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.

Designation: D2863 – 17

Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)[1]

This standard is issued under the fixed designation D2863; 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.

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

1. Scope*

1.1 This fire-test-response standard describes a procedure for measuring the minimum concentration of oxygen, expressed as percent volume, that will just support flaming combustion in a flowing mixture of oxygen and nitrogen.

1.2 This test method provides three testing procedures. Procedure A involves top surface ignition, Procedure B involves propagating ignition, and Procedure C is a short procedure involving the comparison with a specified minimum value of the oxygen index.

1.3 Test specimens used for this test method are prepared into one of six types of specimens (see Table 1).

1.4 This test method provides for testing materials that are structurally self-supporting in the form of vertical bars or sheet up to 10.5-mm thick. Such materials are solid, laminated or cellular materials characterized by an apparent density greater than 15 kg/m^3.

1.5 This test method also provides for testing flexible sheet or film materials, while supported vertically.

1.6 This test method is also suitable, in some cases, for cellular materials having an apparent density of less than 15 kg/m^3.

NOTE 1—Although this test method has been found applicable for testing some other materials, the precision of the test method has not been determined for these materials, or for specimen geometries and test conditions outside those recommended herein.

1.7 This test method 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.

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

1.9 *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.* Specific hazards statement are given in Section 10.

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

NOTE 2—This test method and ISO 4589-2 are technically equivalent when using the gas measurement and control device described in 6.3.1, with direct oxygen concentration measurement.

1.11 *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]

D618 Practice for Conditioning Plastics for Testing

D1071 Test Methods for Volumetric Measurement of Gaseous Fuel Samples

D1622 Test Method for Apparent Density of Rigid Cellular Plastics

D4802 Specification for Poly(Methyl Methacrylate) Acrylic Plastic Sheet

E176 Terminology of Fire Standards

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

2.2 *ISO Standards:*[3]

ISO 4589-2 Plastics—Determination of Flammability by Oxygen Index—Part 2, Ambient Temperatures

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[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**

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TABLE 1 Test Specimen Dimensions

Test Specimen Type[A]	Dimensions			Material Form
	Length, mm	Width, mm	Thickness, mm	
I	80 to 150	10 ± 0.5	4 ± 0.25	for molding materials
II	80 to 150	10 ± 0.5	10 ± 0.5	for cellular materials
III[B]	80 to 150	10 ± 0.5	≤ 10.5	for sheet materials
IV	70 to 150	6.5 ± 0.5	3 ± 0.25	alternative size for self-supporting molding or sheet materials
V[B]	140 ± 5	52 ± 0.5	≤10.5	for flexible film or sheet
VI[B, C]	140 to 200	20	0.02 to 0.10	for thin film; limited to film that can be rolled by the wire specified in 6.7

[A] Test specimens of Types I, II, III, and IV are suitable for materials that are self-supporting at these dimensions. Test specimens of Form V and VI are suitable for materials that require support during testing. Test specimens of Form VI are suitable for film materials that can be rolled into a self-supporting specimen by the procedure in 7.4.

[B] Compare results obtained using Type III, V, and VI test specimens only to those obtained using specimens of the same form and thickness. It is assumed that the amount of variation in thickness for such materials will be controlled by other standards.

[C] The test specimen of Type VI is suitable for thin film that is self-supporting when it is rolled (see 7.4). Dimensions in the table are of the specimen size from which the rolled form is made. If the film is very thin, it is possible that proper results will only be obtained if two or more layers are combined in the preparation of the roll to obtain proper results.

TABLE 2 Criteria for Oxygen Index Measurements[A]

Test Specimen Type (See Table 1)	Ignition Procedure	Alternative Criteria	
		Period of Burning After Ignition(s)	Extent of Burning[B]
I, II, III, IV, and VI	A (top surface ignition)	180	50 mm below the top of the specimen
I, II, III, IV, and VI	B (propagating ignition)	180	50 mm below the upper reference mark
V	propagating ignition	180	80 mm below the upper reference mark (on the frame)

[A] These criteria do not necessarily produce equivalent oxygen index results for specimens of differing shape or tested using different ignition conditions or procedures.

[B] The extent of burning is exceeded when any part of the visibly burning portion of a specimen, including burning drips descending the vertical faces, passes the level indicated in the column.

ISO 7823-1 Poly(Methylmethacrylate) Sheets—Types, Dimensions and Characteristics—Part 1—Cast Sheets
ISO 13943 Fire Safety—Vocabulary

3. Terminology

3.1 *Definitions*

3.1.1 For definitions of terms used in this test method refer to the terminology contained in Terminology E176 and ISO 13943. In case of conflict, the definitions given in Terminology E176 shall prevail.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *ignition*—the initiation of combustion.

3.2.2 *oxygen index (OI)*—the minimum concentration of oxygen determined by the method in 12.1, expressed as volume percent, in a mixture of oxygen and nitrogen that will just support flaming combustion of a material initially at 23 ± 2°C under the conditions of this test method.

3.3 *Symbols Specific To This Test Method:*

3.3.1 C_o—oxygen concentration in percent volume.

3.3.2 C_F—final value of oxygen concentration in percent volume.

3.3.3 C_i—each of the oxygen concentration percentages used during measurement of the last six responses in the N_T series.

3.3.4 *O*—neither the period or extent of burning exceeds the relevant limit specified in Table 2.

3.3.5 *X*—the period or extent of burning exceeds the relevant limit specified in Table 2.

3.3.6 N_L—series of "X" or "O" results.

3.3.7 N_T—series of "X" or "O" results plus five ($N_T = N_L + 5$).

TABLE 3 Determination of *k*

1	2	3	4	5	6
Responses for the Last Five Measurements	Values of *k* for which the first N_L determinations are:				Responses for the Last Five Measurements[A]
	(a) O	OO	OOO	OOOO	
XOOOO	−0.55	−0.55	−0.55	−0.55	OXXXX
XOOOX	−1.25	−1.25	−1.25	−1.25	OXXXO
XOOXO	0.37	0.38	0.38	0.38	OXXOX
XOOXX	−0.17	−0.14	−0.14	−0.14	OXXOO
XOXOO	0.02	0.04	0.04	0.04	OXOXX
XOXOX	−0.50	−0.46	−0.45	−0.45	OXOXO
XOXXO	1.17	1.24	1.25	1.25	OXOOX
XOXXX	0.61	0.73	0.76	0.76	OXOOO
XXOOO	−0.30	−0.27	−0.26	−0.26	OOXXX
XXOOX	−0.83	−0.76	−0.75	−0.75	OOXXO
XXOXO	0.83	0.94	0.95	0.95	OOXOX
XXOXX	0.30	0.46	0.50	0.50	OOXOO
XXXOO	0.50	0.65	0.68	0.68	OOOXX
XXXOX	−0.04	0.19	0.24	0.25	OOOXO
XXXXO	1.60	1.92	2.00	2.01	OOOOX
XXXXX	0.89	1.33	1.47	1.50	OOOOO

[A] Values of *k* for which the first N_L determinations are (b) X, XX, XXX, and XXXX are as given in Table 3 opposite he appropriate response in Column 6, but with the sign of *k* reversed, that is: $OI = C_F - kd$ (see 12.1).

3.3.8 σ*—standard deviation of the oxygen concentration.

3.3.9 *d*—interval between oxygen concentration levels in percent volume.

3.3.10 *k*—a factor to be determined from Table 3.

3.3.11 *n*—number of measurements of oxygen concentration.

4. Summary of Test Method

4.1 A small test specimen is supported vertically in a mixture of oxygen and nitrogen flowing upwards through a transparent chimney. The upper end of the specimen is ignited and the subsequent burning behavior of the specimen is observed to compare the period for which burning continues, or the length of specimen burnt, with specified limits for each burning. By testing a series of specimens in different oxygen concentrations, the minimum oxygen concentration is determined.

4.2 Three procedures are included in this test method. In Procedure A, a complete assessment of the oxygen index is conducted using top surface ignition. In Procedure B, a complete assessment of the oxygen index is conducted using propagating ignition. Procedure C provides a comparison with a specified minimum value of oxygen index and can be conducted using top surface ignition or propagating ignition.

5. Significance and Use

5.1 This test method provides for the measuring of the minimum concentration of oxygen in a flowing mixture of oxygen and nitrogen that will just support flaming combustion of plastics. Correlation with burning characteristics under actual use conditions is not implied.

5.2 In this test method, 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 is not always possible by or from this test to predict changes in the fire-test-response characteristics measured. Therefore, the results are valid only for the fire-test-exposure conditions described in this test method.

6. Apparatus

6.1 *Test Chimney.* The test chimney consists of a heat-resistant glass tube of 75 to 100-mm inside diameter and 450 to 500-mm height. The opening at the top of the chimney shall be restricted to provide an outlet of 40 ± 2-mm diameter, either by providing an overhead cap or by designing the glass chimney appropriately. The bottom of the chimney, or the base to which the tube is attached, shall contain noncombustible material to evenly mix and distribute the gas mixture entering at this base. Glass beads 3 to 5 mm in diameter in a bed 80 to 100-mm deep have been found suitable. The chimney shall be mounted securely on the base to prevent air leaks. One example of a design is shown in Fig. 1.

NOTE 3—It is helpful to place a wire screen above the noncombustible material to catch falling fragments and to aid in keeping the base of the column clean.

6.2 *Specimen Holders*

6.2.1 *Specimen Holder for Self-Supporting Specimens*—Any small holding device that will support the specimen at its base and hold it vertically in the center of the chimney is an acceptable specimen holder. A typical arrangement (see Fig. 1) consists of a laboratory thermometer clamp inserted into the end of a glass tube held in place by glass beads or otherwise firmly supported.

6.2.2 *Specimen Holder for Specimens of Flexible Sheet or Film Materials that Require Support*—A specimen holder for flexible film or sheet materials that require support shall be able to support the specimen by both vertical edges in a frame equivalent to that illustrated by Fig. 2, with reference marks at 20 and 100 mm below the top of the frame. The profile of the holder and its support shall be smooth to minimize induction of turbulence in the rising flow of gas.

6.2.3 *Thin Film Rolling Tool*—In order to prepare self-supporting specimens from thin films (see 7.4), use a 2 ± 0.1-mm stainless steel rod with a 0.3 ± 0.05-mm slit at one end, equivalent to that illustrated in Fig. 3. The actual specimen holder shall be the one in 6.2.1.

6.3 *Gas Measurement and Control Devices.* Gas measurement and control devices shall be suitable for measuring the concentration of oxygen in the gas mixture entering the chimney with an accuracy of ±0.5 %, by volume, of the gas mixture and for adjusting the concentration of oxygen in the mixture with a precision of ±0.1 %, by volume, of the gas mixture, when the gas velocity through the chimney is 40 ± 2 mm/s at 23 ± 2°C.

6.3.1 The system for gas measurement and control involves needle valves on individual and mixed gas supply lines, a paramagnetic oxygen analyzer that continuously samples the mixed gas, and a flow meter to indicate when the gas flow through the chimney is within the required limits. See Annex A4 for an alternate system for gas measurement.

6.3.2 The system used for gas measurement requires calibration after assembly to ensure that the compounded errors of the component parts do not exceed the requirements of 6.3.

6.3.3 Means shall be provided for checking or ensuring that the temperature of the gas mixture entering the chimney is 23 ± 2°C. If this involves an internal probe, its position and profile shall be designed to minimize induction of turbulence within the chimney.

6.4 *Flame Igniter.* The flame igniter shall comprise a tube, with an inside diameter of 2 ± 1 mm, that can be inserted into the chimney to apply the test flame.

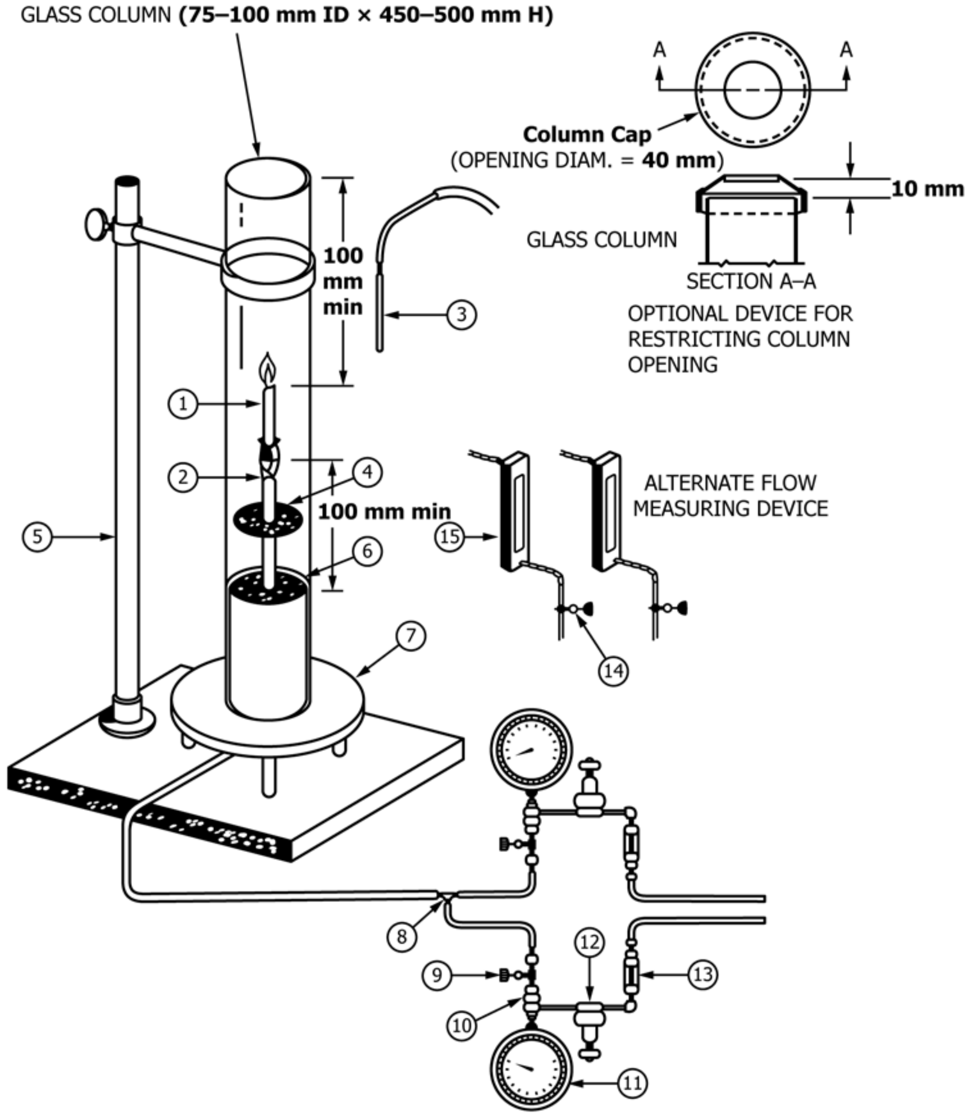
6.4.1 The fuel supply shall be adjusted so that the flame projects 16 ± 4 mm vertically downwards from the outlet when the tube is vertical within the chimney and the flame is burning within the chimney atmosphere.

6.4.2 The flame fuel shall be methane or natural gas of at least 97 % purity, without premixed air.

6.4.3 Alternatively, the flame fuel shall be propane, of at least 98 % purity, without premixed air.

6.5 *Timing Device.* A timing device shall be provided, which is capable of measuring periods up to 5 min with an accuracy of ±0.5 s.

6.6 *Fume Extraction System.* A fume extraction system shall be provided with sufficient ventilation or exhaust to remove



1. Burning Specimen
2. Clamp with Rod Support
3. Igniter
4. Wire Screen
5. Ring Stand
6. Glass Beads in a Bed
7. Brass Base
8. Tee
9. Cut-Off Valve
10. Orifice in Holder
11. Pressure Gauge
12. Precision Pressure Regulator
13. Filter
14. Needle Valve
15. Rotameter

FIG. 1 Typical Equipment Layout

fumes or soot expelled from the chimney without disrupting the gas-flow rate or temperatures in the chimney.

NOTE 4—If soot-generating materials are being tested, it is likely that the glass chimney, gas inlets, and inlet screen will require cleaning between tests to maintain good visibility and to function properly.

6.7 *Gas Supplies.* The gas supplied to the test apparatus shall consist of pressurized sources of oxygen or nitrogen, or both, not less than 98 % pure or clean dry air, or both, (containing 20.9 % oxygen), as appropriate.

6.7.1 The gas mixture entering the chimney shall have a moisture content of <0.1 %, unless the results have been shown to be insensitive to higher moisture levels in the gas mixture. The gas supply system shall incorporate a drying device, or provision for monitoring or sampling the gas supply for moisture content, unless the moisture content of the gas supplies is known to be acceptable.

NOTE 5—It must be noted that bottled oxygen or nitrogen will not always contain <0.1 % of water; moisture contents of 0.003 to 0.01 % are typical for commercial supplies as filled bottles >98 % pure, but as such bottled gases are depressured to below about 1 MPa, the moisture content of the gas drawn off has been found to rise above 0.1 %.

7. Test Specimens

7.1 *General:*

7.1.1 The specimens shall be die-punched, cut by hand using a razor blade or other sharp tool, or cut by an automatic machine. Alternatively, specimens shall be prepared directly by injection molding.

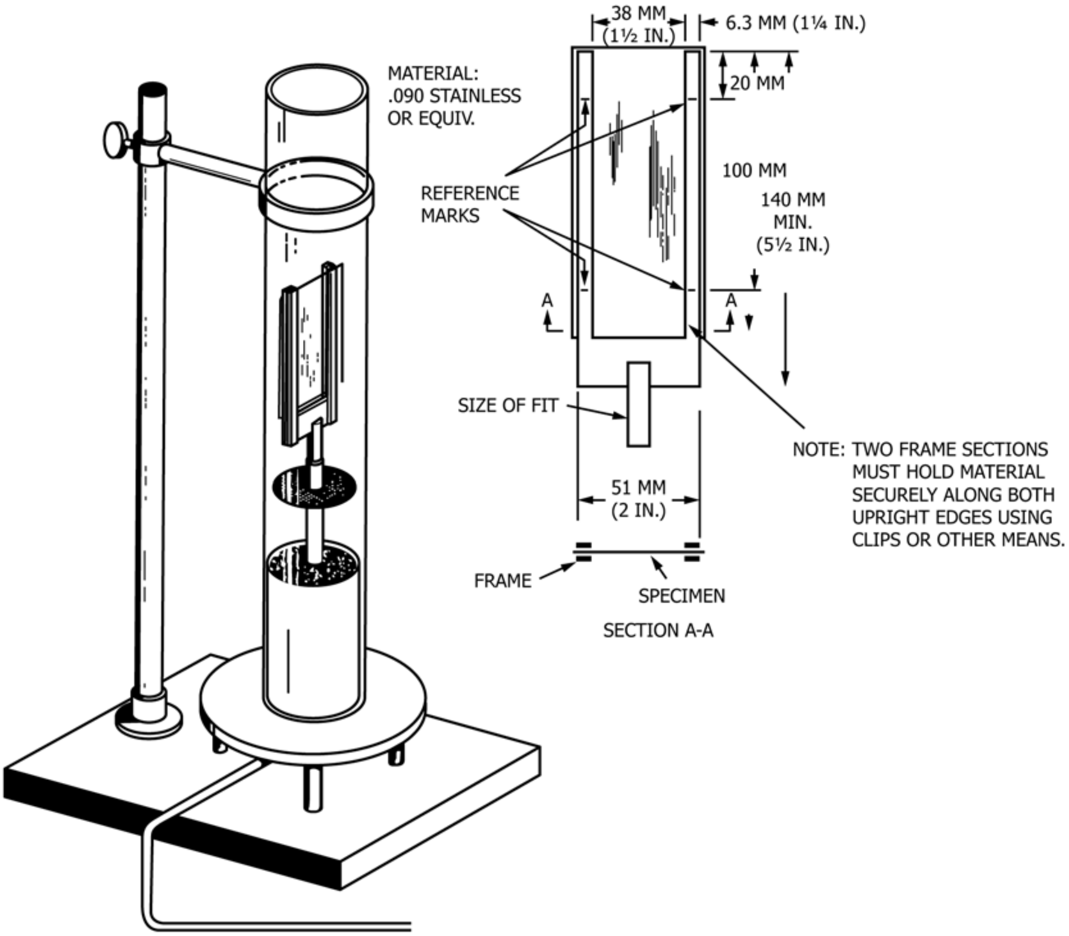


FIG. 2 Frame Design

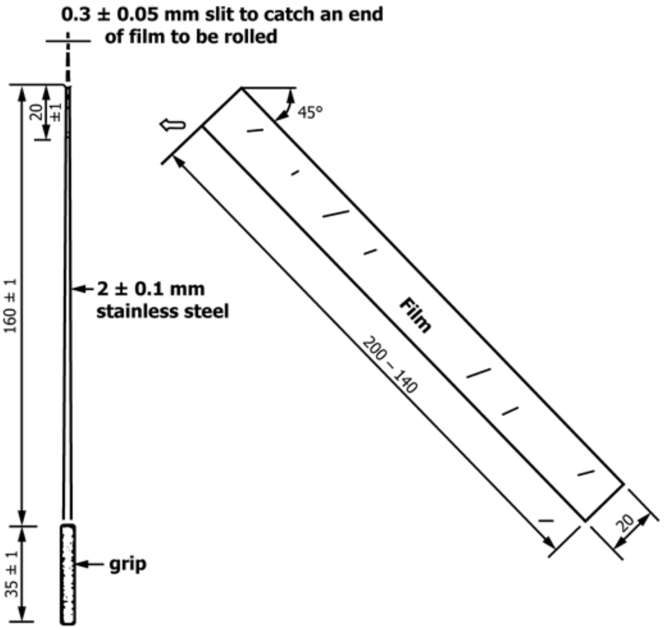


FIG. 3 Rod with a Slit

7.1.2 Ensure that the surfaces of the specimens are clean and free from flaws that could affect burning behavior, for example, peripheral molding flash or burrs from machining. The edges of the specimens shall be smooth and free from fuzz or burrs of material left from machining or molding.

7.1.3 Record the position and orientation of the test specimens with respect to any asymmetry in the sample material (see Note 6).

NOTE 6—Oxygen index results are likely to be significantly affected by differences in burning behavior, due to material inhomogeneity (for example, different levels of shrinkage when heated for specimens cut in different directions from asymmetrically-oriented thermoplastics film).

7.1.4 The test specimens shall conform to the dimensions and geometry listed in Table 1. If non-standard size specimens are used, a difference in oxygen index is likely to result.

7.1.5 It is likely that, for materials where the oxygen index is known to within ±2 % by volume, 15 test specimens will be sufficient. However, for materials of unknown oxygen index, or which exhibit erratic burning characteristics, between 15 and 30 test specimens are likely to be required.

7.2 *Self-Supporting Specimens (Specimen Types I, II, III, and IV)*

7.2.1 The specimens shall be prepared in accordance with 7.1.

7.3 *Specimens of Flexible Sheet or Film Materials that Require Support (Specimen Type IV)*

7.3.1 The specimens shall be prepared in accordance with 7.1 and they shall be supported by both vertical edges in a frame equivalent to that illustrated by Fig. 2 (see 6.2.2).

7.4 *Self-Supporting Specimens Rolled from Thin Films (Specimen Type VI)*

7.4.1 For preparation of Type VI specimens, use the rolling tool described in 6.2.3.

7.4.2 Specimen films shall be prepared in accordance with 7.1.

7.4.3 Insert one corner of the film into the slit of the thin film rolling tool and then wind the film around the rod in a spiral of 45°, as shown in Fig. 3. Ensure that the 45° angle is maintained during the winding process so that the film reaches exactly to the end of the tool, to produce a test piece of the correct length. After the winding is finished, tape the last end of the roll while the material is still on the stainless steel rod to prevent loosening. Then pull the rod out of the rolled film.

7.4.4 Cut off the rolled film at a distance of 20 mm from the top end. See Fig. 4.

7.5 *Specimen Marking*

7.5.1 For monitoring the distance over which burning occurs, mark the specimen with transverse lines at one or more levels which are dependent upon the specimen form and the ignition procedure to be used. Structurally self-supporting specimens are preferably marked on at least two adjacent faces. If wet inks are used, ensure that the marks are dry before the specimen is ignited.

7.5.2 If test specimens of Type I, II, III, IV, or VI are to be tested in accordance with Procedure A, they shall be marked 50 mm from the end to be ignited. If specimens of Type I, II, III, IV, and VI are to be tested in accordance with Procedure C, they shall be marked at 10 mm and at 60 mm from the end to be ignited.

7.5.3 The reference marks for testing specimens of Type V are carried by the supporting frame (see Fig. 2), but it is acceptable to mark thermally stable materials at 20 mm and at 100 mm from the end to be ignited, for convenience.

7.6 For cellular materials, the density shall be determined in accordance with Test Method D1622.

NOTE 7—It is possible that the oxygen index samples of cellular materials that contain volatile flammable blowing agents that diffuse from the sample will change with time.

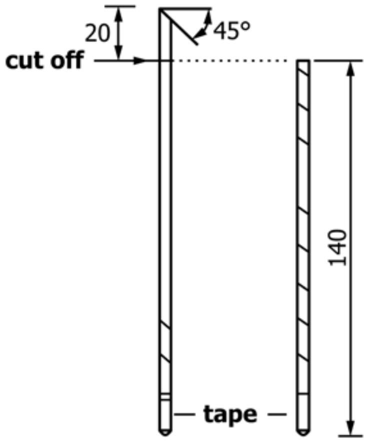


FIG. 4 Rolled Film

8. Conditioning

8.1 Unless otherwise specified, each test specimen shall be conditioned for at least 40 h at 23 ± 2°C and 50 ± 5 % relative humidity (RH) immediately prior to use in accordance with Practice D618.

8.2 Maintain the ambient conditions for the test apparatus at 23 ± 5°C. Keep the test specimens in an enclosure at 23 ± 2°C and 50 ± 5 % RH and take the test specimens out of the enclosure just before testing (so that testing is conducted within 30 minutes of the test specimen removal from the conditioning environment).

9. Calibration of Apparatus

9.1 Calibrate the system for direct oxygen gas concentration measurement with a paramagnetic oxygen analyzer, used for the measurements in 6.3.1, by the following: *(a)* turning the nitrogen flow on and closing the oxygen flow and confirming that the oxygen concentration on the display reads 0.0 %, and *(b)* turning the oxygen flow on and closing the nitrogen flow and confirming that the oxygen concentration on the display reads the same value as the concentration of oxygen in the supply gas (see 6.7).

9.2 Calibrate the flow-measuring system used for the indirect measurements of oxygen concentration and flow rate with the instrumentation in 6.3.2 using a water-sealed rotating drum meter (wet test meter) in accordance with Test Method D1071 or by equivalent calibration devices. The maximum interval between recalibration shall be six months.

9.3 A cast PMMA specimen shall be used as a verification material at least once a month. See Annex A1 for calibration method.

10. Hazards

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

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

11. Test Procedure

NOTE 8—Some materials exhibit a non-flaming type of combustion (for example, glowing combustion) instead of, or at a lower oxygen concentration than that required for, flaming combustion. When testing such materials, it is necessary to identify the type of combustion for which the oxygen index is required or measured.

11.1 *Procedure A*

11.1.1 Select an initial concentration of oxygen to be used. Whenever possible, base the initial concentration on experience of results for similar materials. Alternatively, try to ignite a test specimen in air, and note the burning behavior. If the specimen burns rapidly, select an initial concentration of about 18 % oxygen; if the test specimen burns gently or unsteadily, select an initial oxygen concentration of about 21 %; if the specimen does not continue to burn in air, select an initial concentration of at least 25 %, depending upon the difficulty of ignition or the period of burning before extinguishing in air.

11.1.2 Record the oxygen concentration used as the volume percent measured by an oxygen paramagnetic analyzer (if present) or as the volume percent calculated in accordance with the equations given in Annex A2 (if the system described in 6.3.2 is used).

11.1.3 Ensure that the test chimney is vertical (see Fig. 1). Verify that the temperature at the lower end of the chimney is at least 23 ± 2°C.

11.1.4 Mount a specimen vertically in the center of the chimney so that the top of the specimen is at least 100 mm below the open top of the chimney and the lowest exposed part of the specimen is at least 100 mm above the top of the gas distribution device at the base of the chimney (see Fig. 1 or Fig. 2, as appropriate, for guidance).

11.1.5 Set the gas mixing and flow controls so that an oxygen/nitrogen mixture at 23 ± 2°C, containing the desired concentration of oxygen, is flowing through the chimney at a rate 40 ± 2 mm/s. Let the gas flow purge the chimney for at least 30 s prior to ignition of each specimen, and maintain the flow without change during ignition and combustion of each specimen.

11.1.6 For specimen Types I, II, III, IV, and VI, use top surface ignition, as described in 11.1.7.

NOTE 9—For tests on materials that exhibit steady burning and spread of combustion in oxygen concentrations at, or close to, their oxygen index value, or for structurally self-supporting specimens of ≤3 mm thickness, Procedure B (with specimens marked in accordance with 7.5.2) will often give more consistent results than Procedure A. In such cases, use Procedure B for specimens of Type I, II, III, IV, or VI.

11.1.7 *Top Surface Ignition:*

11.1.7.1 For top surface ignition, the igniter is used to initiate burning only on the top surface of the upper end of the specimen.

11.1.7.2 Apply the lowest visible part of the flame to the top of the specimen using a sweeping motion, if necessary, to cover the whole surface, but taking care not to maintain the flame against the vertical faces or edges of the specimen. Continue to apply the flame for up to 30 s, removing it every 5 s, just briefly, to observe whether or not the entire top surface of the specimen is burning on its own.

11.1.7.3 Consider the specimen to be ignited once the specimen is burning on its own.

11.1.7.4 Remove the igniter once the specimen is ignited.

11.1.7.5 Commence measurement of the period and distance of burning once the specimen is ignited.

11.1.8 *Assessing the Burning Behavior of Individual Test Specimens:*

11.1.8.1 Commence measurement of the period of burning as soon as the specimen has been ignited in accordance with 11.1.7.3, 11.2.3.3 (*1*), or 11.2.3.4 (*1*), as applicable, and observe its burning behavior. If burning ceases, but spontaneous re-ignition occurs within 1 s, continue the observation and measurements. A typical test results sheet is shown in Appendix X1.

11.1.8.2 If neither the period or extent of burning exceeds the relevant limit specified in Table 2 for the applicable specimen, note the duration and extent of burning. This is recorded as an "O" response. (See Appendix X1.)

11.1.8.3 Alternatively, if either the period or the extent of burning exceed the relevant limits specified in Table 2, note the burning behavior accordingly, and extinguish the flame. This is recorded as an "X" response. (See Appendix X1.)

11.1.8.4 Note also the burning characteristics of the material, for example, dripping, charring, erratic burning, glowing combustion, or after-glow.

11.1.8.5 Extinguish the specimen, if necessary, by allowing only nitrogen to flow through the chimney.

11.1.8.6 Remove the specimen and clean, as necessary, any surfaces within the chimney or on the igniter that have become contaminated, for example with soot.

11.1.8.7 Allow the chimney to regain a temperature of 23 ± 2°C, or replace it with another so conditioned.

11.1.8.8 Install the next specimen.

NOTE 10—For screening purposes, it is acceptable to invert sufficiently long specimens or trim them to remove the burnt end, and re-use them. Results from such specimens will save material when establishing an approximate value for the minimum oxygen concentration required for combustion, but cannot be included among those used for estimation of the oxygen index, unless the specimen is reconditioned at the temperature and humidity appropriate for the material involved.

11.1.9 *Selecting Successive Oxygen Concentrations:*

11.1.9.1 Select the oxygen concentration to be used for testing the next test specimen as follows:

(*1*) Decrease the oxygen concentration if the burning behavior of the preceding specimen gave an "X" response.

(*2*) Increase the oxygen concentration if the preceding specimen gave an "O" response.

(*3*) Choose the size of the change in oxygen concentration in accordance with 11.1.10 and 11.1.11, as appropriate. The procedure described in 11.1.10 and 11.1.11 is based upon the "up-and-down method for small samples," using the specific case where $N_T - N_L = 5$ (see 11.1.11.2 and 11.1.11.4), with an arbitrary step size for certain changes to be made in the oxygen concentration used.

11.1.10 *Determining the Preliminary Oxygen Concentration:*

11.1.10.1 Repeat the procedures specified in 11.1.1 to 11.1.8 inclusive, using oxygen concentration changes of any convenient step size, until two oxygen concentrations, in percent volume, have been found that differ by ≤1.0 % and of which one gave an "O" response and the other an "X" response. From this pair of oxygen concentrations, note that which gave the "O" response as the preliminary oxygen concentration level and then proceed in accordance with 11.1.11.

NOTE 11—The two results, at oxygen concentrations ≤1.0 % apart, which give opposite responses, do not have to be from successive specimens.

NOTE 12—At times, the concentration that gave the "O" response will not be lower than that which gave the "X" response. Such apparent inconsistencies, that are likely to be caused by the variability of the test, the equipment, or the material, are not uncommon.

11.1.11 *Oxygen Concentration Changes:*

11.1.11.1 Using, again, the preliminary oxygen concentration from 11.1.10, test one specimen by repeating 11.1.1 to 11.1.9, inclusive. Record both the oxygen concentration (C_o) used and the response, "X" or "O", as the first of the *NL* and of the N_T series of results.

11.1.11.2 Change the oxygen concentration, in accordance with 11.1.9 using concentration changes (*d*) of 0.2 % (see Note 13) of the total gas mixture to test further specimens in accordance with 11.1.1 to 11.1.10 inclusive, noting the values of C_o and corresponding responses, until a different response to that obtained in 11.1.11.1 is recorded.

11.1.11.3 The result from 11.1.11.1 plus those of like response from 11.1.11.2 constitute the N_L series of results. (See example in Appendix X1, Part 2).

NOTE 13—Where experience has shown that the requirements of 11.1.11.6 are usually satisfied by a value of *d* other than 0.2 %, it is appropriate to select that value as the initial value of *d*.

11.1.11.4 Test four more specimens, in accordance with 11.1.1 to 11.1.10 inclusive, maintaining $d = 0.2$ %, and note the C_o used for, and response of, each specimen. Designate the oxygen concentration used for the last specimen as C_F.

11.1.11.5 These four results together with the last result from 11.1.11.2 (that is, that which differed in response from that of 11.1.11.1) constitute the remainder of the N_T series, so that:

$$N_T = N_L + 5$$

See example in Appendix X1, Part 2.

11.1.11.6 Calculate the oxygen index in accordance with 12.1. Calculate the estimated standard deviation, σ*, of the oxygen concentration measurements from the last six responses in the N_T series (including C_F), in accordance with 12.3. If the following condition is satisfied:

$$\frac{2\sigma^*}{3} < d < 1.5\sigma^*$$

report the oxygen in accordance with Section 13, otherwise follow the instructions in 11.1.11.6 (*1*) or (*2*).

(1) If $d < 2\sigma^*/3$, repeat 11.1.11.2 through 11.1.11.6 using increased values for *d*, until the condition is satisfied, or

(2) If $d > 1.5\sigma^*$, repeat 11.1.11.2 through 11.1.11.6 using decreased values for *d*, until the condition is satisfied, except that *d* shall not be reduced below 0.2 % unless so required by the relevant material specification.

11.2 *Procedure B*

11.2.1 Follow the instructions in 11.1.1 through 11.1.6.

11.2.2 When using propagating ignition, follow the procedure described in 11.2.3.

11.2.3 *Propagating Ignition:*

11.2.3.1 For propagating ignition, the igniter is used to produce burning across the top and partially down the vertical faces of the specimen.

11.2.3.2 Apply the lowest visible part of the flame to the end face of the specimen and to its vertical faces to a depth of approximately 6 mm.

11.2.3.3 For specimen Type V, continue to apply the flame for up to 30 s, removing it every 5 s, just briefly, to observe whether or not the vertical surface of the specimen are burning steadily or whether the visibly burning portion has reached the upper reference mark on the support frame.

(1) Consider the specimen to be ignited when the visibly burning portion first reaches the upper reference mark on the support frame.

11.2.3.4 For specimen Types I, II, III, IV, or VI, continue to apply the flame for up to 30 s, removing it every 5 s, just briefly, to observe whether or not the vertical surface of the specimen are burning steadily or whether the visibly burning portion has reached the upper reference mark on the specimen.

(1) Consider the specimen to be ignited when the visibly burning portion first reaches the upper reference mark on the specimen.

11.2.3.5 Remove the igniter once the specimen is ignited.

11.2.3.6 Commence measurement of the period and distance of burning once the specimen is ignited.

NOTE 14—The burning portion includes any burning drips that run down the surface of the specimen.

11.2.4 Follow the instructions in 11.1.8 through 11.1.11.

11.3 *Procedure C—Comparison with a Specified Minimum Value for Oxygen Index (Short Procedure)*

11.3.1 If the actual oxygen index of a material is needed or in case of a dispute, Procedures A or B shall be used, as appropriate.

11.3.2 For Procedure C, set up the apparatus and test specimen in accordance with 11.1.1 through 11.1.6, except that the specified minimum concentration of oxygen shall be selected for the purposes of 11.1.1.

11.3.3 Ignite the test specimen in accordance with 11.1.7 or with 11.2.3, as appropriate.

11.3.4 Using up to three specimens, assess the burning behavior of each specimen in accordance with 11.1.8.

11.3.5 If for at least two out of the three specimens thus tested the flame is extinguished before the relevant criteria from Table 2 are exceeded, that is, an "O" response is recorded, then record that the oxygen index of the material is not less than the specified value. Otherwise, record that the oxygen index of the material is less than the specified value or determine the oxygen index in accordance with 11.1 or 11.2, as appropriate.

12. Calculation

12.1 *Oxygen Index:*

12.1.1 Calculate the oxygen index (*OI*), expressed as a percentage by volume, from the following relationship:

$$OI = C_F + kd$$

where:

C_F = the final value of oxygen concentration, in percent volume to one decimal place, used in the series of N_T measurements performed in accordance with 11.1.11 and noted in accordance with 11.1.11.4,

d = the interval, in percent volume to at least one decimal place, between oxygen concentration levels used and controlled in accordance with 11.1.11, and

k = a factor to be obtained from Table 3 as described in 12.2.

12.1.2 For the purpose of calculation of σ*, as required by 11.1.11.6 and 12.3, the OI shall be calculated to two decimal places.

12.1.3 For the purpose of reporting *OI* results, express *OI* values to the nearest ±0.1 %, with exact intermediate results being rounded downwards.

12.2 *Determination of k:*

12.2.1 Table 3 contains values of *k* for calculating oxygen index concentration from determinations made by Dixon's "Up-and-Down" method. The value and sign of *k* are dependent upon the pattern of the responses of specimens tested in accordance with 11.1.11. Determine them from Table 3 as follows:

12.2.1.1 If the response of the specimen tested according to 11.1.11.1 was "O", so that the first contrary response (see 11.1.11.2) was an "X", refer to Column 1 of Table 3 to select the row for which the last four response symbols correspond to those found when testing in accordance with 11.1.11.4. The value and sign of *k* will be that shown in Column 2, 3, 4, or 5 for which the number of "O"s shown in row (a) of the table corresponds to the number of "O" responses found for the N_L series, in accordance with 11.1.11.1 and 11.1.11.2, or

12.2.1.2 If the responses of the specimen tested according to 11.1.11.1 was "X", so that the first contrary response was an "O", refer to the sixth column of Table 3 to select the row for which the last four response symbols correspond to those found when testing in accordance with 11.1.11.4. The value of *k* will be that shown in Column 2, 3, 4, or 5 for which the number of "X"s shown in row (b) of the table corresponds to the number of "X" responses found for the N_L series, in accordance with 11.1.11.1 and 11.1.11.2 but the sign of *k* must be reversed, so that negative values shown in Table 3 for *k* become positive, and vice versa.

NOTE 15—An example of the determination of the calculation of an *OI* is given in Annex A2.

12.3 *Standard Deviation of Oxygen Concentration Measurements:*

12.3.1 For the purposes of 11.1.11.6 calculate the estimated standard deviation, σ*, of oxygen concentration measurements from the relationship:

$$\sigma^* = \left[\frac{\sum(C_i - OI)^2}{n-1}\right]^{\frac{1}{2}}$$

where:

C_i = in turn, each of the percent oxygen concentrations used during measurement of the last six responses in the N_T series of measurements;

OI = the oxygen index value, calculated in accordance with 12.1; and

n = the number of measurements of oxygen concentration contributing to $\sum(C_i - OI)^2$.

NOTE 16—For this test method, $n = 6$, in accordance with 11.1.11.6. For $n < 6$, the test method loses precision. For $n > 6$, alternative statistical criteria would apply.

13. Report

13.1 Report the following information:

13.1.1 A reference to this test method;

13.1.2 Date of testing;

13.1.3 A statement that test results relate only to the behavior of the test specimens under the conditions of this test method and that these results must not be used to infer the fire hazards of the material in other forms or under other fire conditions;

13.1.4 Identification of the material tested, including, where relevant, the type of material, density, previous history, the specimen orientation with respect to any anisotropy in the material or sample, and the date of manufacture with lot number;

13.1.5 The oxygen index (*OI*) as determined in 12.1;

13.1.6 The test specimen type or dimensions;

13.1.7 The gas measurement and control device accuracy (in accordance with 6.3.1 or with 6.3.2);

13.1.8 The test procedure used (Procedure A, in accordance with 11.1; Procedure B, in accordance with 11.2; or Procedure C, in accordance with 11.3);

13.1.9 When Procedure C, in accordance with 11.3 is used, indicate the relevant specified minimum oxygen index (*OI*) of the material and report if the material tested had a lower or higher oxygen index (*OI*);

13.1.10 If applicable, the estimated standard deviation and the oxygen concentration increment used, if other than 0.2 %;

13.1.11 A description of any relevant characteristics or behavior, such as charring, dripping, severe shrinkage, erratic burning, after-glow; and

13.1.12 Any variations from the requirements of this test method.

14. Precision and Bias[4]

14.1 Table 4 is based on a round robin conducted in 1999 in accordance with Practice E691, involving eight materials

TABLE 4 Oxygen Index (OI), %

Material	Specimen Type	Procedure	Average	S_r[A]	S_R[B]	r[C]	R[D]
PMMA-1	III	A	17.7	0.10	0.23	0.28	0.65
PMMA-2	III	A	17.8	0.13	0.25	0.37	0.70
PVC, plasticized	I	A	38.4	0.60	2.03	1.67	5.68
ABS, FR	I	A	26.8	0.58	1.09	1.61	3.07
PF, thermoset	I	A	49.7	0.36	1.74	1.01	4.87
PS, foam	II	A	20.9	0.44	0.97	1.22	2.71
PC, sheet	V	B	26.1	0.31	1.42	0.88	3.97
PET, film	VI	A	21.9	0.64	1.48	1.79	4.15

[A] S_r is the within-laboratory (or repeatability) 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. It is calculated as the square root of the ratio of (a) the sum of the squares of the individual standard deviations and (b) the number of laboratories.

[B] S_R is the between-laboratories (or reproducibility) standard deviation, calculated as the larger of either (a) the repeatability standard deviation or (b) the standard deviation of laboratory means.

[C] r is the within-laboratory critical interval between two test results = 2.8× S_r.

[D] R is the between-laboratories critical interval between two test results = 2.8 × S_R.

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[4] Supporting data are available from ASTM Headquarters. Request RR:D20-1218.

tested by twelve laboratories. For each material, the samples were prepared by the supplier of the material and conditioned at the laboratories that tested them. Each laboratory obtained two test results for each material. All laboratories utilized gas measurement and control devices in accordance with 6.3 (Type A) for accuracy and precision.

14.2 Table 4 does not include three laboratories that participated in the round robin and utilized measurement and control devices in accordance with 6.3 (Type B) for accuracy and precision. The results from these laboratories could not be incorporated into this precision statement, due to the limited number of participants to comply with Practice E691 guidelines. Therefore, the resulting precision is provided in Annex A3.

NOTE 17—Two statistically designed interlaboratory round robins for precision evaluation were conducted earlier, one with 18 laboratories and five materials (supporting data are available from ASTM Headquarters, request RR:D20-0102) and one with 29 laboratories and twelve materials.[4] The first study indicated a higher standard deviation for specimens with higher oxygen index, while the second study indicated a dependence of precision with the type of specimen used.

14.3 *Concept of repeatability, "r" and Reproducibility, "R", in Table 4*—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 two specimens for each test result, then:

14.3.1 *Repeatability*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material. The concept of "*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 in the same laboratory.

14.3.2 *Reproducibility*—Two test results obtained by different laboratories shall be judged not equivalent if they differ by more than the "*R*" value for that material. The concept of "*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.

14.3.3 Any judgement in accordance with 14.3.1 or 14.3.2 would have an approximate 95 % (0.95) probability of being correct. (**Warning—**The explanation of the concepts of repeatability, "*r*", and reproducibility, "*R*", in 14.3 is only intended to present a meaningful way of considering the approximate precision of this test method. It is inappropriate to apply the test results and precision in Table 4 to 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. The principles outlined in Practice E691 need to be applied by users of this test method to generate data specific to their materials and laboratory (or between specific laboratories). The principles of repeatability and reproducibility would then be valid for such data.)

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

15. Keywords

15.1 candle-like combustion; minimum oxygen concentration; oxygen; oxygen concentration; oxygen index

ANNEXES

(Mandatory Information)

A1. CALIBRATION OF EQUIPMENT

A1.1 *Leak Tests*—Leak tests shall be carried out thoroughly on all joints where leaks could change the oxygen concentration levels in the chimney from the concentration levels set or indicated.

A1.2 *Gas-Flow Rates:*

A1.2.1 The system for indicating the gas-flow rate through the chimney, to satisfy 6.3 and 11.1.5 shall be checked using a calibrated flow meter, or an equivalent device, with an accuracy equivalent to ±0.2 mm/s flow rate through the chimney.

A1.2.2 The flow rate shall be estimated by dividing the total gas-flow rate through the chimney by the cross sectional area of the bore of the chimney, for example, by using the following equation:

$$F = 1.27 \times 10^6 \frac{q_v}{D^2}$$

where:

F = flow rate through the chimney, mm/s,

q_v = total gas-flow at 23 ± 2°C through the chimney, L/s,

D = diameter of the bore of the chimney, mm.

A1.3 *Oxygen Concentration:*

A1.3.1 The concentration of oxygen in the mixture of gases flowing into the chimney shall be checked to an accuracy of 0.1 % of mixture, either by sampling the chimney atmosphere for analysis or by using an independently calibrated analyzer in situ. If an oxygen analyzer is incorporated in the equipment, this shall be calibrated using the following gases, each of which shall conform with 6.3.2 for purity and moisture content:

A1.3.1.1 Any two gases selected from the following: nitrogen; oxygen; or clean air; and

A1.3.1.2 A mixture of any two of the preceding gases having an oxygen concentration within the range of concentrations to be used for most test specimens.

A1.4 *Verification of Complete Equipment*—For monthly verification, in accordance with 11.1, use Type III specimens of the PMMA. The PMMA shall be a non-modified transparent cast sheet based on a homopolymer of methylmethacrylate in accordance with Specifications D4802, Category A-1 (ISO 7823-1 for Cast Sheets). The PMMA shall have an oxygen index (OI) between 17.0 and 18.5.

NOTE A1.1—Other PMMA sheets such as cast sheets based on copolymer of methylmethacrylate, extruded or melt calendered PMMA sheets may give a different burning behavior depending on the comonomer used, its contents or molecular weight which effects melt behavior when being burned.

A2. CALCULATION OF OXYGEN CONCENTRATION

A2.1 Oxygen concentrations required for the purposes of Section 11 shall be calculated in accordance with the equation:

$$C_o = \frac{100\ V_o}{V_o + V_N} \qquad \text{(A2.1)}$$

where:

C_o = oxygen concentration, in percent by volume,
V_o = volume of oxygen per volume of mixture, at 23°C, and
V_N = volume of nitrogen per volume of mixture, at 23°C.

NOTE A2.1—If an oxygen analyzer is used, determine the oxygen concentration using the readout from the particular instrument used.

NOTE A2.2—If the result is calculated from flow or pressure data for individual gas streams contributing to the mixture, it is necessary to allow for the proportion of oxygen present in streams other than a pure oxygen supply. For example, for mixtures made using air mixed with oxygen of 98.5 % purity or with nitrogen containing 0.5 % of oxygen, calculate the oxygen concentration, in percent by volume, using the relationship:

$$C_o = \frac{98.5\ V'_o + 20.9\ V'_A + 0.5\ V'_N}{V'_o + V'_A + V'_N} \qquad \text{(A2.2)}$$

where:

V'_o = volume of oxygen stream used, per volume of mixture,
V'_A = volume of air stream used, per volume of mixture, and
V'_N = volume of nitrogen stream used, per volume of mixture; assuming that the streams are at the same pressure at 23°C.

For mixtures based on two gas streams, V'_o, V'_A , or V'_N becomes zero, as appropriate.

A3. PRECISION AND BIAS ASSESSMENT USING GAS CONTROL DEVICES WITHOUT DIRECT OXYGEN CONCENTRATION MEASUREMENT

A3.1 Table A3.1 is based on a limited round robin[4] conducted in 1999, along with the round robin in Section 14. This limited round robin does not comply with Practice E691 because only three laboratories participated on a limited number of materials using the 6.3.2 control devices for accuracy and precision, without direct oxygen concentration measurement. For each material, the samples were prepared by the supplier of the material and conditioned at the laboratories that tested them. Each laboratory obtained either one or two test results for each material. All laboratories utilized gas measurement and control devices in accordance with 6.3.2 for accuracy and precision.

TABLE A3.1 Oxygen Index (OI), %[A]

Material	Specimen Type	Procedure	Average	S_r[B]	S_R[C]	r[D]	R[E]
PMMA-1	III	A	17.1	0.20	0.43	0.57	1.21
PMMA-2	III	A	17.4	0.00	0.61	0.00	1.72
PVC, plasticized	I	A	48.0	0.27	7.84	0.77	22.0
ABS, FR	I	A	26.5	0.27	11.1	0.95	31.1
PF, thermoset	I	A	52.2	0.15	0.82	0.42	2.30
PS, foam	II	A	23.3	0.00	3.04	0.00	8.50

[A] Based on data from only two laboratories.
[B] S_r is the within-laboratory (or repeatability) 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. It is calculated as the square root of the ratio of (a) the sum of the squares of the individual standard deviations and (b) the number of laboratories.
[C] S_R is the between-laboratories (or reproducibility) standard deviation, calculated as the larger of either (a) the repeatability standard deviation or (b) the standard deviation of laboratory means.
[D] r is the within-laboratory critical interval between two test results = 2.8 × S_r.
[E] R is the between-laboratories critical interval between two test results = 2.8 × S_R.

A3.2 See 14.3 for explanations of the concepts of repeatability and reproducibility. (**Warning—**The explanations of the concepts of repeatability, "*r*", and reproducibility, "*R*", is only intended to present a meaningful way of considering the approximate precision of this test method. Do not apply the test results and precision in Table A3.1 to 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. The principles outlined in Practice E691 need to be applied by users of this test method to generate data specific to their materials and laboratory (or between specific laboratories). The principles of repeatability and reproducibility would then be valid for such data.)

A3.2.1 Any judgement in accordance with repeatability and reproducibility would have an approximate 95 % (0.95) probability of being correct.

A4. OPTIONAL ALTERNATE SYSTEM FOR GAS MEASUREMENT

A4.1 If direct measurement of oxygen concentration is not available, it is acceptable to conduct gas measurements by means of a system that includes the following: calibrated orifices, gas pressure regulators, pressure gauges on the individual gas supply lines and needle valves and calibrated flow meters on the individual gas supply lines.

A4.2 The system in A4.1 was consistently used when direct measurement of oxygen concentration was not easily available.

APPENDIX

(Nonmandatory Information)

X1. TYPICAL TEST RESULTS SHEET

Material: Phenolic laminate
Specimen Type: 1 (4 mm thick)
Test procedure: A
Conditioning procedure: 23/50
Oxygen concentration increment (d): 0.2

Oxygen Index (concentration, %): 29.5 (rounded to 0.1 %)

σ^*: 0.152
Date of test: 13/10/80
Laboratory No. 19 Test No. 1

Determination of oxygen concentration for one pair of "X" and "O" response at ≤1 % O_2 concentration interval (in accordance with 11.1.10)

Oxygen concentration, %	25.0	35.0	30.0	32.0	31.0				
Burning period, s	10	>180	140	>180	>180				
Length burnt, mm									
Response, "X" or "O"	O	X	O	X	X				

Oxygen concentration of the "O" response for the pair = 30.0 (being the concentration to be used again for the first measurement in Part 2)

Determination of oxygen index value (in accordance with 11.1.1)

Step size to be used for successive changes in oxygen concentration of d % = 0.2% (initially to be 0.2%, unless otherwise instructed):

Oxygen concentration, %
Burning period, s
Length burnt, mm
Response, "X" or "O"

N_T series measurements											
N_L series measurements (11.1.11.1 + 11.1.11.2)							(11.1.11.3)				C_F
30.0	29.8	29.6	29.4				29.4	29.6	29.4	29.6	29.8
>180	>180	>180	150				150	>180	110	165	>180
X	X	X	------------------------------→				O	X	O	O	X
Column (2, 3, 4 or 5): 4							Row (1 to 16): 7				
k value from table 4: 1.25											
Hence $k = -1.25$											

$OI = C_F + kd = 29.8 + (-1.25 \times 0.2)$
= 29.5% (to one decimal place, for reporting *OI*)
= 29.5% (to two decimal places, for calculation of and verification of *d* as required in Part 3)

Part 3: Verification of Step size *d* % oxygen concentration (in accordance with 1.1.11.6 and 12.3)–

Last six result	Oxygen Concentration, %			
	C_I^A	OI	$C_I - OI$	$(C_I - OI)^2$
C_F 1	29.8	29.55	0.25	0.0625
2	29.6	29.55	0.05	0.0025
3	29.4	29.55	−0.15	0.0225
4	29.6	29.55	0.05	0.0025
5	29.4	29.55	−0.15	0.0225
n 6	29.6	29.55	0.05	0.0025
	Total $\Sigma(C_I - OI)^2$			0.115
	Column C_I contains the oxygen concentrations used for the measurements of C_F and for each of the 5 preceding measurements, for $n = 6$			

Estimation of Standard deviation:

$$\sigma^* = \left[\frac{\Sigma(C_I - OI)^2}{n-1}\right]^{1/2} = \left[\frac{0.115}{5}\right]^{1/2} = 0.152$$

$$\frac{2\sigma}{3} = 0.101 \quad d = 0.2 \quad \frac{3\sigma^*}{2} = 0.227$$

$$\text{If } 2\frac{\sigma^*}{3} < d < \frac{3\sigma^*}{2} \text{ or if } 0.2 = d > \frac{3\sigma^*}{2};\ OI \text{ is valid}$$

Otherwise
If $2\frac{\sigma^*}{3} > d$, repeat Part 2 using a larger value for d; or
if $\frac{3\sigma^*}{2} < d$, repeat Part 2 using a smaller value for d.

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D2863 - 13) that may impact the use of this standard. (August 15, 2017)

(1) Deleted old Note C in Table 1.

(2) Revised 6.4.

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