Designation: D3801 – 20a

Standard Test Method for Measuring the Comparative Burning Characteristics of Solid Plastics in a Vertical Position[1]

This standard is issued under the fixed designation D3801; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This fire-test-response standard covers a small-scale laboratory procedure for determining comparative burning characteristics of solid-plastic material, using a 20-mm (50W) premixed flame applied to the base of specimens held in a vertical position.

NOTE 1—This test method and the 20 mm (50W) Vertical Burning Test (V-0, V-1, or V-2) of ANSI/UL 94 are equivalent.

NOTE 2—This test method and Test Method B of IEC 60695–11–10 are equivalent. IEC 60695–11–10 has replaced ISO 1210.

NOTE 3—For additional information on materials that burn up to the holding clamp by this test method, see Test Method D635. For test methods of flexible plastics in the form of thin sheets and film, see Test Method D4804. For additional information on comparative burning characteristics and resistance to burn-through, see Test Method D5048.

1.2 This test method was developed for polymeric materials used for parts in devices and appliances. The results are intended to serve as a preliminary indication of their acceptability with respect to flammability for a particular application. The final acceptance of the material is dependent upon its use in complete equipment that conforms with the standards applicable to such equipment.

1.3 The classification system described in the appendix is intended for quality assurance and the preselection of component materials for products.

1.4 It is possible that this test is applicable to nonmetallic materials other than plastics. Such application is outside the scope of this technical committee.

1.5 This test method does not cover plastics when used for building construction, finishing or contents such as wall and floor coverings, furnishings, decorative objects etc. In addition, the fire resistance (in terms of an hourly rating), flame spread, smoke characterization and heat release rate are not evaluated by this test. Other fire tests exist and shall be used to evaluate the flammability of materials in these intended end use product configuration.

1.6 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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

D4804 Test Method for Determining the Flammability Characteristics of Nonrigid Solid Plastics

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

D5048 Test Method for Measuring the Comparative Burning Characteristics and Resistance to Burn-Through of Solid Plastics Using a 125-mm Flame

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

[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 (Section D20.30.03).

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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.

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

E456 Terminology Relating to Quality and Statistics
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
E2935 Practice for Conducting Equivalence Tests for Comparing Testing Processes
2.2 *IEC Standard:*[3]
60695–11–10 Fire Hazard Testing—Part 11-10: Test Flames—50W Horizontal and Vertical Flame Test Methods
2.3 *ISO Standard:*[3]
ISO 1210 Plastics—Determination of the Burning Behaviour of Horizontal and Vertical Specimens in Contact with a Small-Flame Ignition Source (Withdrawn)
ISO 13943 Fire Safety—Vocabulary
2.4 *UL Standard:*[4]
ANSI/UL 94 Test for Flammability of Plastic Materials for Parts in Devices and Appliances

3. Terminology

3.1 *Definitions*—For definitions of terms relating to plastics, the definitions in this test method are in accordance with Terminology D883. For terms relating to fire, the definitions in this test method are in accordance with Terminology E176 and ISO 13943. In case of conflict, the definitions given in Terminology E176 shall prevail. For terms relating to precision and bias and associated issues, the terms used in this test method are in accordance with the definitions in Terminology E456.

3.2 *Definitions of Terms Specific to This Standard:*

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

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

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

3.2.4 *afterglow time, n*—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.

3.2.5 *flame-impingement time, n*—the time in seconds that the flame from the burner is in contact with the specimen.

3.2.6 *flaming material, n*—flaming drips or particles from the specimen that ignite the absorbent 100 % cotton.

4. Summary of Test Method

4.1 The procedure consists of subjecting a set of preconditioned specimens of identical composition and geometry to a standard test flame for two 10-s flame applications. 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 specimen (and whether these drips ignite a cotton indicator) and total flame time for a particular specimen set.

5. Significance and Use

5.1 The tests results represent afterflame and afterglow time in seconds for a material of specified shape, under the conditions of this test method.

5.2 The effect of material thickness, color additives, and possible loss of volatile components is measurable.

5.3 The results, when tabulated, are potentially useful as a reference for comparing the relative performance of materials and as an aid in material selection.

5.4 In this procedure, the specimens are subjected to one or more specific sets of laboratory test conditions. Different test conditions will likely result in 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,* enclosed laboratory hood or chamber, having an inside volume of at least 0.5 m^3. The chamber shall permit observation of tests in progress and shall be , free of induced or forced draft during test, while allowing normal thermal circulation of air past the test specimen during burning. 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 recorded light level shall be less than 20 lx. For safety and convenience, it is desirable that this enclosure be fitted with an extraction device, such as an exhaust fan, to remove products of combustion. The extraction device shall be turned off during the test and turned on immediately after the test to remove the fire effluents. (**Warning—**Combustion products are toxic. A system to contain and remove the products of combustion after a test is required.)

NOTE 4—Laboratory hoods often have induced drafts even with the exhaust fan off. In such cases, a positive-closing damper shall be used.

NOTE 5—A mirror in the chamber, to provide a rear view of the specimen, has been found useful in some enclosures.

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, minimum 98 % pure, with suitable regulator and meter for uniform gas flow. Natural gas having an energy density of 37 ± 1 MJ/m^3 at 25°C has been found to provide similar results. However, technical-grade methane gas shall be used as the referee gas in cases of dispute.

6.5 *Timing Device,* accurate to 0.5 s.

6.6 *Cotton,* absorbent 100 % cotton.

[3] Publications of the International Electrotechnical Commission (IEC) and International Organization for Standardization (ISO) are available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from Underwriters Laboratories (UL), 333 Pfingsten Rd., Northbrook, IL 60062-2096, http://www.ul.com.

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

6.8 *Conditioning Room or Chamber,* capable of being maintained at 23 ± 2°C and a relative humidity of 50 ± 5 %.

6.9 *Conditioning Oven,* a full-draft circulating-air oven capable of being maintained at 70 ± 2°C while providing a minimum of five air changes per hour.

6.10 *Micrometer,* having a resolution of at least 0.01 mm.

6.11 *Measuring Scale,* graduated in millimetres.

6.12 *Flame Clearance Gauge,* (optional) used to determine flame position on specimen during testing. See Appendix X2.

7. Test Specimens

7.1 The standard specimen geometry shall be 13.0 ± 0.5 by 125 ± 5 mm, and shall be provided in the minimum and maximum thickness. Materials thicker than 13 mm shall not be tested by this test method.

7.1.1 The test specimens shall be molded in accordance with the ASTM specifications for the material; or in accordance with the material manufacturer's instructions.

7.2 Surfaces shall be smooth and unbroken. Corner radius shall not exceed 1.3 mm. After any cutting operation, edges shall be fine-sanded to remove burrs, saw marks, and residual filaments.

8. Conditioning

8.1 Condition specimen sets as follows:

8.1.1 Condition one set of five specimens (Set A) for a minimum of 48 hours at a temperature of 23 ± 2°C and a relative humidity of 50 ± 10 %. Once removed from the conditioning room or chamber, specimens shall be tested within one hour.

8.1.2 Condition a second set of five specimens (Set B) in a circulating-air oven for 168 ± 2 h at 70 ± 2°C and then cool in a desiccator for at least 4 h at room temperature prior to testing. Once removed from the desiccator, specimens shall be tested within 30 min.

8.2 All specimens shall be tested in a laboratory atmosphere of 15 to 35°C and 45 to 75 % relative humidity.

8.3 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.

9. Procedure

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

9.2 Clamp a specimen from the upper 6 mm of its length, with the longitudinal axis vertical, so that the lower end of the specimen is 300 ± 10 mm above a horizontal layer of cotton, approximately 50 by 50 mm, thinned to a maximum uncompressed thickness of 6 mm, maximum mass of 0.08 g. See Fig. 1.

9.3 Place the burner remote from the specimen, ignite, and adjust it to produce a blue flame 20 ± 2 mm high. Adjust the needle valve and the air ports of the burner until a 20-mm yellow-tipped blue flame is produced, and then increase the air supply until the yellow tip just disappears. Measure the height of the flame. If the flame height is not 20 ± 2 mm, adjust the burner needle valve to give the proper flame height. The flame shall be confirmed using Practice D5207 at least once per month during active testing or whenever the gas supply is changed.

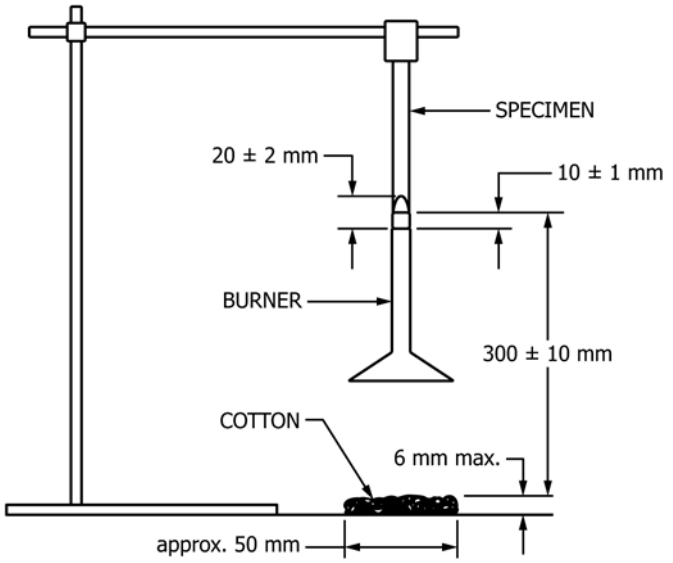

FIG. 1 Vertical Burning Test for V-0, V-1, and V-2 Classification

9.4 Approaching the specimen from the wide side in a horizontal plane (see Fig. 2), place the test flame centrally under the lower end of the test specimen with the burner tube 10 ± 1 mm below the specimen and maintain that distance for a flame-impingement time of 10.0 ± 0.5 s, moving the burner as necessary in response to any changes in the length or position of the specimen. Withdraw the test flame sufficiently so that there is no effect on the burning specimen (see Note 7) and measure the afterflame time, in seconds.

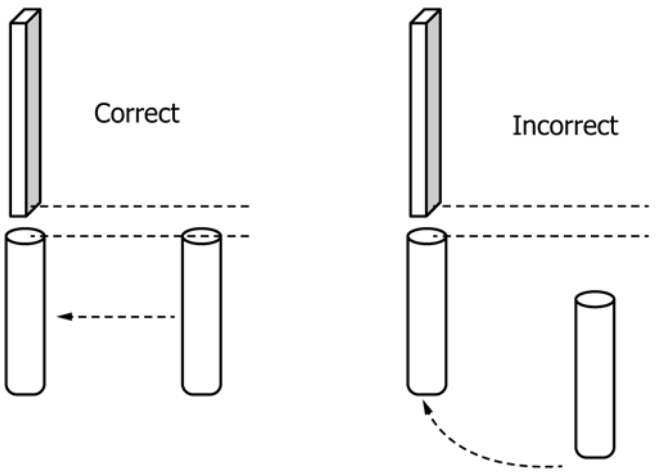

FIG. 2 Approaching the Specimen from the Wide Side in a Horizontal Plane

NOTE 6—A flame clearance gauge, pictured in Fig. X2.1, has been found helpful in determining the burner tube position 10 ± 1 mm below the bottom of the specimen.

9.4.1 When the flaming of the specimen ceases, immediately place the test flame under the major portion of the specimen (see Note 8) maintaining a distance of 10 ± 1 mm for a flame-impingement time of 10.0 ± 0.5 s. After this second flame application, withdraw the test flame (see Note 7) and measure the afterflame and afterglow times, in seconds.

9.4.2 Record the afterflame time after the first flame application as t_1. Record the afterflame and afterglow times after the second flame application as t_2 and t_3, respectively. Note and record whether any particles fall from the specimen and, if so, whether they ignite the cotton.

NOTE 7—Withdrawing the burner a distance of 150 mm from the specimen while measuring t_1, t_2, and t_3 has been found suitable.

NOTE 8—When the flaming of the specimen ceases after the first flame application, the second flame application shall be started immediately. The test shall not be interrupted, for example, to record data, replace cotton, or evacuate the test chamber.

NOTE 9—Measuring and recording the afterflame time t_2 and then continuing the measurement of the sum of the afterflame time t_2 and the afterglow time t_3, (without resetting the timing device) has been found satisfactory in the recording of t_3.

9.5 If the specimen drips molten or flaming material during either flame application, tilt the burner to an angle up to 45° towards the wide side of the specimen (see Fig. 3), and withdraw the burner slightly from one of the sides of the specimens during the flame application 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. Disregard any molten strings of material for purposes of positioning the top of the burner tube. Always apply the flame to the bottom of the major portion of the specimen.

9.6 Repeat the procedure in 9.2 – 9.5 on the remaining specimens for each set.

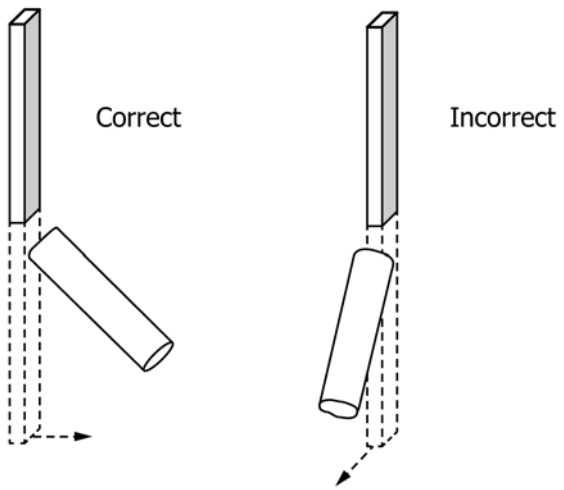

FIG. 3 Tilting the Burner Towards the Wide Side of the Specimen

10. Calculation

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

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

where:

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

10.2 Determine the maximum afterflame time for each flame impingement, t_1 and t_2, and the maximum afterflame plus afterglow time for the second flame impingement, t_2 plus t_3, recorded for each set of five specimens.

11. Report

11.1 The complete report shall include the following:

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

11.1.2 Conditioning or aging.

11.1.2.1 Conditioning time for Set A at 23 ± 2°C, h.

(1) Conditioning time for Set B at 70 ± 2°C, h.

11.1.2.2 Cooling time for Set B in desiccator, h.

11.1.3 Individual test specimen data.

11.1.3.1 Thickness.

11.1.3.2 Afterflame time after first flame impingement.

11.1.3.3 Afterflame time after second flame impingement.

11.1.3.4 Afterflame plus afterglow time after second flame impingement.

11.1.3.5 Whether or not the specimen burned up to the holding clamp.

11.1.3.6 Whether or not the specimen dripped flaming material which ignited the cotton.

(1) If the specimen dripped, whether it ignited the cotton.

11.1.4 The total afterflame time for each set of five specimens.

11.1.5 Maximum of burning times (afterflame and afterglow) for each specimen set.

12. Precision and Bias

12.1 *Precision*—The precision of this test method is based on two interlaboratory studies.

12.1.1 For the polypropylene (I and II), polyphthalamide, and polysulfone materials the interlaboratory study was conducted in 1994. Eighteen laboratories tested four different materials. Every "test result" represents the average of five individual determinations. Each laboratory was asked to submit two replicate test results, from a single operator, for each material. Practice E691 was followed for the design and analysis of data, the details are given in ASTM Research Report No. D20-1069.[5]

12.1.2 For the polyamide material the interlaboratory study was conducted in 1995. Seven laboratories tested one material.

[5] Supporting data are available from ASTM Headquarters. Request RR:D20-1069.

Every "test result" represents the average of five individual determinations. Each laboratory was asked to submit four replicate test results, from a single operator, for each material. Practice E691 was followed for the design and analysis of data, the details are given in ASTM Research Report No. D20-1188.[6]

12.2 **Warning—**The data in Tables 1-3 shall not be rigorously applied to acceptance or rejection of material, as those data are specific to the interlaboratory study and are not necessarily representative of other lots, conditions, materials, or laboratories. Users of this test method shall apply the principles outlined in Practice E691 to generate data specific to their laboratory and materials, or between specific laboratories.

12.3 Equivalence testing on numerical data from two sources shall be conducted in accordance with Practice E2935.

12.4 *Bias*—There are no recognized standards by which to estimate bias of this test method.

13. Keywords

13.1 burning characteristics; flammability; plastics; small-scale burning tests; solid; vertical burning tests

[6] Supporting data are available from ASTM Headquarters. Request RR:D20-1188.

TABLE 1 First Impingement, Afterflame Time

Material	Values, s				
	Average	S_r [A]	S_R [B]	r [C]	R [D]
Polyamide	0.7	0.2	0.4	0.6	1.1
Polypropylene II	2.0	0.6	2.1	1.6	5.8
Polyphthalamide	2.6	0.8	1.5	2.1	4.3
Polypropylene I	2.7	0.9	1.8	2.4	5.0
Polysulfone	5.4	1.6	2.9	4.5	8.1

[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] $R = 2.8\ S_R$.

TABLE 2 Second Impingement, Afterflame Time

Material	Values, s				
	Average	S_r [A]	S_R [B]	r [C]	R [D]
Polyamide	3.0	1.1	3.2	3.0	9.0
Polypropylene I	1.4	0.6	1.2	1.6	3.2
Polyphthalamide	4.4	1.4	3.2	3.9	8.8
Polypropylene II	4.5	1.5	4.2	4.2	11.7
Polysulfone	8.8	2.6	3.1	7.3	8.6

[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] $R = 2.8\ S_R$.

TABLE 3 Second Impingement, Afterflame Plus Afterglow

Material	Values, s				
	Average	S_r [A]	S_R [B]	r [C]	R [D]
Polyamide	3.0	1.1	3.2	3.0	9.0
Polypropylene I	3.1	1.1	2.3	3.1	6.5
Polyphthalamide	4.7	1.3	3.1	3.8	8.7
Polypropylene II	4.7	1.5	4.1	4.2	11.5
Polysulfone	9.2	2.7	3.2	7.7	8.9

[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] $R = 2.8\ S_R$.