



Designation: D 3985 – 95

AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428
Reprinted from the Annual Book of ASTM Standards. Copyright ASTM

Standard Test Method for Oxygen Gas Transmission Rate Through Plastic Film and Sheeting Using a Coulometric Sensor¹

This standard is issued under the fixed designation D 3985; 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 procedure for determination of the steady-state rate of transmission of oxygen gas through plastics in the form of film, sheeting, laminates, coextrusions, or plastic-coated papers or fabrics. It provides for the determination of (1) oxygen gas transmission rate (O_2 GTR), (2) the permeance of the film to oxygen gas (PO_2), and (3) oxygen permeability coefficient PO_2 in the case of homogeneous materials.

1.2 *This standard does not purport to address all of the safety problems, 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.*

2. Referenced Documents

2.1 ASTM Standards:

- D 1434 Test Method for Determining Gas Permeability Characteristics of Plastic Film and Sheetings²
- D 1898 Practice for Sampling of Plastics³

3. Terminology

3.1 Definitions:

3.1.1 *oxygen transmission rate* (O_2 GTR)—the quantity of oxygen gas passing through a unit area of the parallel surfaces of a plastic film per unit time under the conditions of test. The SI unit of transmission rate is the $\text{mol}/(\text{m}^2 \cdot \text{s})$. The test conditions, including temperature and oxygen partial pressure on both sides of the film must be stated.

3.1.1.1 A commonly used unit of O_2 GTR is the $\text{cm}^3(\text{STP})/(\text{m}^2 \cdot \text{d})$ at one atmosphere pressure difference where 1 $\text{cm}^3(\text{STP})$ is 44.62 μmol , 1 atm is 0.1013 MPa, and one day is $86.4 \times 10^3 \text{ s}$. The O_2 GTR in SI units is obtained by multiplying the value in inch-pound units by 5.160×10^{-10} .

3.1.2 *oxygen permeance* (PO_2)—the ratio of the O_2 GTR to the difference between the partial pressure of O_2 on the two sides of the film. The SI unit of permeance is the $\text{mol}/(\text{m}^2 \cdot \text{s} \cdot \text{Pa})$. The test conditions (see 5.1) must be stated.

3.1.3 *oxygen permeability coefficient* ($\bar{P}O_2$)—the product of the permeance and the thickness of film. The permeability is meaningful only for homogeneous materials, in which case it is a property characteristic of the bulk material. This quantity should not be used, unless the relationship between thickness and permeance has been verified on tests using several different thicknesses of the material. The SI unit of oxygen permeability is the $\text{mol} \cdot \text{m} \cdot \text{s} \cdot \text{Pa}$. The test conditions (see 3.1.1) must be stated.

4. Summary of Test Method

4.1 The oxygen gas transmission rate is determined after the sample has equilibrated in a dry test environment. In this context, a “dry” environment is considered to be one in which the relative humidity is less than 1 %.

4.2 The specimen is mounted as a sealed semi-barrier between two chambers at ambient atmospheric pressure. One chamber is slowly purged by a stream of nitrogen and the other chamber contains oxygen. As oxygen gas permeates through the film into the nitrogen carrier gas, it is transported to the coulometric detector where it produces an electrical current, the magnitude of which is proportional to the amount of oxygen flowing into the detector per unit time.

5. Significance and Use

5.1 The O_2 GTR is an important determinant of the packaging protection afforded by barrier materials. It is not, however, the sole determinant, and additional tests, based on experience, must be used to correlate packaging performance with O_2 GTR. It is suitable as a referee method of testing, provided that the purchaser and the seller have agreed on sampling procedures, standardization procedures, test conditions, and acceptance criteria.

5.2 Limited statistical data on correlations with Test Method D 1434 methods are available.⁴ However, the oxygen transmission rate of a standard reference material (see 12.1) as determined manometrically by the National Bureau of Standards, is in good agreement with the values obtained in the coulometric interlaboratory test using material from the same manufacturing lot. Thus, this test method may be used as a referee method.

¹ This test method is under the jurisdiction of ASTM Committee F-2 on Flexible Barrier Materials and is the direct responsibility of Subcommittee F02.30 on Test Methods.

Current edition approved Sept. 10, 1995. Published November 1995. Originally published as D 3985 – 81. Last previous edition D 3985 – 81 (1988)ε¹.

² Annual Book of ASTM Standards, Vol 15.09.

³ Annual Book of ASTM Standards, Vol 08.01.

⁴ Supporting data for this test method can be obtained from ASTM Headquarters. Request RR:D20-1085.

6. Interferences

6.1 The presence of certain interfering substances in the carrier gas stream may give rise to unwanted electrical outputs and error factors. Interfering substances include free chlorine and some strong oxidizing agents. Exposure to carbon dioxide should also be minimized to avoid damage to the sensor through reaction with the potassium hydroxide electrolyte.

7. Apparatus

7.1 *Oxygen Gas Transmission Apparatus*, as diagrammed in Fig. 1⁵ with the following:

7.1.1 *Diffusion Cell* shall consist of two metal halves, which, when closed upon the test specimen, will accurately define a circular area. Typical acceptable diffusion cell areas are 100 cm² and 50 cm². The volume enclosed by each cell half, when clamped, is not critical; it should be small enough to allow for rapid gas exchange, but not so small that an unsupported film which happens to sag or bulge will contact the top or bottom of the cell. Each half of the diffusion cell shall be provided with a thermometer well for measuring temperature.

7.1.1.1 *O-Ring*—An appropriately sized groove, machined into the oxygen (or test gas) side of the diffusion cell, retains a neoprene O-ring. The test area is considered to be that area established by the inside contact diameter of the compressed O-ring when the diffusion cell is clamped shut against the test

specimen. The area, A , can be obtained by measuring the inside diameter of the imprint left by the O-ring on the specimen after it has been removed from the diffusion cell.

7.1.1.2 The nitrogen (or carrier gas) side of the diffusion cell shall have a flat raised rim. Since this rim is a critical sealing surface against which the test specimen is pressed, it shall be smooth and flat, without radial scratches.

7.1.1.3 *Diffusion Cell Pneumatic Fittings*—Each half of the diffusion cell shall incorporate suitable fittings for the introduction and exhaust of gases without significant loss or leakage.

7.1.1.4 It is desirable to thermostatically control the diffusion cell. A simple resistive heater, attached to the carrier gas side of the cell in such a manner as to ensure good thermal contact, is adequate for this purpose. A thermistor sensor and an appropriate control circuit will serve to regulate the cell temperature unless measurements are being made close to ambient temperature. In this case, it is desirable to provide cooling coils to remove some of the heat.

7.1.1.5 Experience has shown that arrangements using multiple diffusion cells are a practical way to increase the number of measurements which can be obtained from a coulometric sensor. A valving manifold connects the carrier gas side of each individual diffusion cell to the sensor in a predetermined pattern. Carrier gas is continually purging the carrier gas sides of those cells that are not connected to the sensor. Either test gas or carrier gas, as is appropriate, purges the test gas chamber of any individual cell.

7.1.2 *Catalyst Bed*—A small metal tube with fittings for attachment to the inlet on the nitrogen side of the diffusion cell shall contain 3 to 5 g of 0.5 % platinum or palladium catalysts

⁵ Suitable apparatus, identified as Oxtran Model 100 and Oxtran Model 10-50, can be obtained from Modern Controls, Inc. 6820 Shingle Creek Parkway, Minneapolis, MN 55430.

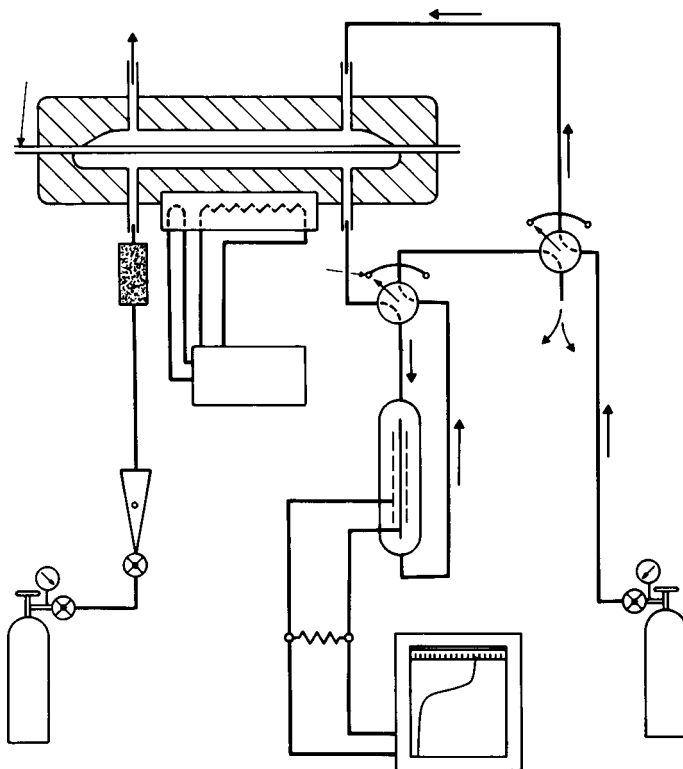


FIG. 1 A Practical Arrangement of Components for the Measurement of Oxygen Transmission Rate Using the Coulometric Method