 80 kg/m<sup>3</sup>)) and uncoated.

8.7 If a backing of aluminum foil 0.002 in. (0.05 mm) thick, with the bright side against the specimen, produces a higher flame spread index than without the foil, this higher result shall be adopted as the flame spread index.

8.8 Materials, including fabrics, not applied to a base but supported at one or more edges shall be mounted on a special backing of 1/2-in. (13-mm) thick millboard of which the surface opposite the test specimen is covered with a sheet of highly reflective aluminum foil 0.002 in. thick, with the bright side against the specimen. Millboard spacers 1/2 by 1/2 in. (12.7 by 12.7 mm) shall be used at the perimeter of the foil-covered face of the backing to separate the test material from the foil. Flexible materials shall



be cut to 10 by 22-in. (255 by 560-mm) size, folded around the frame and fastened to the rear surface of the millboard with tension sufficient only to remove slack.

NOTE 23—Wherever millboard is specified, the material shall be cement bound of commercial quality nominal ½-in. (13-mm) thick and density of  $60 \pm 5 \text{ lb/ft}^3$  ( $960 \pm 80 \text{ kg/m}^3$ ).

8.8.1 For cellular elastomers and cellular plastics, whether flexible or not, the back and sides of the test specimen shall be wrapped with aluminum foil 0.002 in. (0.05 mm) thick, with the bright side against the specimen. High density inorganic reinforced cement board, 0.25 in. (6.4 mm) in thickness, shall be used as backing. The test specimen shall be retained in the specimen holder by a 6 by 18-in. (152 by 457-mm) sheet of nominally 1-in. (25.4-mm) hexagonal steel wire mesh, 20 AWG, placed against the exposed face of the specimen. Molded skin or treated surfaces shall face the exposure.

8.8.2 For testing of flexible cellular materials see also Test Method D 3975, which uses a different pilot burner.

8.9 Finish materials, including sheet laminates, tiles, fabrics, and others applied to a base material with adhesive as well as laminated materials not attached to a base shall be tested for possible increased flame spread or associated hazard due to delamination, cracking, peeling, or other separation of the finish material. An increase in flame spread may be caused by flaming on the reverse face of the test material, or by ignition of the adhesive or base material. Determination of the existence of such effects shall be made as follows:

8.9.1 One or more specimens of the sample material shall be tested as received in the manner prescribed herein for the flame spread determination of ordinary materials.

8.9.2 Materials that tend to delaminate or in any way separate from the specimen holder during the above test exposure shall be retested using one or more specimens in which the material is retained in position by a 6 by 18-in. (150 by 460-mm) sheet of 1-in. (25-mm) hexagonal wire mesh placed in the specimen holder and against the exposed face of the specimen.

8.9.3 Materials as described in this paragraph, and tested in accordance with 8.9.1 or 8.9.1 and 8.9.2 combined shall be further tested using one or more specimens. These specimens shall be prepared by scoring grooves of ¼-in. (1.6-mm) max width in the finish material, making one longitudinal groove 1 in. (25 mm) from an edge, and five lateral grooves 4 in. (102 mm) apart and 1 in. (25 mm) from the top and bottom edges. The resulting pattern contains four large sections, each 4 by 5 in. (102 by 127 mm) held on the back by the substrate lamina or by adhesive, and supported on the unscored side by the specimen holder. Unapplied laminates should be grooved through three fourths of the thickness; materials applied to a base should be scored completely through the finish.

8.9.4 The flammability test of the sample material shall be conducted under the appropriate condition of 8.9.1-8.9.3 that had yielded the highest flame spread index. However, if in a grooved assembly any increase in the flame-spread index can be attributed primarily to accelerated flame travel within the grooves, the flammability test shall be conducted in the conventional manner, without grooves.

8.10 If, in this initial test, any material tends to melt, soften, crack, split, or fall from the specimen holder, it shall be retested with a wire support as described in 8.9.2 and the higher of the two results shall be adopted as the flame spread index.

8.11 All specimens except those over ¾ in. (19.0 mm) thick shall be backed with ½-in. (13-mm) millboard of  $60 \text{ lb/ft}^3$  ( $960 \text{ kg/m}^3$ ) density. To protect the back surface of the specimen, a 1 by 6-in. (25 by 152-mm) strip of flexible ceramic paper shall be placed across the top edge of the specimen and folded down over the back face of the millboard.

NOTE 34—Wherever ceramic paper is specified, the material shall be capable of maintaining its integrity with a minimum service temperature of 2300°F (1260°C).

## 9. Conditioning

9.1 Predry specimens for 24 h at 140°F (60°C) and then condition to equilibrium at an ambient temperature of  $73 \pm 5^\circ\text{F}$  ( $23 \pm 3^\circ\text{C}$ ) and a relative humidity of  $50 \pm 5\%$ .

## 10. Number of Test Specimens

10.1 At least four

9.1 Four test specimens of each sample shall be tested under the conditions applicable tested. If one or more tests are deemed to be invalid, additional tests shall be conducted until four valid test results have been developed.

## 10. Conditioning

10.1 Predry specimens for 24 h at 140°F (60°C) and then condition to equilibrium (constant weight) at an ambient temperature of sample:  $73 \pm 5^\circ\text{F}$  ( $23 \pm 3^\circ\text{C}$ ) and a relative humidity of  $50 \pm 5\%$ .

## 11. Procedure

11.1 Remove objectionable combustion product deposits from the thermocouples by brush-cleaning or other effective method after each test.

11.2 During the conduct of the test, control extraneous drafts by closing windows and doors, stop air-circulating devices, and arrange baffles between the apparatus and any remaining sources of drafts.

11.3 Ignite

11.3 At the start of each testing day, ignite the gas-air mixture passing through the radiant panel and allow the unit to heat for 0.5 h. Before each test, check the radiant output by means of the radiation pyrometer. Do this by placing the pyrometer placed in such a manner as to view a central panel area about 10 in. (254 mm) in diameter. Adjust the rate of air supply to between 750 and 800 ft<sup>3</sup>/h (5.9 and 6.3 L/s) and then adjust the fuel gas supply upwards from zero until it is just sufficient to produce a radiant output equal to that which would be obtained from a blackbody of the same dimensions operating at a temperature of 1238 ± 7°F (670 ± 4°C).

11.4 Turn on the recording potentiometer for measuring the stack thermocouple temperature.

11.5 The adequacy of measures to control drafts shall be established by ensuring that stack temperature variations before the specimen is put in place for test (see 11.7) do not exceed ±9°F (5°C).

11.6 Ignite the pilot and adjust it to give a flame 2 to 3 in. (51 to 76 mm) long. Move the pilot into operating position. The pilot burner shall remain ignited and in position for the duration of the test whether or not there is flaming of the specimen. For materials that tend to shrink or contract upon application of heat, position the pilot burner flame to directly contact the specimen.

11.7 Place the specimen holder containing the specimen into the supporting framework and start the timer simultaneously. A maximum of 5 min shall elapse between the time the specimen is removed from the conditioning chamber until it is placed in position on the framework. During this time place the specimen and holder in an appropriate vapor barrier jacket, removing it only when the specimen and holder are placed on the framework for the test. A polyethylene bag has been found suitable as a vapor barrier envelope.

11.8 Record the time of arrival of the flame on the surface of the specimen at each of the 3-in. (76-mm) marks on the specimen holder or on the corresponding lines of the specimen. At the same time, make the observations for “flash” required in 12.4.1. Also, record observations on dripping (see 12.5) and any other behavior characteristics of the specimen that appear to be of interest.

11.9 Record the maximum rise of the stack thermocouples.

11.10 *Exposure Time*—The test is completed when the flame front has progressed to the 15-in. (380-mm) mark or after an exposure time of 15 min, whichever occurs first, provided the maximum temperature of the stack thermocouples is reached.

11.11 If during the test of one or more of the test specimens, any of the following unusual behavior occurs: (1) excessive molten material flows out of the specimen holder, (2) one or more portions of a test specimen is forcefully displaced from the zone of controlled irradiance (explosive spalling); or (3) the test specimen swells sufficiently prior to ignition to touch the burner during combustion; the test is invalid.

11.12 When a test on a specimen is invalid, test an additional specimen of the identical preconditioned test specimens. Do not incorporate data obtained from the tests noted above, yielding inadequate results, in the averaged data but report the occurrence.

## 12. Calculation

12.1 Calculate the ~~flame spread~~ radiant panel index,  $I_s$ , of a specimen as the product of the flame spread factor,  $F_s$ , and the heat evolution factor,  $Q$ , as follows:

$$I_s = F_s Q$$

where  $F_s$  and  $Q$  are as defined in 12.2 and 12.3.

The radiant panel index ( $I_s$ ) reported shall be the value calculated as above for each of the four specimens tested. The average ( $I_s$ ) of the four specimens shall be rounded to the nearest multiple of five.

12.2 *Calculation of  $F_s$* —On linear graph paper, plot distance vertically against time of arrival of flame at each mark horizontally. For this purpose, assume that the flame starts at 0 in. (0 mm) at time 0 min, and plot this initial point also. Connect the six (or fewer) points with straight-line segments. If the upward slope of all the line segments becomes less steep, or remains constant, calculate  $F_s$  as follows:

$$F_s = 1 + \frac{1}{t_3 - t_0} + \frac{1}{t_6 - t_3} + \frac{1}{t_9 - t_6} + \frac{1}{t_{12} - t_9} + \frac{1}{t_{15} - t_{12}}$$

where  $t_0$  is conventionally 0, and  $t_3 \dots t_{15}$  correspond to the time, in minutes, from initial specimen exposure until arrival of the flame front at the positions 3 ... 15 in. (76 ... 380 mm), respectively, along the length of the specimen.

12.2.1 If there are any segments where the slope increases, eliminate the increase by drawing a straight line from the previous point to the succeeding point, thus “skipping” the point at which the slope increases; (so, a “skip point” will always be located below the new line segment). Repeat this as often as necessary to eliminate slope increases. In some cases, it ~~may~~ will be necessary to skip 2, 3, or 4 consecutive points.

12.2.2 Points that are left below the final segmented curve are designated “skip points.” Points on the curve are “curve points.” There should be no points above the curve. Using the equation for  $F_s$  given in 12.2, drop the two terms involving a single skip point, or the three to five terms involving two to four consecutive skip points, or both, and in each case replace them with the single new term  $K/(T_f - T_b)$ , where  $K$  is an integer related to the number of skip points, as follows:

|                       |     |
|-----------------------|-----|
| Number of skip points | $K$ |
| One single            | 4   |
| Two consecutive       | 9   |
| Three consecutive     | 16  |
| Four consecutive      | 25  |



(Note that it is possible to have two, but no more, distinct groups of skip points: example in Annex A1.54.)

$T_f$  = time in minutes at the first curve point following a skip point.

$T_b$  = time in minutes at the last curve point before a skip point.

12.2.3 Procedures equivalent to the preceding, for example, computer programs, are equally valid.

12.3 Calculate  $Q$  as follows:

$$Q = CT/\beta$$

where:

$C$  = arbitrary constant 5.7, chosen to make results consistent with those obtained prior to the metrication of this calculation,  
 $T$  = observed maximum stack thermocouple temperature difference in degrees Celsius between the temperature-time curve for the specimen and that for a similar curve of the inorganic reinforced cement board calibration specimen (see Annex A1.2),  
 and

$\beta$  = mean stack thermocouple temperature rise for unit heat input rate of the calibration burner in degrees Celsius per kilowatt, a constant for the apparatus (see Annex A1.2). ( $\beta$  will probably be found to lie between 0.6 and 1.2°F/Btu-min, or between 20 and 40°C/kW.)

NOTE 5—When using English units, arbitrary constant  $C = 0.1$ ,  $T$  shall be expressed in degrees F, and  $\beta$  shall be expressed in degrees F per Btu/min.

NOTE 6—The value of the radiant panel index,  $I_r$ , is independent of the system of units used.

12.4 ~~Flame Fronts Not Sustained, All~~—All flame fronts, however temporary, are to be taken into account.

12.4.1 ~~Rapid Flame Spread~~—If flame spreads from any of the 3-in. marks to the next in 3 s or less, the fact ~~should~~ shall be mentioned in the report and the word “Flashing” in parentheses ~~should~~ shall follow the flame spread radiant panel index; it ~~should~~ shall be reported in the form: ~~for example, “Flame spread~~ “Radiant panel index = 100 (Flashing).”

12.5 Materials that have a tendency to exhibit rapid running or dripping of flaming material, either separately or in conjunction with a general flame front advance, due to melting and the steep inclination of the specimen during test, shall be noted as “Running (or Dripping) of Flaming Materials,” and the time of occurrence ~~should~~ shall be reported in addition to the regularly determined flame spread radiant panel index.

12.6 For low-density, cellular, or other materials in which the flaming is rapid and is limited to the early part of the test exposure, it is possible for a slight temperature rise ~~may~~ to remain undetected if recording is done ~~intermittently (for example, at 15-s intervals).~~ Continuous intermittently. If the first test indicates such behavior, the test shall be deemed invalid, and additional tests shall be conducted by recording of the stack thermocouple temperature at time intervals sufficiently small to ensure that no temperature rise values remain undetected; this can be achieved by taking recorder measurements every second or by using an appropriate data acquisition unit and computer.

### 13. Report

13.1 Report the following information:

13.1.1 Complete identification of the material tested, including type, source, manufacturer’s code numbers, form, principal dimensions, color, previous history, etc.,

13.1.2 Type of test specimens, for example, molded, slab, core, skin, surface treated, etc.; dimensions, and whether tested with or without backing or aluminum foil,

13.1.3 Conditioning procedure used. A justification shall be given if different from the procedure does not comply with that specified in 9.10.1,

13.1.4 Number of specimens tested, including an explanation of any invalid test results,

13.1.5 Exposure time and whether the specimen was completely destroyed or was exposed for 15 min,

13.1.6 Average ~~flame spread~~ radiant panel index ( $I_r$ ) for each set of specimens-a, round-æd to the nearest multiple of five,

13.1.7 and; the individual calculated values.

13.1.78 Any visual characteristics of the individual specimens, and

13.1.9 Designation of “Flashing” and “Running (or Dripping) of Flaming Material” where applicable, including time of occurrence and any other visual burning characteristics deemed relevant.

### 14. Precision and Bias

14.1 This test method has been in use for many years, but no information has been presented to ASTM International upon which to base statements on precision-and-bias-statement or bias. Round robin testing is-being-developed.-planned to develop data for a precision statement.

### 15. Keywords

15.1 beta factor; fire-test-response standard; flame spread factor; ~~flame spread~~ radiant panel index; heat evolution factor; radiant heat energy; radiant panel; surface flame spread; surface flammability

ANNEX

(Mandatory Information)

A1. PROCEDURE FOR CALIBRATION OF APPARATUS

A1.1 Radiation Pyrometer

A1.1.1 Calibrate the radiation pyrometer by means of a conventional commercial blackbody enclosure placed within a furnace and maintained at a uniform temperature of  $1238 \pm 10^\circ\text{F}$  ( $670 \pm 5^\circ\text{C}$ ). A typical blackbody enclosure consists of a closed Chromel metal cylinder with a small sight hole in one end. The radiation pyrometer is sited upon the opposite end of the cylinder from that where a thermocouple indicates the blackbody temperature. Perform the calibration by placing the thermocouple within a drilled hole and in good thermal contact with the blackbody.

A1.2 Stack Thermocouples

A1.2.1 With the panel at operating temperature, and the exhaust blower producing a steady stack velocity (suitable for conducting the tests), note the temperature of the stack thermocouples. Initial positioning of the exhaust hood system shall be made so as to maintain the operating stack thermocouple temperature within the range from  $356$  to  $446^\circ\text{F}$  ( $180$  to  $230^\circ\text{C}$ ) when no specimen is in position. Place an inorganic reinforced cement board specimen in position, ignite the pilot burner, adjust the flame to a 2 to 3-in. (51 to 76-mm) length, and place the burner into the operating position. Record the increase in temperature of the stack thermocouple over the 15-min. interval by obtaining temperature data at intervals not exceeding 5 s, and preferably at even shorter intervals. Use this time-temperature curve as a base for the measurement of stack thermocouple temperature rise in the testing of materials.

A1.2.2 Place an inorganic reinforced cement board specimen, with a nominally 0.5-in. (13-mm) millboard backing in the test position, and note the ensuing equilibrium temperature of the stack thermocouples which will be used as a base temperature for the following procedure: Prepare a multiported diffusion (no premixed air) burner from a 12 to 15-in. (305 to 381-mm) length of nominally 0.25-in. (6-mm) standard wrought iron or steel pipe capped at one end and containing ten  $0.070 \pm 0.008$ -in. ( $1.8 \pm 0.2$ -mm) diameter radial holes spaced  $0.625 \pm 0.04$  in. ( $16 \pm 1$  mm) on centers along a line parallel to the axis of the pipe. Place the center-line of the pipe burner in horizontal position  $1 \pm 0.1$  in. ( $25 \pm 2$  mm) (measured along the specimen surface) below the upper exposed edge of the inorganic reinforced cement board specimen. The pipe wall shall be in contact with both side edges of the specimen holder so that the portion of the pipe containing the burner holes is centered with respect to the specimen. The axes of the burner holes shall be vertical causing flames from the burner to impinge at or near the top of the inorganic reinforced cement board specimen. The type and orientation of the yellow diffusion flames produced are comparable to the flames emitted from a burning specimen. Ignite the pilot burner and adjust it in the manner described in 11.6. Record the maximum stack thermocouple temperature rise above the previously defined base for each of several gas flow rates to the burner, allowing a minimum of 10 min at each flow rate for stack temperature stabilization. The gas supplied to the calibration burner shall be

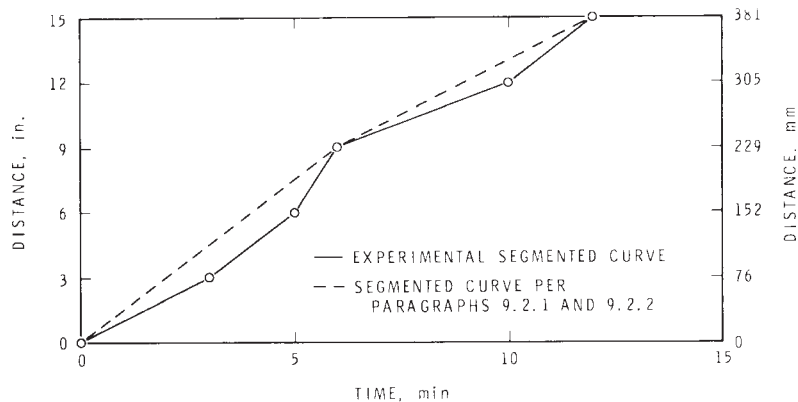


FIG. A1.1 Example of Flame Spread Factor

manufactured methane, or natural gas, or combinations of these gases. The gas flow rate to the calibration burner shall be measured by means of a calibrated flowmeter. Use the higher (gross) heating value of the gas to convert the gas flow rates to heat input rates. Moisture, temperature, and pressure corrections shall be applied, when applicable, to convert the gas flow rates and the higher (gross) heating value of the gas to a dry basis at a standard temperature of  $60^\circ\text{F}$  ( $15.6^\circ\text{C}$ ) and a standard pressure of 30.0 in. (762 mm) Hg (101 kPa). Plot the maximum stack thermocouple temperature rise in degrees Fahrenheit (or Celsius) as a function of the

corresponding measured heat input in Btu per minute (or kilowatts). The value of  $\beta$  used in the formula in 12.3 is based on the ratio of a temperature rise to the heat input required to produce it. This shall be measured at the level required to produce a temperature rise of 180°F (100°C). For those using degrees Fahrenheit for  $T$  in 12.3,  $\beta$  is 57 times the ratio of a temperature rise of 180°F to the heat input in Btu per minutes producing it. For those using degrees Celsius for  $T$  in 12.3,  $\beta$  is the simple ratio of a temperature rise of 100°C to the heat input in kilowatts producing it.

### A1.3 Calibration Check

A1.3.1 The proper calibration of the radiation pyrometer at a blackbody temperature of 1238°F (670°C) as described in 6.1.9 and A1.1.1 is important. Use an outside calibration agency to provide calibration traceable to the National Institute of Standards and Technology (NIST).

### A1.4 Example of Flame Spread Factor, $F$ , Calculation (12.2.1 and 12.2.2)

A1.4.1 Suppose  $t_3 = 3$  min,  $t_6 = 5$  min,  $t_9 = 6$  min,  $t_{12} = 10$  min, and  $t_{15} = 12$  min. These points appear in a graph in Fig. A1.1.  $t_3$ ,  $t_6$ , and  $t_{12}$  are recognized as skip points with the first two being consecutive. Thus using the equation in 12.2 modified by 12.2.2:

$$\frac{1}{t_3 - t_0} + \frac{1}{t_6 - t_3} + \frac{1}{t_9 - t_6} \text{ are replaced by } \frac{9}{t_9 - t_0}$$

and

$$\frac{1}{t_{12} - t_9} + \frac{1}{t_{15} - t_{12}} \text{ are replaced by } \frac{4}{t_{15} - t_9}$$

The final equation becomes:

$$F_s = 1 + \frac{9}{t_9 - t_0} + \frac{4}{t_{15} - t_9}$$

Thus, substituting the appropriate times:

$$F_s = 1 + (9/6) + (4/6) = 3.17$$

### A1.5 Surface Flammability Standard Material

A1.5.1 The National Bureau of Standards (now National Institute of Standards and Technology (NIST), Gaithersburg, MD 20899) has made available a surface flammability standard material, for checking operational and procedural details of this test method, through its Standard Reference Materials Program. The use of this standard material does not replace the need for following the calibration and standardization procedures outlined herein.

## APPENDIX

### X1. COMMENTARY

X1.1 There are several different test methods for assessing the surface flammability of materials. This test method was developed by the National Bureau of Standards (now National Institute of Standards and Technology) to obtain surface flame spread information based on a radiant heat source, as an alternative to the traditional Steiner tunnel test (Test Method E 84). The references in footnote 5 describe the original test method, as developed at the National Bureau of Standards, and contain test data for this method and for other test methods on several building materials. The indices determined in Test Method E 84 and in Test Method E 162 are different and should not be compared directly.

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