Designation: D4804 – 14

Standard Test Method for Determining the Flammability Characteristics of Nonrigid Solid Plastics[1]

This standard is issued under the fixed designation D4804; 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 test methods describe small-scale laboratory procedures for determining the comparative burning characteristics of solid plastic materials that, due to specimen thinness and nonrigidity, distort, shrink, and/or are consumed up to holding clamp when tested using Test Method D3801. A flame is applied to the base of specimens held in a vertical position and the extinguishing times are determined upon removal of the test flame.

1.2 The classification system described in Appendix X1 is intended for quality assurance and the preselection of component materials for products.

1.3 This standard measures and describes 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 assessment of the materials, products, or assemblies under actual fire conditions.

NOTE 1—This standard is equivalent to ISO 9773, IEC 60695-11-10, and UL 94 (Section 11).

NOTE 2—For rate of burning of nonrigid solid plastics in a horizontal position, formerly Test Method B of this test method, see Test Method D635.

1.4 This test method is not intended to cover plastics when used as materials for building construction or finishing.

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

1.6 *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.* For specific hazard statements, see 6.1.1.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D635 Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position

D883 Terminology Relating to Plastics

D3801 Test Method for Measuring the Comparative Burning Characteristics of Solid Plastics in a Vertical Position

D5025 Specification for Laboratory Burner Used for Small-Scale Burning Tests on Plastic Materials

D5207 Practice for Confirmation of 20–mm (50–W) and 125–mm (500–W) Test Flames for Small-Scale Burning Tests on Plastic Materials

E176 Terminology of Fire Standards

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 *ISO Standards:*

ISO 9773–98 Plastics—Determination of Burning Behaviour of Thin Flexible Vertical Specimens in Contact With a Small Flame Ignition Source[3]

3. Terminology

3.1 *Definitions*—For terms relating to plastics, the definitions in this test method are in accordance with Terminology D883. For definitions of fire-related terms used in this test method, refer to Terminology E176.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *flame-application time*—the time in seconds that the flame from the burner is in contact with the specimen.

3.2.2 *flaming material*—flaming drips or particles from the specimen which ignite the dry, absorbent 100 % surgical cotton placed 300 mm ± 10 mm below the test specimen.

3.2.3 *afterflame*—persistence of flaming of a material, after the ignition source has been removed.

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

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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 American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

***A Summary of Changes section appears at the end of this standard**

3.2.4 *afterflame time*—the length of time for which a material continues to flame, under specified conditions, after the ignition source has been removed.

3.2.5 *afterglow*—persistence of glowing of a material, after cessation of flaming or, if no flaming occurs, after removal of the ignition source.

3.2.6 *afterglow time*—the length of time for which a material continues to glow under specified test conditions, after the ignition source has been removed or cessation of flaming, or both.

3.2.7 *flame*—to undergo combustion in the gaseous phase with emission of light.

3.2.8 *glow*—visible light, other than from flaming, emitted by a solid undergoing combustion.

4. Summary of Test Method

4.1 This test method consists of subjecting the lower end of vertically held specimens to a 20 ± 1 mm test flame for two 3-second flame applications. The 200 ± 5 mm by 50 ± 2 mm specimens are preformed around a 13 ± 0.5 mm diameter mandrel. The afterflame time is recorded after the first flame application and the afterflame and afterglow times are recorded after the second flame application. Information is also recorded on whether or not flaming material drips from the specimens.

5. Significance and Use

5.1 The test results represent the afterflame and afterglow times, in seconds, for a material under the conditions of the test.

5.2 The afterflame and afterglow times and other burning phenomena will vary with thickness. Test data shall only be compared with data for material of comparable thickness.

5.3 The effect of material thickness, colors, additives, deterioration, and possible loss of volatile components is measurable.

5.4 The results serve as a reference for comparing the relative performance of materials and can be an aid in material selection.

5.5 In this procedure, the specimens are subjected to one or more specific sets of laboratory test conditions. If different test conditions are substituted or the end-use conditions are changed, it will not always be possible by or from this test method 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 test method.

6. Apparatus

6.1 *Test Chamber*—An enclosure or laboratory hood with a minimum capacity of 0.5 m^3, free of induced or forced draft during testing. An enclosed laboratory hood with a heat-resistant glass window and an exhaust fan for removing the products of combustion immediately after the tests are recommended. If a draft is noted with the exhaust fan off, further measures are needed to eliminate the draft, such as adding a positive closing damper. The inside surfaces of the chamber shall be of a dark color. When a light meter, facing towards the rear of the chamber is positioned in place of the test specimen, the light level shall be less than 20 lx.

6.1.1 **Warning—**Products of combustion are toxic. An exhaust fan is recommended for removing the products of combustion immediately after the test.

NOTE 3—Placing a mirror in the hood, to provide a rear view of the test specimen, has been found useful.

6.2 *Laboratory Burner,* constructed in accordance with Specification D5025.

6.3 *Ring Stand,* with a clamp or the equivalent, adjustable for vertical positioning of specimens.

6.4 *Gas Supply*—A supply of technical-grade methane gas (Min. 98 % pure) with suitable regulator and meter for uniform gas flow. Natural gas having an energy density of 37 ± 1 MJ/m^3 (1000 Btu/ft^3) has been found to provide similar results. However, technical-grade methane gas shall be used as the referee gas in cases of dispute. Other fuel gases such as butane, propane, and acetylene have higher energy density and are not suitable.

6.5 *Timer*—Stopwatch or other suitable timing device capable of timing to the nearest 0.5-seconds.

6.6 *Cotton*—A supply of dry, absorbent 100 % surgical cotton.

6.7 *Desiccator,* containing anhydrous calcium chloride or other suitable drying agent, capable of maintaining a relative humidity not exceeding 20 % at 23 ± 2°C.

6.8 *Conditioning Room or Chamber,* capable of being maintained at 23 ± 2°C and a relative humidity of 50 ± 10 %.

6.9 *Conditioning Oven*—A full-draft circulating-air oven capable of being maintained at 70 ± 2°C.

6.10 *Specimen Mandrel Guide,* 13 ± 0.5-mm diameter rod.

6.11 *Micrometer,* capable of being read to 0.01 mm.

6.12 *Pressure-Sensitive Adhesive Tape,* of a commercially-available type.

6.13 *Weighing Scale or Balance,* having an accuracy and resolution of 0.01 g.

6.14 *Stainless steel or nichrome wire,* of diameter 0.2 mm to 0.5 mm.

7. Sampling

7.1 Unless otherwise agreed, material shall be sampled in accordance with good statistical practice.

8. Test Specimens

8.1 It is possible that the results of tests carried out on test specimens of different colors, thicknesses, densities, molecular weights, directions of orientation, or with different additives, fillers/reinforcements, will be different.

8.2 Test specimens in the minimum and maximum densities, melt flows and fillers/reinforcements contents shall be considered representative of the range, if the test results yield the same flame test classification. If the burning characteristics are not essentially the same for all specimens representing the range, evaluation is to be limited only to the materials in the

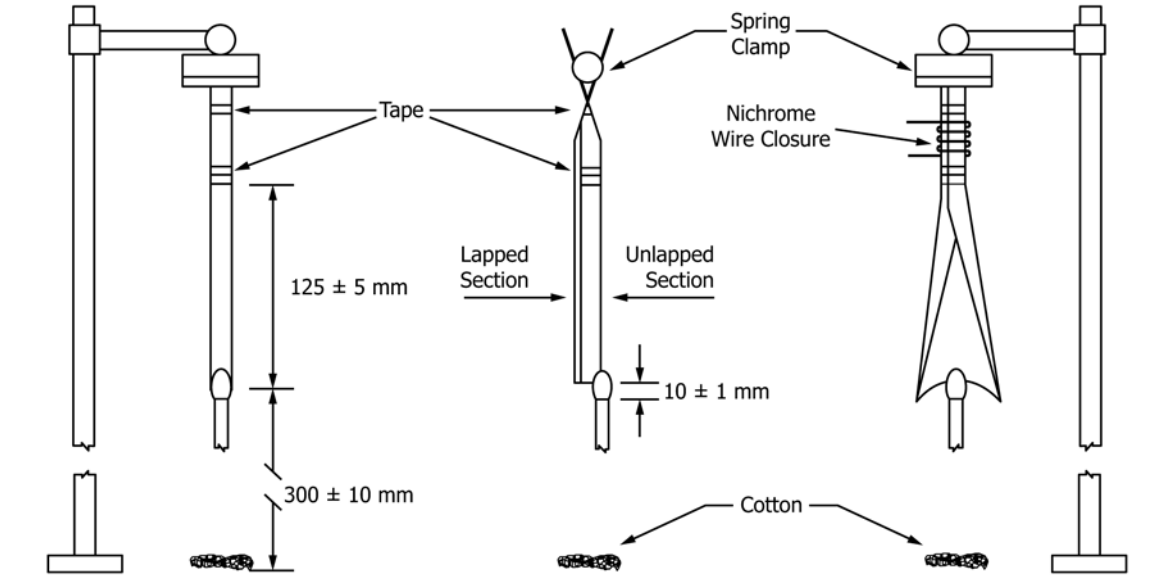

FIG. 1 Test Apparatus

densities, melt flows, and fillers/reinforcements contents tested, or additional test specimens in the intermediate densities, melt flows, and fillers/reinforcements contents are to be tested.

8.3 Un-pigmented test specimens and test specimens with the highest level of organic and inorganic pigment loading by weight are considered representative of the color range, if the test results yield the same flame test classification. When certain pigments are known to affect flammability characteristics, they are also to be tested. Test specimens to be tested are those that:

(a) contain no pigments (natural)
(b) contain the highest level of organic pigments
(c) contain the highest level of inorganic pigments
(d) contain pigments which are known to adversely affect flammability characteristics

8.4 All specimens shall be cut from a representative sample of the material (sheets or end-products). After any cutting operation, care shall be taken to remove all dust and any particles from the surface; cut edges shall have a smooth finish.

8.5 Standard specimens shall be 200 ± 5 mm long, 50 ± 2 mm wide and a maximum of 0.25 mm thick. Measure the thickness of each to the nearest 0.01 mm and note the measurements.

8.5.1 Specimens >0.25 mm thick can be subjected to this test method if the specimens due to their thinness and nonrigidity, distort, shrink and/or are consumed up to holding clamp when tested using Test Method D3801.

8.5.2 Tests made on specimens of different thicknesses and made in different directions of anisotropy are not always comparable.

8.6 Specimens shall be prepared by marking a line across the specimen width 125 mm ± 5 mm from one end (bottom) of the cut specimen. The longitudinal axis of the specimen shall be wrapped tightly around the longitudinal axis of the mandrel to form a lapped cylinder with the 125-mm line exposed. The overlapping portions of the specimens shall be secured within the upper 75-mm segment above the 125-mm mark and at the upper end of the tube with pressure-sensitive adhesive tape. The mandrel shall then be removed. If the material is prone to developing static charges that make the formation of a cylinder difficult, it is acceptable to deionize the unformed specimen using a device or material intended for that purpose.

8.7 A minimum of 20 specimens shall be prepared. Prepare additional specimens for retest purposes, if necessary.

8.8 It is possible that different generic materials, although capable of being wrapped and taped around the mandrel, will exhibit varying degrees of flaring out of the untaped end, some of which will potentially result in nonlapped “U” type specimens. These various forms are considered acceptable to test if it is possible to form the upper end into the cylinder. When testing stiff specimens, reinforce or replace the pressure-sensitive tape by wrapping nichrome wire around the top 75 mm of the specimen. See Fig. 1(c).

9. Conditioning

9.1 Prepare the cylindrical specimens before the conditioning. Condition specimen sets as follows:

9.1.1 Condition one set of five specimens for at least 48 h at a temperature of 23 ± 2°C and a relative humidity of 50 ± 10 % prior to testing.

9.1.2 Condition a second set of five specimens in a circulating-air oven for a duration of 168 h at 70 ± 2°C and then cool in a desiccator capable of maintaining a relative not exceeding 20 % at 23 ± 2°C for at least 4 h at room temperature prior to testing.

9.1.3 Upon removal from the conditioning environment, specimens shall be tested within 30 minutes.

9.2 All specimens shall be tested in a laboratory atmosphere of 15 to 35°C and ≤75 % relative humidity.

9.3 Cotton shall be conditioned in the desiccator for at least 24 hours prior to use. Once removed from the desiccator, the cotton shall be used within 30 minutes.

10. Procedure

10.1 Conduct the burning test in a chamber, enclosure, or laboratory hood free of induced or forced draft.

10.2 Support a specimen from the upper 6 mm of the specimen, with the longitudinal axis vertical, by a heavy spring clamp, so that the upper end of the tube is closed to prevent any chimney effects during the test. The lower end of the specimen shall be 10 ± 1 mm above the top of the burner tube and 300 ± 10 mm above a horizontal layer of 0.05 to 0.08 g of cotton thinned to an area approximately 50 by 50 mm and a maximum thickness of 6 mm (see Fig. 1, View (*a*)).

10.2.1 To form the horizontal layer, it is acceptable to pull a small portion (approximately 13 by 25 mm) of cotton from the supply with the fingers and then thin and spread the cotton into a 50 by 50 mm square having a free-standing thickness of 6 mm.

10.3 Place the burner remote from the specimen, ignite, and adjust it to produce a blue flame 20 ± 1 mm high. Obtain the flame by adjusting the gas supply and the air ports of the burner until a 20 ± 1 mm yellow-tipped blue flame is produced. Increase the air supply until the yellow tip just disappears. Measure the height of the flame again, and if necessary, adjust the burner-gas supply to give the proper flame height. The test flame is to be calibrated using Practice D5207 monthly, when the gas supply or equipment is changed or when test results are questioned.

10.4 Place the test flame centrally under the lower end of the unlapped section of the test specimen with the burner tube 10 ± 1 mm below the specimen for a flame-application time of 3 ± 0.5 s (see Fig. 1, View (*b*)). Withdraw the test flame at least 150 mm away and record the duration of afterflame, in seconds, of the specimen after the removal of the test flame. When flaming of the specimen ceases, immediately replace the test flame under the specimen. After this additional 3 ± 0.5-s flame application time, withdraw the test flame again. Record the duration of afterflame and afterglow times in seconds.

NOTE 4—For specimens that flare and are not lapped at the lower end, apply the flame in line with the longitudinal axis of the specimen (see Fig. 1, View (*c*)).

10.5 If the specimen drips molten or flaming material during either flame application, tilt the burner to an angle up to 45° and withdraw the burner slightly from one of the sides of the specimen during the flame applications to avoid dripping into the tube of the burner. If the specimen drips molten or flaming material or is consumed during the test, hand-hold the burner and maintain the proper distance between the bottom of the specimen and the top of the burner tube during the flame application. Ignore any molten strings of the material and always apply the flame to the bottom of the major portion of the specimen.

10.6 Repeat the procedure given in 10.2 – 10.5 on the remaining specimens for each set.

11. Calculation

11.1 Calculate the total afterflame time for each set of five specimens, t_f, using the following formula:

$$t_f = \sum_{i=1}^{i=5} (t_{1,i} + t_{2,i}) \quad (1)$$

where:

t_f = total flaming time, seconds,
i = individual specimen number,
$t_{1,i}$ = afterflame time after the first flame application, seconds, of the i^{th} specimen, and
$t_{2,i}$ = afterflame time after the second flame application, seconds, of the i^{th} specimen.

11.2 Calculate the arithmetic mean of the afterflame time for each flame application, t_1 and t_2, and the afterflame plus afterglow time for the second flame application, t_2 plus t_3, recorded for each set of five specimens to the nearest second.

12. Report

12.1 Report the following information:

12.1.1 *Material Identification*—Include generic description, manufacturer, commercial designation, lot number, and color.

12.1.2 *Conditioning or Aging:*

12.1.2.1 Conditioning time at 23 ± 2°C in hours.

12.1.2.2 Cooling time in desiccator in hours.

12.1.3 The total afterflame time for each set of five specimens, t_f.

12.1.4 Duration of afterflame time after first flame application, t_1.

12.1.5 Duration of afterflame time after second flame application, t_2.

12.1.6 Duration of afterflame and afterglow times after second flame application, $t_2 + t_3$.

12.1.7 Whether or not any of the specimens burn up to the 125-mm mark.

12.1.8 Whether or not any of the specimens drip flaming particles which ignite the cotton swatch.

12.1.9 If the material will be classified, indicate the category designation from the Classification System in Appendix X1.

13. Precision and Bias[4]

13.1 Tables 1 and 2 are based on a round robin completed in 1986 in accordance with Practice E691, involving four materials tested by six laboratories. For each material, all the specimens were cut and distributed by one laboratory. Each laboratory conditioned, at 23°C and 50 % relative humidity, the specimens that it tested. The round robin did not include specimens conditioned at 70°C. Each test result was the average of five individual determinations.

13.1.1 Do not apply the data given in Tables 1 and 2 rigorously to accept or reject materials, as this data is specific to the round robin and not necessarily representative of other

[4] Supporting data is available from ASTM Headquarters. Request RR:D20-1146.

TABLE 1 First Application, Afterflame Time Only

Material	Afterflame Time, s				
	Average	s_r[A]	S_R[B]	r[C]	R[D]
Polyimide (PI)	0.3	0.4	0.7	1.1	2.0
Polyurethane (PUR)	0.8	0.7	0.7	2.0	2.0
Polyethylene terephthalate (PET)	2.3	0.7	0.9	2.0	2.5
Poly(vinyl fluoride) (PVF)	6.0	4.4	4.4	12.5	12.5

[A] s_r = within-laboratory standard deviation of the average.
[B] S_R = between-laboratory standard deviation of the average.
[C] $r = 2.83\ s_r$, and
[D] $R = 2.83\ S_R$.

TABLE 2 Second Application, Afterflame and Afterglow Times

NOTE 1—None of the materials exhibited afterglow; therefore, afterflame plus afterglow is the same as afterflame only, after the second application.

Material	Afterflame Time, s				
	Average	s_r[A]	S_R[B]	r[C]	R[D]
Polyimide (PI)	0.0	. . .	. . .	. . .	. . .
Polyurethane (PUR)	1.3	1.2	1.2	3.4	3.4
Polyethylene terephthalate (PET)	2.1	0.8	1.4	2.3	4.0
Poly(vinyl fluoride) (PVF)	7.2	3.8	6.2	10.8	14.7

[A] s_r = within-laboratory standard deviation of the average.
[B] S_R = between-laboratory standard deviation of the average.
[C] $r = 2.83\ s_r$, and
[D] $R = 2.83\ S_R$.

lots, conditions, materials, or laboratories. It is important that users of this test method conduct experiments, based on statistically appropriate procedures specific to their material and the laboratories involved, to determine repeatability or reproducibility limits for their material.

13.1.2 The explanations shown in 13.2 – 13.2.3 regarding r and R are intended only to present a meaningful way of considering the approximate precision of these test methods.

13.2 *Concept of r and R*—If s_r and s_R have been calculated from a large enough body of data, and for test results that were averages from testing five specimens.

13.2.1 *Repeatability, r*—In comparing two test results for the same material, obtained by the same operator using the same equipment on the same day, the two test results shall be judged not equivalent if they differ by more than the r value for that material.

13.2.2 *Reproducibility, R*—In comparing two test results for the same material, obtained by different operators using different equipment on different days, the two test results shall be judged not equivalent if they differ by more than the R value for that material.

13.2.3 Any judgment in accordance with 13.2.1 and 13.2.2 would have an approximate 95 % probability of being correct.

13.3 *Bias*—There are no recognized standards on which to base an estimate of bias for this test method.

14. Keywords

14.1 flammability; plastics, nonrigid; plastics, solid; vertical position

APPENDIX

(Nonmandatory Information)

X1. CLASSIFICATION SYSTEM FOR DETERMINING THE COMPARATIVE BURNING CHARACTERISTICS OF NONRIGID SOLID MATERIALS IN A VERTICAL POSITION

X1.1 This appendix describes a classification system that can be used to characterize the burning behavior of nonrigid materials, supported in a vertical position, in response to a small-flame ignition source. The use of a category designation code is optional and is determined by examining the test results of materials tested by this test method. Each category code represents a preferred range of performance levels that simplifies description in material designations or specifications and is in use by certification bodies to determine compliance with applicable requirements.

X1.2 The behavior of specimens shall be classified in one of the categories shown in Table X1.1 by selecting the appropriate column using test results to answer the conditional questions posed.

X1.3 Recording the category designation in the test report is optional.

X1.4 If only one specimen from a set of five specimens fails to comply with the requirements of 11.1.3 or the total number of seconds of flaming is in the range of 51 to 55 s for VTM-0 or 251 to 255 for VTM-1 or VTM-2, an additional set of five specimens shall be tested. All specimens from this second set shall comply with the appropriate requirements in order for the material in that thickness to be classified VTM-0, VTM-1, or VTM-2.

TABLE X1.1 Material Classifications

Criteria Conditions	VTM-0	VTM-1	VTM-2
Afterflame time for each individual specimen t_1 or t_2.	≤10s	≤30s	≤30s
Total afterflame time for any condition set (t_1 plus t_2 for the five specimens)	≤50s	≤250s	≤250s
Afterflame plus afterglow time for each individual specimen after the second flame application ($t_2 + t_3$)	≤30s	≤60s	≤60s
Afterflame or afterglow of any specimen up to the 125-mm mark	No	No	No
Cotton indicator ignited by flaming particles or drops	No	No	Yes

X1.5 If the material does not comply with this criteria, consider testing the material in accordance with Test Method D635.

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D4804 - 09) that may impact the use of this standard. (December 1, 2014)

(1) Added to 1.1: "consumed up to the holding clamp" to harmonize with UL 94.
(2) Added additional reference standards in Note 1 to indicate equivalency. Also, deleted the word "considered" from Note 1, and delete "Section 9.4" from Note 2.
(3) Added limitation for this test method for the end-application in 1.4. Renumbered subsequent subsections.
(4) Clarified statement in 3.1.
(5) Deleted unnecessary characters in 3.2.1 to 3.2.7.
(6) Clarified the requirements for cotton indicator and also added tolerance for the distance between specimen and cotton in 3.1 (same as 10.2).
(7) Reworded sentence in 4.1 for clarity and added tolerance for the specimen, flame and mandrel.
(8) Clarified the requirements for Methane and Natural gas in 6.4 (same as D5207, clause 6.9.1 and D5048, clause 6.4 respectively).
(9) Expanded the abbreviated letter (s) in 6.5.
(10) Clarified the cotton type in 6.6.
(11) Clarified the requirements for type of drying agent in 6.7.
(12) Reworded 8.1 and 8.3for clarity.
(13) Added new subsection 8.5.1, which made the proposed new note 3A mandatory language.
(14) Added clarity to the use of the desiccator in 9.1.2.
(15) Added 9.1.3 to indicate how long it should take to test the specimens after removal of desiccator in harmony with UL 94.
(16) Removed the lower humidity requirement in 9.2 to harmonize with UL 94 and because the specimens are controlled environments prior to the actual burn test.
(17) Added 10.2.1, which made the proposed new note 5A mandatory language.
(18) Changed word "impingement" to "application" throughout the standard.