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By American National Standards Institute

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Method of Test for FLAMMABILITY OF PLASTICS USING THE OXYGEN INDEX METHOD[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.

1. Scope

1.1 This method describes a procedure for determining the relative flammability of plastics by measuring the minimum concentration of oxygen in a slowly rising mixture of oxygen and nitrogen that will just support combustion. This method is presently limited to the use of physically self-supporting plastic test specimens.

NOTE 1—This method has been found applicable for testing plastics that are not physically self-supporting and other materials. However, the accuracy of the method has not been determined for these materials, or for specimen geometries and test conditions outside those recommended herein.

2. Significance

2.1 This method provides a means for comparing the relative flammability of physically self-supporting plastics. It may also be used to study the effect of changes in material on the flammability. Correlation with flammability under actual use conditions is not necessarily implied.

3. Definition

3.1 *oxygen index*—the minimum concentration of oxygen, expressed as volume percent, in a mixture of oxygen and nitrogen that will just support combustion of a material under the conditions of this method.

4. Principle of Method

4.1 The minimum concentration of oxygen in a slowly rising mixture of oxygen and nitrogen that will just support combustion is measured under equilibrium conditions of candle-like burning. The balance between the heat from the combustion of the specimen and the heat lost to the surroundings establishes the equilibrium. This point is approached from both sides of the critical oxygen concentration in order to establish the oxygen index.

5. Apparatus

5.1 *Test Column*, consisting of a heat-resistant glass tube of −75 mm minimum inside diameter and 450-mm minimum height. The bottom of the column 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 (an example is shown in Fig. 1).

NOTE 2—A column with a 95-mm inside diameter and 210 mm high with a restricted upper opening (diameter = 50 mm) has been found to give equivalent results.

NOTE 3—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.

5.2 *Specimen Holder*—Any small holding device that will support the specimen at its base and hold it vertically in the center of the column is acceptable. A typical arrangement, shown in Fig. 1, consists of a laboratory thermometer clamp inserted into the end of a glass tube held in place by the glass beads.

5.3 *Gas Supply*—Commercial grade (or better) oxygen and nitrogen shall be used. If an air supply is used with oxygen or nitrogen, it must be clean and dry.

[1] This method is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D-20.30 on Thermal Properties.
Effective May 8, 1970.

5.4 *Flow Measurement and Control Devices*—Suitable flow measurement and control devices shall be available in each line which will allow monitoring the volumetric flow of each gas into the column within 1 percent. After the flow is measured in each line, the lines should be joined to allow the gases to mix before being fed into the column.

NOTE 4—One satisfactory flow control system consists of calibrated jeweled orifices (**3**),[2] precision pressure regulating devices, and precision gas gages. An equally satisfactory system consists of needle valves and rotameters. Some manometer-orifice systems have not been found to be sufficiently accurate.

5.5 *Ignition Source*—The igniter should be a tube with a hydrogen, propane, or natural gas flame at the end that can be inserted into the open end of the column to ignite the test specimen. A suitable flame may be from 6 to 12 mm long.

5.6 *Timer*—A suitable timer capable of indicating at least 10 min and accurate to 5 s shall be used.

5.7 *Soot, Fumes, and Heat Removal*—To ensure the removal of toxic fumes, soot, heat, and other possible noxious products, the column shall be installed in a hood or other facilities providing adequate exhaust.

NOTE 5—If soot-generating specimens are being tested, the glass column becomes coated on the inside with soot and should be cleaned as often as necessary for good visibility.

6. Test Specimens

6.1 At least ten specimens 70 to 150 mm long by 6.5 ± 0.5 mm wide and 3.0 ± 0.5 mm thick shall be cut from the materials being tested.

NOTE 6—If other than standard size specimens are used, differences in oxygen index may occur.

6.1.1 The specimens shall be tested in the as-received condition unless otherwise agreed upon.

NOTE 7—Moisture content of some materials has been shown to affect the oxygen index.

6.1.2 The edges of the specimens shall be relatively smooth and free from fuzz or burrs of material left from machining.

7. Procedure

7.1 Calibrate the flow measuring system using a water-sealed rotating drum meter (wet test meter) in accordance with ASTM Method D 1071, for Measurement of Gaseous Fuel Samples,[3] or by equivalent calibration devices. It is recommended that this calibration be repeated at least every 6 months.

NOTE 8—One step in the calibration should be to check carefully for leaks at all joints.

7.2 Clamp the specimen in the holder vertically in the approximate center of the column with the top of the specimen at least 100 mm below the top of the open column.

NOTE 9—If a restricted opening column is used (see Note 2), the top of the specimen should be at least 40 mm below the opening.

7.3 Select the desired initial concentration of oxygen based on past experience with similar materials. If there is no experience with the material, light a specimen in the air and note the burning. If the specimen burns rapidly, start at a concentration of about 18 percent, but if the specimen goes out, select a concentration of about 25 percent or higher depending on the difficulty of ignition and time of burning.

7.4 Set the flow valves so that the desired initial concentration of oxygen is flowing through the column. The gas flow rate in the column shall be 4 ±1 cm/s as calculated at standard temperature (0 C) and pressure (760 mm Hg) from the total flow of gas in cm^3/s, divided by the area of the column in cm^2.

7.5 Allow the gas to flow for 30 s to purge the system.

7.6 Ignite the top of the specimen with the ignition flame so that the specimen is well lit and the entire top is burning. Remove the ignition flame and start the time.

7.6.1 The concentration of oxygen is too high and must be reduced if:

7.6.1.1 The specimen burns 3 min or longer, OR

7.6.1.2 The specimen burns 50 mm.

7.6.2 The concentration of oxygen must be raised if the specimen is extinguished before burning 3 min or 50 mm.

7.7 Adjust the oxygen concentration, insert a new specimen, or if the previous specimen is long enough, turn it end for end or cut off the burned end, then purge and re-ignite.

[2] The boldface numbers in parentheses refer to the list of references at the end of this method.

[3] *Annual Book of ASTM Standards*, Part 19.

NOTE 10—Do not adjust the oxygen concentration after igniting the specimen.

7.8 Continue repeating 7.5 through 7.7 until the limiting concentration of oxygen is determined. This is the lowest oxygen concentration which will meet the conditions of 7.6.1. At the next lower oxygen concentration possible with the equipment, the specimen should extinguish as defined in 7.6.2.

7.9 For a material having consistent burning characteristics, the difference in oxygen concentration between burning as defined in 7.6.1 and extinguishing as defined in 7.6.2 will be reproducible within 0.1 to 0.3 percent depending on the sensitivity of the flow measuring equipment and upon the particular oxygen concentration involved. Some materials, however, exhibit erratic burning characteristics because of inhomogeneity, char formation, dripping, bending, etc., which cause less reproducible results. In such cases, the limiting concentration should be determined by a statistical testing method.[4]

7.10 Perform the test at least three times by starting at a slightly different flow rate still within the 3 to 5 cm/s limits and again performing steps 7.4 through 7.8.

8. Calculations

8.1 Calculate the oxygen index, n, of the material as follows:

$$n, \text{ percent} = (100 \times O_2)/(O_2 + N_2)$$

where O_2 is the volumetric flow of oxygen, cm^3/s, at the limiting concentration determined in 7.8, and N_2 is the corresponding volumetric flow rate of nitrogen, cm^3/s.

NOTE 11—If air is used and either oxygen or nitrogen is added as required, calculate n assuming that air contains 20.9 percent oxygen as follows:

$$n, \text{ percent} = (100 \times O_2) + (20.9 \times A)/(O_2 + N_2 + A)$$

where A is the volumetric flow rate of air, cm^3/s, and O_2 and N_2 are the volumetric flow rates of oxygen and nitrogen added to the mixture. One of these will be zero depending on which gas is added.

9. Report

9.1 The report shall include the following:

9.1.1 Description of the material tested including as much as is known about the type, source, manufacturer's code number, form and principal dimensions, and previous history.

9.1.2 Test specimen dimensions,

9.1.3 Average oxygen index value,

9.1.4 Individual oxygen index values found for each of the tests, and

9.1.5 Description of any unusual behavior such as charring, dripping, bending, etc.

10. Precision

10.1 Based on the results of statistically designed round-robin testing program (**4, 5**) in which 18 laboratories checked 5 materials, the standard deviation of the mean of 3 replicates (for comparing laboratory-to-laboratory) was as follows:

10.1.1 For materials with an oxygen index below 21 percent, the standard deviation was below 0.4.

10.1.2 For materials with an oxygen index above 21 percent, the standard deviation ranged from 0.7 to 1.4. The higher value was for a material that exhibits the erratic behavior noted in 7.9.

10.2 The standard deviation within a laboratory ranged from 0.1 for clean burning materials to 1.0 for erratic materials.

[4] Such a statistical method as the Bruceton Staircase Method may be used. See Dixon, W. J., and Massey, F. J., Jr., *Introduction to Statistical Analysis* (2nd Edition), 1957, Chapter 19, McGraw-Hill Book Co., Inc., New York, N.Y. or Natrella, Mary, "Experimental Statistics," Section 10-4, *National Bureau of Standards Handbook 91*, 1963. Other procedures, such as using ten specimens at each oxygen concentration tried, have also proved successful.

REFERENCES

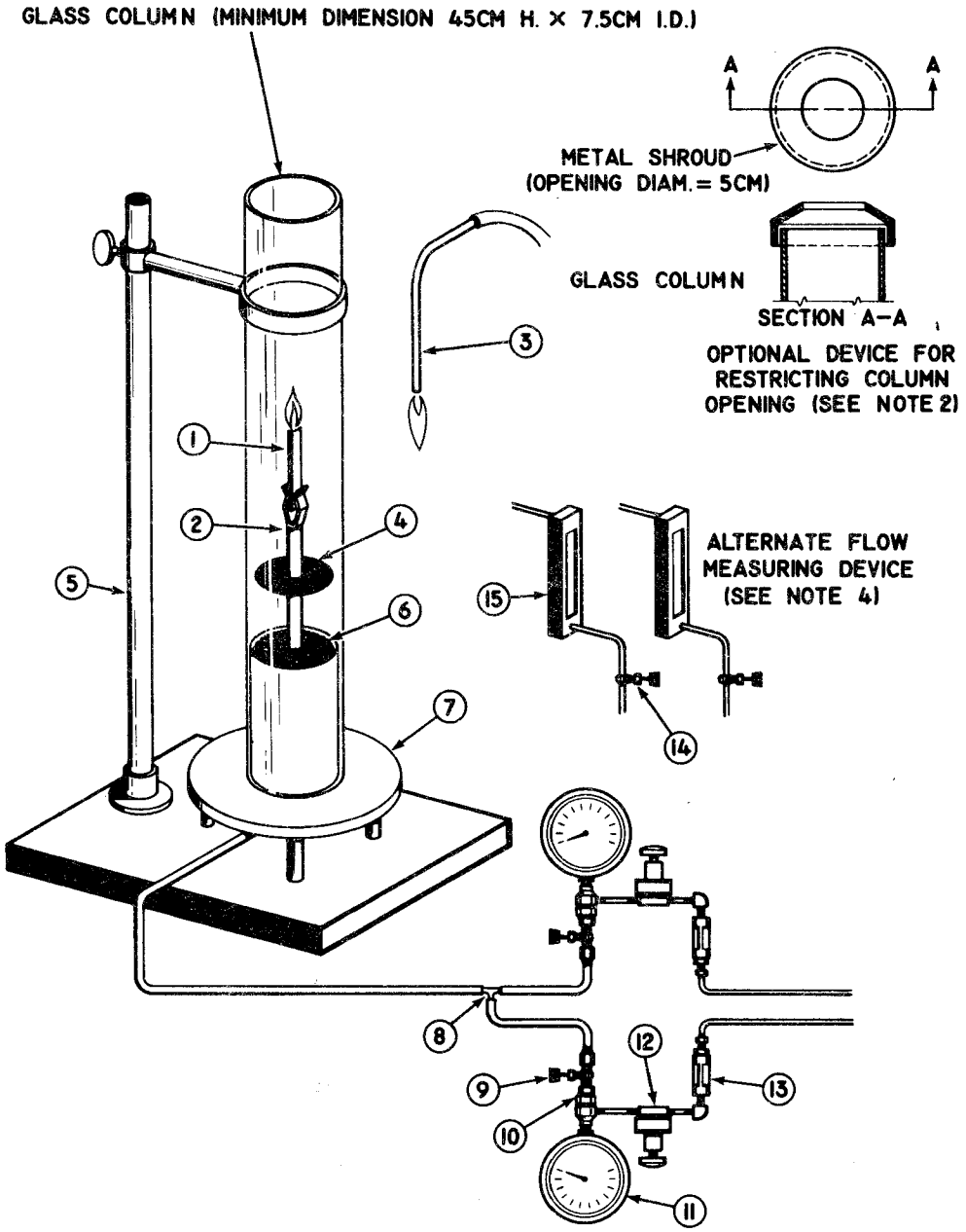
(1) Fenimore, C. P., and Martin, F. J. "Candle-type Test for Flammability of Polymers," *Modern Plastics*, MOPLA, Vol 43, November 1966, p. 141.

(2) Goldblum, K. B., "Oxygen Index: Key to Precise Flammability Ratings," *Society of Plastics Engineers Journal*, SPEJA, Vol 25, February 1969, p. 50.

(3) Andersen, J. W., and Friedman, R., "An Accurate Gas Metering System for Laminar Flow Studies," *Review of Scientific Instruments*, RSINA, Vol 20, 1949, p. 61.

(4) Isaacs, J. L., "The Development, Standardization and Utilization of the Oxygen Index Flammability Test," *General Electric TIS Report 69-MAL-13*, August 1969, Louisville, Ky.

(5) Supporting data for this method have been filed at ASTM Headquarters as RR 102: D-20.



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.

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