Designation: D 2863 – 00

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 D 2863; 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 test method covers a fire-test-response procedure. This test method describes a procedure for measuring the minimum concentration of oxygen that will just support flaming combustion in a flowing mixture of oxygen and nitrogen.

1.2 Methods are provided for testing materials that are structurally self-supporting in the form of vertical bars or sheet up to 10.5 mm thick. These methods are suitable for solid, laminated or cellular materials characterized by an apparent density greater than 15 kg/m^3. The methods may also be applicable to some cellular materials having an apparent density of less than 15 kg/m^3. A method is provided for testing flexible sheet or film materials while supported vertically.

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

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

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific hazards statement are given in Note 2.

NOTE 2—**Warning:** During the course of combustion, gases or vapors, or both, are evolved which may be hazardous to personnel.

NOTE 3—This test method and ISO 4589-2 are technically equivalent when using the Type A gas measurement and control device accuracy as described in 6.4.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 618 Practice for Conditioning, Plastics and Electrical Insulating Materials for Testing

D 1071 Test Methods for Volumetric Measurement of Gaseous Fuel Samples

D 1622 Test Method for Apparent Density of Rigid Cellular Plastics

D 2444 Test Method for Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)

D 4802 Specification for Poly(Methyl Methacrylate) Acrylic Plastic Sheet

E 176 Terminology of Fire Standards

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

2.2 *ISO Standards:*

4589-2 Plastics—Determination of Flammability by Oxygen Index—Part 2, Ambient Temperatures[3]

7823-1 Poly(Methylmethacrylate) Sheets—Types, Dimensions and Characteristics—Part 1—Cast Sheets[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *ignition*—for the purpose of this standard shall imply the initiation of flaming combustion.

3.1.2 *oxygen index (OI)*—the minimum concentration of oxygen determined by the method in 9.1, 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.

3.1.3 Definitions of terms relating to fire are in accordance with Terminology E 176.

3.2 *Symbols Specific To This Test Method:*

3.2.1 C_o —oxygen concentration in percent volume.

[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).

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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.

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

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

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

3.2.4 *O*—neither the period or extent of burning exceeds the relevant limit specified in Table 1.

3.2.5 *X*—the period or extent of burning exceeds the relevant limit specified in Table 1.

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

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

3.2.8 σ*—standard deviation of the oxygen concentration.

3.2.9 *d*—internal between oxygen concentration levels in percent volume.

3.2.10 *k*—a factor to be determined from Table 2.

3.2.11 *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.

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 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 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 procedure.

TABLE 1 Criteria for Oxygen Index Measurements[A]

Test Specimen Type (See Table 3)	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
	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.

6. Apparatus

6.1 *Test Chimney*, consisting of a heat-resistant glass tube of 75 to 100 mm inside diameter and 450 to 500 mm height. The bottom of the chimney or the base to which the tube is attached shall contain noncombustible material to mix and distribute evenly 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. See Fig. 1.

NOTE 4—For tubes of 75 to 100 mm diameter, a cap converging to an outlet of 40 mm diameter at a level at least 10 mm above the top of the cylindrical chimney has been found satisfactory for restricting the column opening.

NOTE 5—It is helpful to place a wire screen above the noncombustible material to catch falling fragments and aid in keeping the base of the column clean.

6.2 *Specimen Holder*—Any small holding device that will support the specimen at its base and hold it vertically in the center of the chimney is acceptable. For physically self-supporting specimens, 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. For supported film or sheet test specimens, the specimen shall be supported 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.

6.3 *Gas Supplies*, comprising 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.

6.3.1 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 6—It should not be assumed that bottled oxygen or nitrogen will 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 depressed to below about 1 MPa, the moisture content of the gas drawn off may rise above 0.1 %.

6.4 *Gas Measurement and Control Devices*, suitable for establishing the following accuracies when the gas velocity through the chimney is 40 ± 2 mm/s at 23 ± 2°C;

6.4.1 *Type A*—Maintaining the volumetric concentration of oxygen in the gas mixture entering the chimney with an accuracy of ±0.5 % of the mixture and for adjusting the concentration with a precision of ± 0.1 % of the mixture;

6.4.2 *Type B*—Maintaining the volumetric concentration of oxygen in the gas mixture entering the chimney with an accuracy of ±1.0 % of the mixture and for adjusting the concentration with a precision of ±0.5 % of the mixture.

TABLE 2 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 2 opposite he appropriate response in Column 6, but with the sign of *k* reversed, that is: $OI = C_F - kd$ (see 9.1).

NOTE 7—Systems of measurement and control that have proved satisfactory include the following:

(*a*) *For Type A*—Needle valves on individual and mixed gas supply lines, a paramagnetic oxygen analyzer that continuously samples the mixed gas, and a flowmeter to indicate when the gas flow through the chimney is within the required limits;
(*b*) *For Type A or B*—Calibrated orifices, gas pressure regulators and pressure gages on the individual gas supply lines; or
(*c*) *For Type B*—Needle valves and calibrated flowmeters on the individual gas supply lines.

6.4.3 These systems require calibration after assembly to ensure that the compounded errors of the component parts do not exceed the requirements of 6.4.

6.4.3.1 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.

6.5 *Flame Igniter*, comprising a tube, with an inside diameter of 2 ± 1 mm, that can be inserted into the chimney to apply the test flame.

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

6.6 *Timing Device*, capable of measuring periods up to 5 min with an accuracy of ±0.5 s.

6.7 *Fume Extraction System*, having sufficient ventilation or exhaust to remove fumes or soot expelled from the chimney without disrupting the gas-flow rate or temperatures in the chimney.

NOTE 8—If soot-generating materials are being tested, the glass chimney may require cleaning to maintain good visibility, and the gas inlets, or inlet screen may also require cleaning to function properly.

6.8 *Thin Film Rolling Tool*—A 2 ± 0.1 mm stainless steel wire with a 0.3 ± 0.05 mm slit at one end, equivalent to that illustrated in Fig. 3.

7. Test Specimens

7.1 Cut or mold at least 15 specimens. Use Table 3 to determine specimen dimensions.

NOTE 9—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.

NOTE 10—If non-standard size specimens are used, a difference in oxygen index may result.

7.1.1 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.

7.1.2 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 position and orientation of test specimens with respect to any asymmetry in the sample material (see Note 12).

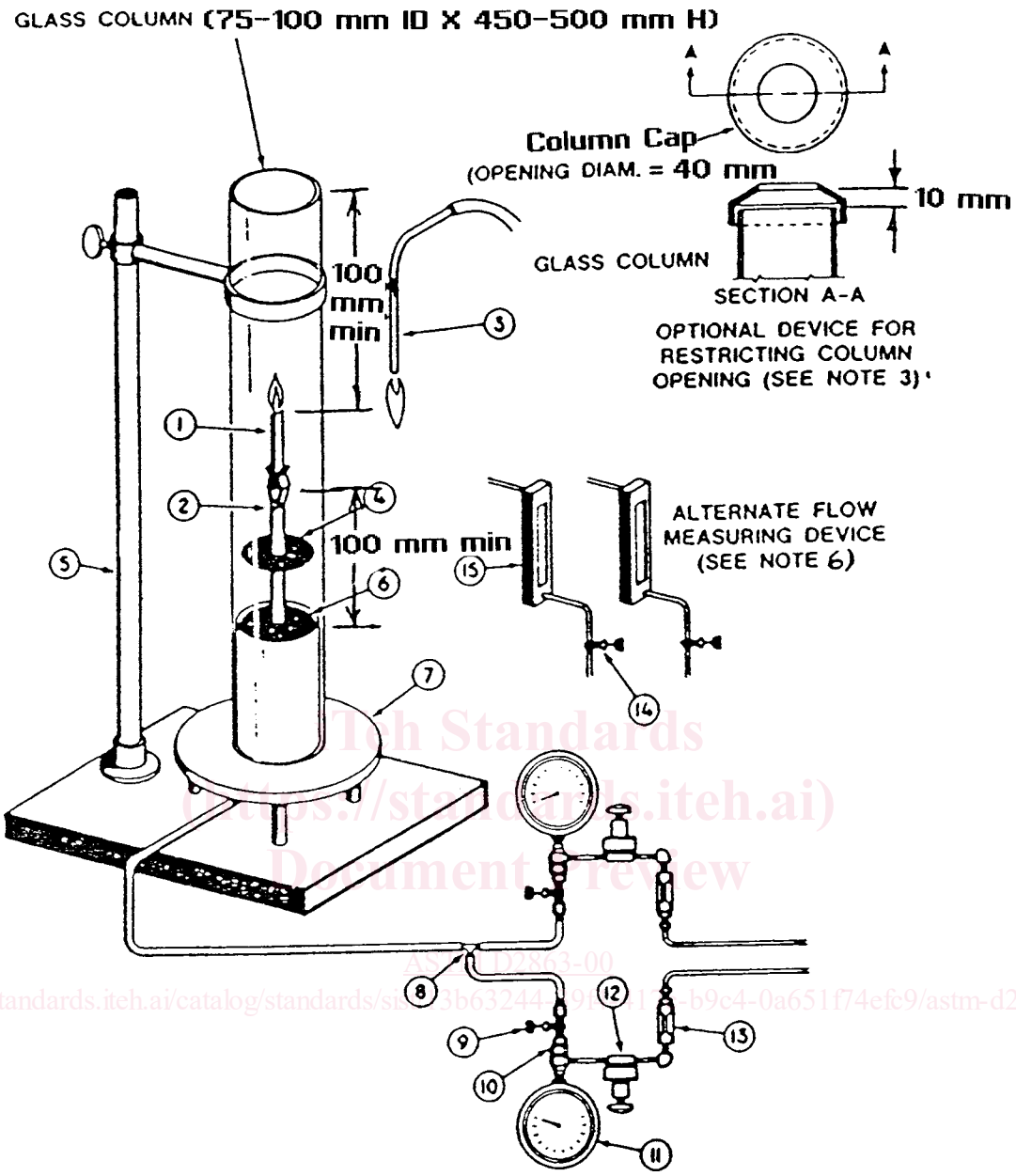
NOTE 11—Oxygen index results are likely to be significantly affected by differences in burning behavior, due to material inhomogeneity (for example, different levels of shrinkage when heated for specimens cut in different directions from asymmetrically-oriented thermoplastics film).

7.2 For preparation of Type VI specimens, use the rolling tool described in 6.8.

7.2.1 The rolled film is obtained by first inserting one corner of the film into the slit of the thin film rolling tool (see 6.8) and then winding the film around the wire 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 wire to prevent loosening. Then pull the wire out of the rolled film.

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

7.3 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



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 Gage
12. Precision Pressure Regulator
13. Filter
14. Needle Valve
15. Rotameter

FIG. 1 Typical Equipment Layout

procedure to be used. Structurally self-supporting specimens are preferably marked on at least two adjacent faces. If wet inks are used, the marks shall be dry before the specimen is ignited.

7.3.1 Test specimens of Type I, II, III, IV or VI are to be tested in accordance with Procedure A (see 8.8), and shall be marked 50 mm from the end to be ignited.

7.3.2 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.

7.3.3 If specimens of Type I, II, III, IV and VI are to be tested in accordance with Procedure B (see 8.8 and 8.10), they shall be marked at 10 mm and at 60 mm from the end to be ignited.

7.4 Unless otherwise specified, each test specimen shall be conditioned for at least 88 h at 23 ± 2°C and 50 ± 5 % relative humidity (RH) immediately prior to use.

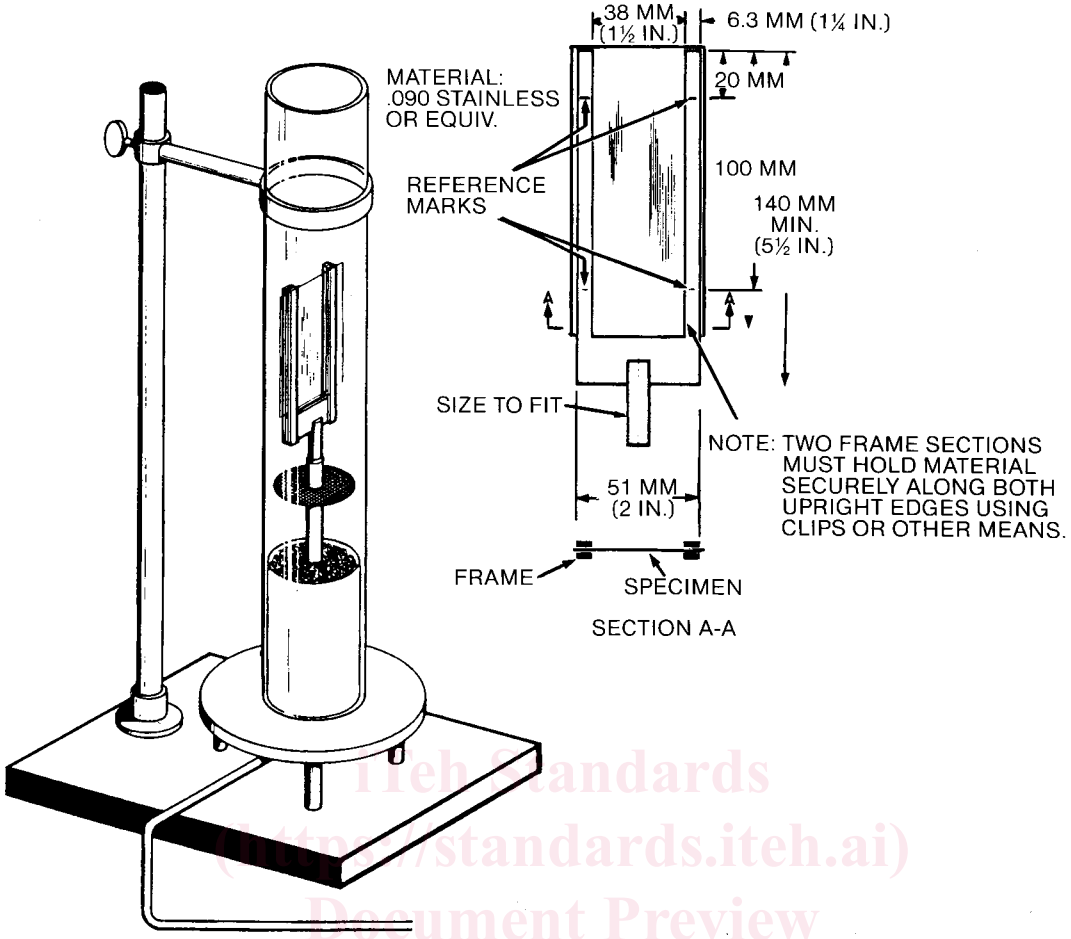


FIG. 2 Frame Design

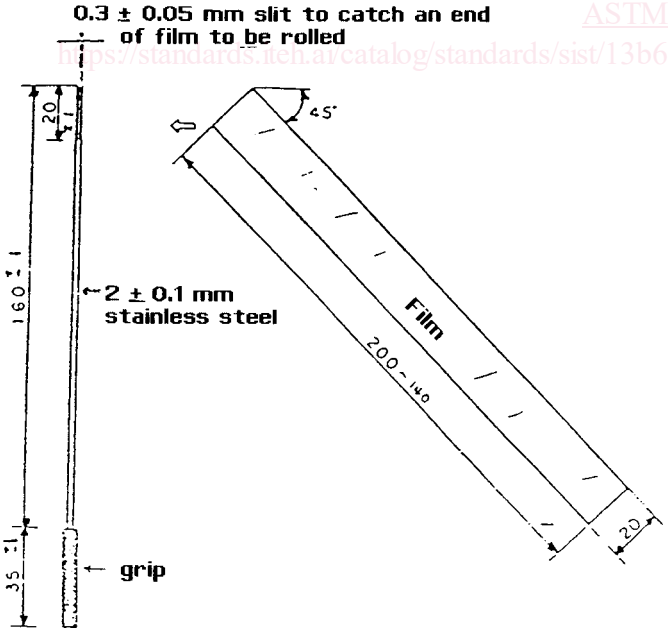


FIG. 3 Wire With a Slit

TABLE 3 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[C]	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[BD]	140 to 200	20	0.02 to 0.10	for thin film; limited to film that can be rolled by the wire specified in 6.8

[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.

[B] Results obtained using Type III, V, and VI test specimens may only be comparable for 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 Type IV (ASTM) specimen will eventually be discontinued in favor of the Type 1 (ISO) specimen.

[D] The test specimen of Type VI is suitable for thin film that is self-supporting when it is rolled. 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.

7.5 For cellular materials, the density shall be determined in accordance with Test Method D 1622.

NOTE 12—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.

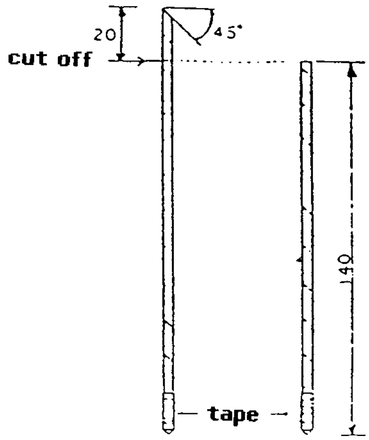


FIG. 4 Rolled Film

8. Procedure A

8.1 Calibrate the flow-measuring system using a water-sealed rotating drum meter (wet test meter) in accordance with Test Method D 1071 or by equivalent calibration devices. The maximum interval between recalibration shall be six months. A cast PMMA specimen shall be used as a verification material at least once a month. See Annex A1 for calibration method.

8.2 Maintain the ambient temperature for the test apparatus at 23 ± 2°C. If necessary, 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.

8.3 Recalibrate equipment components, more frequently if necessary (see 8.1 and Annex A1).

8.4 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.

8.5 Ensure that the test chimney is vertical (see Fig. 1). 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).

8.6 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.

8.7 Verify the temperature at the lower end of the chimney to be 23 ± 2°C and record the oxygen concentration used as the volume percent calculated according to the equations given in Annex A2.

8.8 Select one of two alternative ignition procedures which are dependent upon the specimen form as follows:

8.8.1 For specimen Types I, II, III, IV and VI use Method A, top surface ignition, as described in 8.9.

8.8.2 For specimen Type V, use Method B, propagating ignition, as described in 8.10.

NOTE 13—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 7.3.2) may be found to give more consistent results than Test Method A. Test Method B may then be used for specimens of Type I, II, III, IV or VI.

NOTE 14—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.

8.9 *Test Method A—Top Surface Ignition*:

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

8.9.2 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. 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.

8.9.3 Consider the specimen to be ignited, and commence measurement of the period and distance of burning, as soon as removal of the igniter, after a contact period increment of 5 s, reveals, burning supported by the whole of the top end of the specimen.

8.10 *Test Method B—Propagating Ignition*:

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

8.10.2 Lower and move the igniter sufficiently to apply the visible flame to the end face of the specimen and also, to a depth of approximately 6 mm, to its vertical faces. Continue to apply the igniter for up to 30 s, with interruptions for inspection of the specimen every 5 s, until its vertical faces are burning steadily or until the visibly burning portion first reaches the level of the upper reference mark on the support frame or, if used for specimens of Type I, II, III, IV or VI on the specimen.

8.10.3 Consider the specimen to be ignited, for the purpose of measuring the period and extent of burning, as soon as any part of the visibly burning portion reaches the level of the upper reference mark.

NOTE 15—The burning portion includes any burning drips that run down the surface of the specimen.

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

8.11.1 Commence measurement of the period of burning as soon as the specimen has been ignited in accordance with 8.9 or 8.10 as applicable, and observe its burning behavior. If burning ceases but spontaneous re-ignition occurs within 1 s, continue the observation and measurements.