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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Method for Surface Flammability of Flexible Cellular Materials Using A Radiant Heat Energy Source[1]

This standard is issued under the fixed designation D 3675; 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 is a fire test response standard.

1.2 This test method covers the measurement of surface flammability of flexible cellular materials.

1.3 *This standard should be used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions and should not be used to describe or appraise the fire-hazard or fire-risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire-hazard assessment or a fire-risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard or fire risk of a particular end use.*

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.*

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

2. Referenced Documents

2.1 *ASTM Standards:*

E 162 Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source[2]

3. Summary of Test Method

3.1 This test method of measuring surface flammability of flexible cellular materials employs a radiant panel heat source consisting of a 300 by 460-mm (12 by 18-in.) panel in front of which an inclined 150 by 460-mm (6 by 18-in.) 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.

3.2 Factors derived from the rate of progress of the flame front and heat liberated by the material under test are combined to provide a flame spread index.

4. Significance and Use

4.1 This test method is intended for measurements on materials whose surfaces may be exposed to fire. It provides a laboratory test procedure for measuring and comparing the surface flammability of materials when exposed to a prescribed level of radiant heat energy. The test is made on 150 by 460-mm (6 by 18-in.) specimens that are representative, to the extent possible, of the material or assembly being evaluated.

4.2 The rate at which flames will travel along surfaces depends upon the physical and thermal properties of the material, its method of mounting and orientation, the type and level of fire or heat exposure, the availability of air, and properties of the surrounding enclosure.[3,4]

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

4.4 If the test results obtained by this test method are to be considered in the total assessment of fire hazard in a building structure, then all pertinent established criteria for fire hazard assessment developed by ASTM Committee E-5 must be included in the consideration.

5. Apparatus

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

5.1.1 *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 300 by 460 mm (12 by 18 in.) and shall be capable of operating

[1] This test method is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.30 on Thermal Properties.

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[2] *Annual Book of ASTM Standards*, Vol 04.07.

[3] For additional information refer to the following:

(*1*) 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.

(*2*) Robertson, A. F.," Surface Flammability Measurements by the Radiant Panel Methods," *ASTM STP 344*, ASTM, 1962, pp. 33–46.

(*3*) 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.

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

[4] Also see Test Method E 162.

FIG. 1 Radiant Panel Flame Spread Test Equipment

at temperatures up to 820°C (1500°F). 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 47 dm^3/s (100 ft^3/min) air at a pressure of 0.7 kPa (2.8 in. water); 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.

5.1.2 *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 75-mm (3-in.) interval lines on the specimen.

5.1.3 *Framework for Support of the Specimen Holder*—The framework shall have two transverse rods of stainless steel, each about 12.5 mm (0.5 in.) in diameter, with a stop to center the specimen holder directly in front of the radiant panel. The support and bracing members should 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 3.0 mm (0.13 in.) of the values given in Fig. 2.

5.1.4 *Pilot Burner*—The pilot burner shall be a porcelain tube 230 mm (9 in.) in length, 6.3 mm (0.25 in.) in diameter, with two holes 1.5 mm (0.059 in.) in diameter equally spaced in the tube (see Fig. 4). The burner shall be mounted horizontally and at an angle of 15 to 20° to the intersection of the horizontal plane of the burner with the plane of the specimen with the outlet end of the burner spaced 32 ± 2 mm (1.25 ± 0.1 in.) from the specimen (see Fig. 4). The pilot shall provide a 150 to 180-mm (6 to 7-in.) flame of gas premixed with air in an aspirating type fitting. Acetylene has been found satisfactory for this purpose. Properly adjusted, the pilot flame should have 25-mm (1-in.) inner blue cones and should impinge on the upper central surface of the specimen within 13 mm (0.5 in.) of the edge of the specimen support frame. Flow rates of 0.015 dm^3/s (0.032 ft^3/min) of acetylene and 0.075 dm^3/s (0.16 ft^3/min) of air have been found to provide the desired flame.

5.1.5 *Stack*—The stack shall be made from 1.0-mm (0.040-in.) 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.

5.1.6 *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. 5. Each junction shall be formed by fusing the end of a twisted pair of chromel and alumel wires of 0.5-mm (0.02-in.) diameter. The wiring shall be insulated in a manner that adequately protects those segments subjected to elevated temperatures.

5.1.7 *Automatic Potentiometer Recorder*—An automatic potentiometer recorder in the range from 38 to 538°C (100 to 1000°F) shall be installed to record the temperature variation of the stack thermocouples as described in 5.1.6. The recorder shall give a continuous record or shall print at time intervals of not more than 5 s.

5.1.8 *Hood*—A hood with exhaust blower placed over the stack is required. The blower should produce a velocity that adequately exhausts smoke and combustion gases. The velocity is not critical for flame spread measurements provided a stack thermocouple calibration is performed (see A1.3) for the established test conditions. The hood surfaces should clear the top and sides of the stack by a minimum of 250 mm (10 in.) and 190 mm (7.5 in.) respectively.

5.1.9 *Radiation Pyrometer*—The radiation pyrometer for standardizing the thermal output of the panel shall be suitable for viewing a circular area 250 mm (10 in.) in diameter at a range of about 1.2 m (4 ft). It shall be calibrated over the operating black body temperature range in accordance with the procedure described in Annex A1.

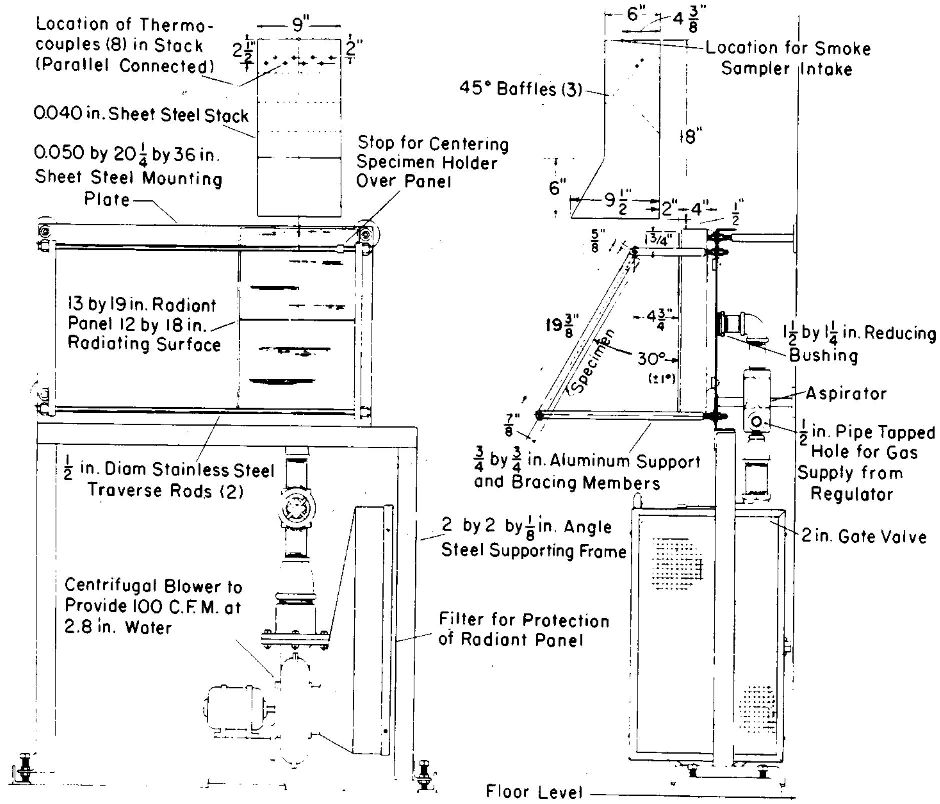
5.1.10 *Portable Potentiometer*—The electrical output of the radiation pyrometer shall be monitored by means of a potentiometer provided with a millivolt range suitable for use with the radiation pyrometer described in 5.1.9.

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

6. Test Specimens

6.1 The test specimens shall be 150 by 460 by 25 mm (6 by 18 by 1.0 in.). Materials produced at less than 25-mm thickness shall be tested at the maximum thickness produced. Materials produced at less than 460 mm (18 in.) in length shall be mounted in series to provide a specimen of the proper length. No segment of the specimen shall be less than 150 mm (6 in.) in length.

6.2 The back and sides of the test specimen shall be wrapped with aluminum foil, the shiny side against the test specimen, 0.05 mm (0.002 in.) in thickness. Insulation board,



Metric Equivalents

in.	mm	in.	mm
0.040	1.0	6	152
½	12.7	9½	241
⅝	16.0	18	457
⅞	22.2	19⅜	492
1¾	44	¾ by ¾	19.2 by 19.2
2	51	1½ by 1¼	38 by 32
2½	64	12 by 18	305 by 457
2.8	71	13 by 19	330 by 483
4	102	2 by 2 by ⅛	51 by 51 by 3.2
4⅜	111	0.050 by 20¼ by 36	13 by 514 by 914
4¾	121		

100 cfm = 47.21 litres/s

FIG. 2 Details of Construction of Test Equipment

6.4 mm (0.25 in.) in thickness, shall be used as backing. The test specimen shall be retained in the specimen holder by a 150 by 460-mm (6 by 18-in.) sheet of 25-mm (1-in.) 20-gage hexagonal steel wire mesh placed against the exposed face of the specimen. Molded skin or treated surfaces shall face the exposure.

6.3 At least four test specimens of each sample shall be tested.

7. Conditioning

7.1 Condition the specimens for a minimum of 24 h at a temperature of 23 ± 3°C (73 ± 5°F) and a relative humidity of 50 ± 5 %.

8. Procedure

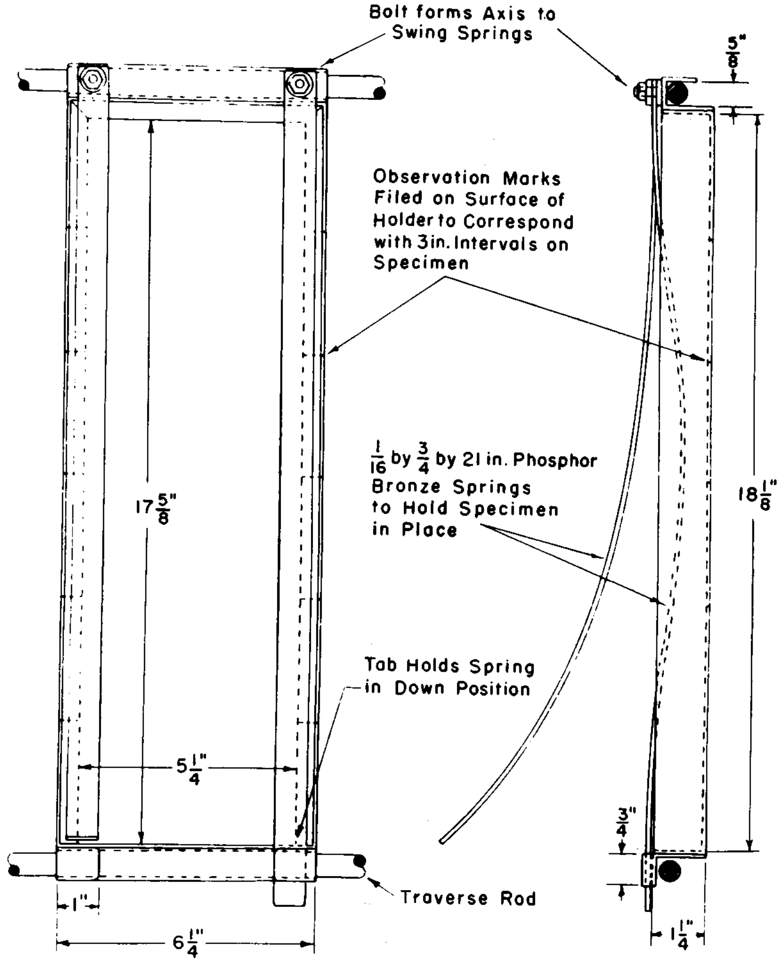
8.1 Remove objectionable combustion deposits from the thermocouples by brush cleaning or other effective method after each test.

8.2 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 placed in such a manner as to view a central panel area about 250 mm (10 in.) in diameter. Adjust the rate of gas supply to maintain the radiant output equal to that which would be obtained from a blackbody of the same dimensions operating at a temperature of 670± 4°C (1238 ± 7°F).

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

8.4 Ignite the pilot and adjust it to give a flame 150 to 180 mm (6 to 7 in.) long with inner blue cones 25 mm (1.0 in.) in length.

8.5 Place the specimen holder containing the specimen into the supporting framework and start the timer. A maximum of 5 min shall lapse between the time the specimen is removed from the conditioning chamber until it is placed in position on the



Metric Equivalents

in.	mm	in.	mm
3⁄4	19.0	61⁄4	159
1	25	175⁄8	433
11⁄4	32	181⁄8	460
3	76	1⁄16 by 3⁄4 by 21	1.6 by 19 by 533
51⁄4	133		

FIG. 3 Specimen Holder

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.

8.6 Record the time of arrival of the flame at each of the 75-mm (3-in.) marks on the specimen holder. Also record the maximum temperature rise of the stack thermocouples.

8.7 Record any observations made of any behavior characteristics of a specimen that appear to be of interest.

8.8 *Exposure Time*—The test is completed when the flame front has progressed the full length of the specimen or after an exposure time of 15 min, whichever occurs earlier, provided the maximum temperature of the stack thermocouples is reached.

9. Calculation

9.1 Calculate the flame spread index, I_s, of a specimen as the product of the flame spread factor, F_s, and the heat evolution factor, Q, as follows:

$$I_s = F_s Q \quad (1)$$

where F_s and Q are as defined in 9.2 and 9.3.

9.2 *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:

$$F_s = 1 + \frac{1}{t_3 - t_0} + \frac{1}{t_6 - t_3} + \frac{1}{t_9 - t_6} + \frac{1}{t_{12} - t_9} + \frac{1}{t_{15} - t_{12}} \quad (2)$$

where t_0 is conventionally 0, and t_3... 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),

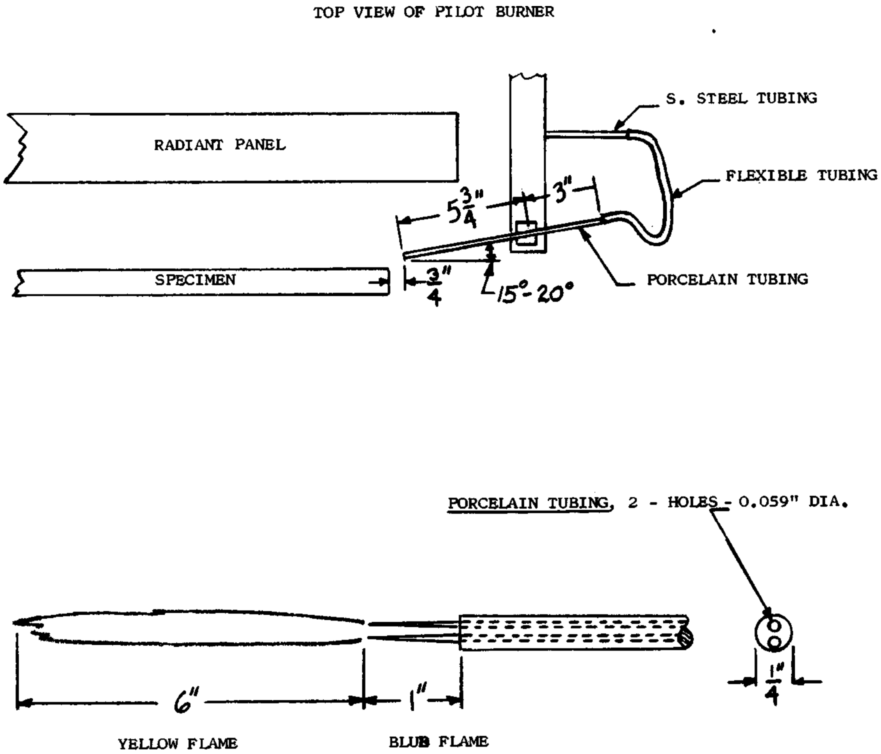


FIG. 4 Pilot Burner

respectively, along the length of the specimen.

9.2.1 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 be necessary to skip 2, 3, or 4 consecutive points.

9.2.2 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 9.2, 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.)

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

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

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

9.3 Calculate Q as follows:

$$Q = CT/\beta \qquad (3)$$

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 A1.2), and

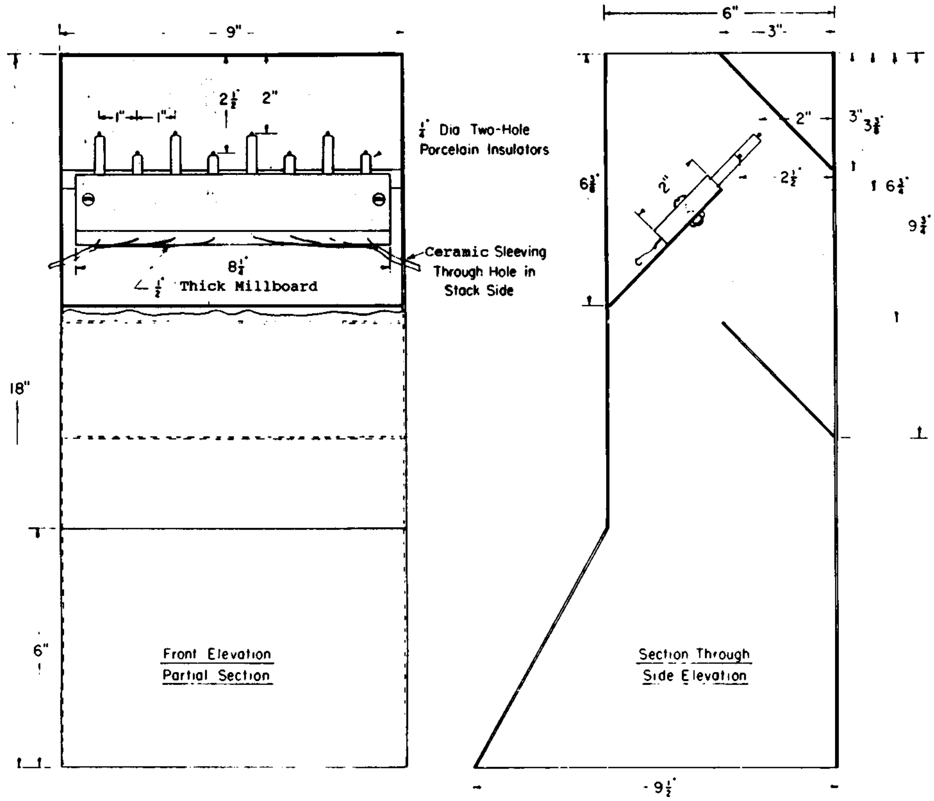
β = mean stack thermocouple temperature rise for unit heat input rate of the calibration burner in degrees Celsius per kilowatt, a constant for the apparatus (see A1.2). (β will probably be found to lie between 0.6 and 1.2°F/Btu·min, or between 20 and 40°C/kW.)

NOTE 2—For those using English units, arbitrary constant C = 0.1, T shall be expressed in °F, and Beta shall be expressed in °F per Btu/min.

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

9.4.1 *Rapid Flame Spread*—If flame spreads from any of the 3-in. marks to the next in 3 s or less, the fact should be mentioned in the report and the word "Flashing" in parentheses should follow the flame spread index; it should be reported in the form, for example," Flame spread index = 100 (Flashing)."

9.5 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 be reported in addition to the regularly determined flame spread index.



Metric Equivalents

in.	mm	in.	mm	in.	mm
¼	6.4	3	76	9	229
½	12.7	3⅜	86	9½	241
1	25	6	152	9¾	248
2	51	6¾	171	18	457
2½	64	8¼	210		

FIG. 5 Thermocouple Mounting Arrangement

9.6 For materials in which the flaming is rapid and is limited to the early part of the test exposure, a slight temperature rise may remain undetected if recording is done intermittently (for example, at 15-s intervals). Continuous recording of the stack thermocouple temperature is required in such cases.

10. Report

10.1 Report the following information:

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

10.1.2 Type of test specimens, such as molded, slab, core, skin surface treated, etc., and thickness,

10.1.3 Conditioning procedure used if different from that specified in 7.1,

10.1.4 Number of specimens tested,

10.1.5 Exposure time and whether completely destroyed or exposed for 15 min,

10.1.6 Average flame spread index for each set of specimens and range, and

10.1.7 Designation of "Flash Potential" and" Running (or Dripping) of Flaming Material" where applicable, including time of occurrence and any other visual burning characteristics deemed relevant.

11. Precision and Bias [5]

11.1 These precision data are based on tests of six materials by eleven laboratories. Sufficient quantities of each of the six materials were prepared in one laboratory and sent to the participating laboratories. The repeatability and reproducibility results therefore do not include "material preparation" components of variation. Four replicate determinations were conducted on each material. Due to a shortage of materials any individual laboratory tested only four of the six materials. The six materials are as follows:

11.1.1 Urethane, 1 in. thick.

11.1.2 Neoprene, 1 in. thick.

11.1.3 Neoprene, ½in. thick.

11.1.4 Polyester urethane, 1 in. thick.

11.1.5 Polyether urethane, 1 in. thick.

11.1.6 PVC acrylonitrile butadiene copolymer, ½ in. thick. The approximate range of test values obtained on these materials for each test response are as follows:

$$\frac{F_s, \text{min}^{-1}}{1 - 92} \quad \frac{Q, \text{Btu min}^{-1}}{5 - 21} \quad \frac{I_s, \text{Btu min}^{-2}}{7 - 1950} \tag{4}$$

[5] Supporting data are available from ASTM Headquarters. Request RR: D11-1014.

Precision is expressed in relative terms (2S%, D2S%).

11.2 *Repeatability*—Two test results, reported as the average of four replicates, do not differ significantly unless their difference as a percent of their average value exceeds the following percentages:

$$\frac{F_s}{31\,\%}\quad\frac{Q}{43\,\%}\quad\frac{I_s}{70\,\%} \tag{5}$$

11.3 *Reproducibility (Multilaboratory)*—Two test results, reported as the average of four replicates, do not differ significantly unless their difference as a percent of their average value exceeds the following percentages:

$$\frac{F_s}{174\,\%}\quad\frac{Q}{104\,\%}\quad\frac{I_s}{192\%} \tag{6}$$

11.4 The percent error of these responses is larger than usually desired. However, this test can distinguish between materials which characteristically differ by a large amount.

12. Keywords

12.1 beta factor; flame spread index; radiant panel; 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 blackbody enclosure placed within a furnace and maintained at a uniform temperature of 670 ± 5°C (1238 ± 10°F). The blackbody enclosure may consist of a closed Chromel metal cylinder with a small sight hole in one end. Sight the radiation pyrometer upon the opposite end of the cylinder where a thermocouple indicates the blackbody temperature. Place 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 an established stack velocity, note the temperature of the stack thermocouples. It is recommended that initial positioning of the exhaust hood system be made so as to maintain the operating stack thermocouple temperature within the range from 180 to 230°C (356 to 446°F) when no specimen is in position. Place an insulation board specimen in position, ignite the pilot burner, adjust the flame to a 150 to 180-mm (6 to 7-in.) length with 25-mm (1.0-in.) inner blue cones. Continuously, record the increase in temperature measured by the stack thermocouple over the 15-min interval. Use this time-temperature curve as a base for measurement of stack thermocouple temperature rise in the testing of materials.

A1.2.2 Place an inorganic reinforced cement board specimen, with a 13-mm (½-in.) asbestos 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 300 to 380-mm (12 to 15-in.) length of 6 mm (¼-in.) standard wrought iron or steel pipe capped at one end and containing ten 1.8-mm (0.070-in.) diameter radial holes spaced 16 mm (⅝ in.) on centers along a line parallel to the axis of the pipe. Place the center-line of the pipe burner in horizontal position 25 mm (1 in.) (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 4.1.4. 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 manufactured methane, or natural gas, or combinations of these gases. The gas flow rate to the calibration burner should 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 should 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 16°C (60°F) and a standard pressure of 101 kPa (30.0 in. Hg). Plot the maximum stack thermocouple temperature rise in degrees Celsius (Fahrenheit) as a function of the corresponding measured heat input in kilowatts (Btu per minute). The value of β used in the flame spread index formula in 9.3 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 100°C (180°F). For those using degrees Celsius β is the simple ratio of a temperature rise of 100°C to the heat input in kilowatts producing it. For those using degrees Fahrenheit for T in 9.3, β is the ratio of a temperature rise of 180°F to the heat input in Btu per minutes producing it.

A1.3 Calibration Check

A1.3.1 The proper calibration of the radiation pyrometer of a blackbody temperature of 670°C (1238°F) as described in 5.1.9 and A1.1.1 is important. Where facilities for performing such a calibration are not available to laboratories equipped with the radiant panel test apparatus, a check calibration may be secured upon request to the Center for Fire Research, National Institute of Standards and Technology, Washington, D.C. 20025.

SUMMARY OF CHANGES

This section identifies the location of selected changes to this test method. For the convenience of the user, Committee D-20 has highlighted those changes that may impact the use of this test method. This section may also include descriptions of the changes or reasons for the changes, or both.

D 3675–98:

(1) Added ISO equivalency statement.

(2) Amended last sentence of A1.2.2.

(3) Added Note 2 to 9.3 for use of English units.