Designation: D 3801 – 00

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 D 3801; 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 flame applied to the base of specimens held in a vertical position.

NOTE 1—This test method and Test Method B of IEC 60695-11-10 are equivalent. IEC 60695-11-10 has replaced ISO 1210.

NOTE 2—For additional information on materials that burn up to the holding clamp by this test method, see Test Method D 635. For test methods of flexible plastics in the form of thin sheets and film, see Test Methods D 4804. For additional information on comparative burning characteristics and resistance to burn-through, see Test Method D 5048.

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

1.6 The values stated in SI units are to be regarded as the 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 and health practices and determine the applicability of regulatory limitations prior to use.* See 9.1.1 for a specific hazard statement.

2. Referenced Documents

2.1 *ASTM Standards:*

D 635 Test Method for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position[2]

D 883 Terminology Relating to Plastics[2]

D 4804 Test Methods for Determining the Flammability Characteristics of Nonrigid Solid Plastics[3]

D 5025 Specification for a Laboratory Burner Used for Small-Scale Burning Tests on Plastic Materials[3]

D 5048 Test Method for Measuring the Comparative Burning Characteristics and Resistance to Burn-Through of Solid Plastics Using a 125-mm Flame[3]

D 5207 Practice for Calibration of 20 and 125-mm Test Flames for Small-Scale Burning Tests on Plastic Materials[3]

E 176 Terminology of Fire Standards[4]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[5]

2.2 *IEC Standard:*[6]

60695-11-10 Fire Hazard Testing—Part 11-10: Test Flames—50W Horizontal and Vertical Flame Test Methods

2.3 *ISO Standard:*[6]

ISO 1210 Plastics—Determination of the Burning Behaviour of Horizontal and Vertical Specimens in Contact with a Small-Flame Ignition Source

3. Terminology

3.1 *Definitions*—For terms relating to plastics, the definitions in this test method are in accordance with Terminology

[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] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.03.

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

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] Publications of the International Electrotechnical Commission (IEC) and International Organization for Standardization (ISO) are available from ANSI, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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

D 883. For terms relating to fire, the definitions used in this test method are in accordance with Terminology E 176.

3.2 *Definitions of Terms Specific to This Standard:*

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

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

3.2.3 *afterglow*—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*—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*—the time in seconds that the flame from the burner is in contact with the specimen.

3.2.6 *flaming material*—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 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.

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. If different test conditions are substituted or the end-use conditions are changed, it may not 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*, enclosed laboratory hood or chamber, free of induced or forced draft during test, having an inside volume of at least 0.5 m^3. An enclosed laboratory hood with a heat-resistant glass window and an exhaust fan for removing the products of combustion after the tests is recommended.

NOTE 3—Laboratory hoods may have induced drafts even with the exhaust fan off. A positive-closing damper may be needed.

NOTE 4—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 D 5025.

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 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.

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 ± 1°C.

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

7. Test Specimens

7.1 The standard specimen geometry shall be 13.0 ± 0.5 by 125 ± 5 mm in the thickness appropriate to the objectives of the determination. Materials thicker than 13 mm shall not be tested by this test method.

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 for at least 48 h at a temperature of 23 ± 2°C and a relative humidity of 50± 5 % prior to testing. 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 in a circulating-air oven for 168 h at 70 ± 1°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.

9. Procedure

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

9.1.1 **Warning**—Combustion products contain toxic compounds. A system to contain and remove the products of combustion after a test, such as a laboratory hood with an exhaust fan, is required.

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

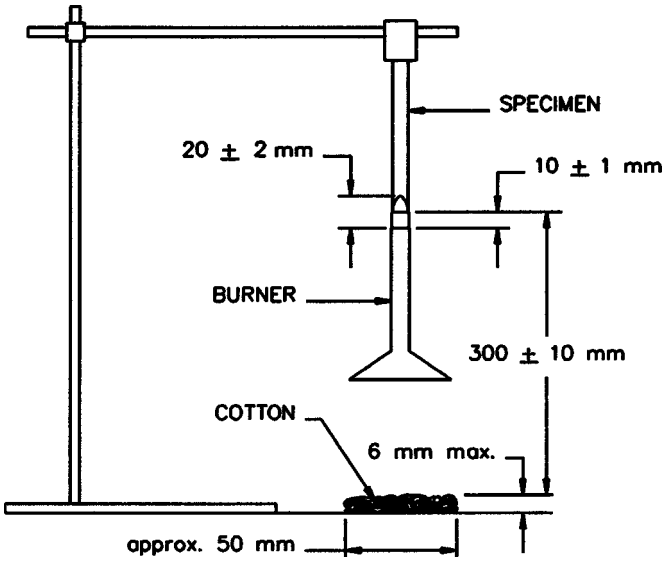

FIG. 1 Vertical Burning Test for V-0, V-1, and V-2 Classification

gas supply 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 gas supply to give the proper flame height.

NOTE 5—See Practice D 5207 for recommended back pressure and flow rate for the gas supply and calibration procedure for the 20-mm flame.

9.4 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 6) and measure the afterflame time, in seconds. When the flaming of the specimen ceases, immediately place the test flame under the specimen again (see Note 7) 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 6) and measure the afterflame and afterglow times, in seconds. 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 6—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 7—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 or replace cotton.

NOTE 8—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°, 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.

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

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 at 23 ± 2°C, h.

11.1.2.2 Cooling time 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.

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

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

12. Precision and Bias

12.1 *Precision*—Table 1, Table 2, and Table 3 are based on a round robin conducted in accordance with Practice E 691. For each material, all the samples were prepared at one source, but the individual specimens were conducted in accordance with 8.1.1 by the laboratories that tested them. Each test result was the average of five individual determinations.

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 for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories:

$$S_r = [[(S_1)^2 + (S_2)^2 \ldots + (S_n)^2]/n]^{\frac{1}{2}}$$

[B] S_R = between-laboratories reproducibility, expressed as standard deviation:

$$S_R = [S_r^2 + S_L^2]^{\frac{1}{2}}$$

where S_L = standard deviation of laboratory means.

[C] r = within-laboratory critical interval between two test results = $2.8 \times S_r$.

[D] R = between-laboratories critical interval between two test results = $2.8 \times S_R$.

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 for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the paticipating laboratories:

$$S_r = [[(S_1)^2 + (S_2)^2 \ldots + (S_n)^2]/n]^{\frac{1}{2}}$$

[B] S_R = between-laboratories reproducibility, expressed as standard deviation:

$$S_R = [S_r^2 + S_L^2]^{\frac{1}{2}}$$

where S_L = standard deviation of laboratory means.

[C] r = within-laboratory critical interval between two test results = $2.8 \times S_r$.

[D] R = between-laboratories critical interval between two test results = $2.8 \times S_R$.

12.1.1 The polypropylene (I and II), polyphthalamide, and polysulfone materials were tested by 18 laboratories. Each laboratory obtained two test results for each material. The round robin was conducted in 1994.[7]

12.1.2 The polyamide material was tested by seven laboratories. Each laboratory obtained four test results. The round robin was conducted in 1995.[8]

NOTE 9—**Caution:** The following explanations of r and R (12.2-12.2.3) are only intended to present a meaningful way of considering the approximate precision of this test method. The data in Table 1, Table 2, and Table 3 should not be applied to the acceptance or rejection of materials, as these data apply only to the materials tested in the round robin and are unlikely to be rigorously representative of other lots, formulations, conditions, materials, or laboratories. Users of this test method should apply the principles outlined in Practice E 691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles of 12.2-12.2.3 would then be valid for such data.

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 for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the paticipating laboratories:

$$S_r = [[(S_1)^2 + (S_2)^2 \ldots + (S_n)^2]/n]^{\frac{1}{2}}$$

[B] S_R = between-laboratories reproducibility, expressed as standard deviation:

$$S_R = [S_r^2 + S_L^2]^{\frac{1}{2}}$$

where S_L = standard deviation of laboratory means.

[C] r = within-laboratory critical interval between two test results = $2.8 \times S_r$.

[D] R = between-laboratories critical interval between two test results = $2.8 \times S_R$.

12.2 *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, then:

12.2.1 *Repeatability—r* is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory. The two test results shall be judged not equivalent if they differ by more than the r value for that material.

12.2.2 *Reproducibility—R* is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories, not necessarily 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.

12.2.3 Any judgment in accordance with 12.2.1 and 12.2.2 would have an approximate 95 % (0.95) probability of being correct.

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

13. Keywords

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

[7] Supporting data are available from ASTM Headquarters. Request RR: D20-K069.

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

APPENDIX

(Nonmandatory Information)

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

X1.1 This appendix describes a classification system that can be used to characterize the burning behavior of rigid 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 may assist certification bodies to determine compliance with applicable requirements.

X1.2 The behavior of specimens may 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.

TABLE X1.1 Materials Classifications[A]

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

[A] If only one specimen from a set of five specimens does not comply with the requirements, another set of five specimens shall be tested. In the case of the total number of seconds of flaming, an additional set of five specimens shall be tested if the totals are in the range from 51 to 55 s for V-0 and from 251 to 255 s for V-1 and V-2. All specimens from this second set shall comply with the appropriate requirements in order for the material in that thickness to be classified V-0, V-1, or V-2.

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

SUMMARY OF CHANGES

This section identifies the location of selected changes to this test method. For the convenience of the user, Committee D20 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 3801 – 00:

(*1*) Updated ISO/IEC equivalency statement.
(*2*) Deleted reference to ASTM D 3713.
(*3*) Deleted section on sampling.
(*4*) Added tolerances on gas supply in 6.4.
(*5*) Added micrometer to Apparatus, new 6.10.
(*6*) Added requirement to 9.1.1 to test within one hour after removal of specimens from conditioning room or chamber.
(*7*) Added Note 8.