Designation: F1927 – 14

# Standard Test Method for Determination of Oxygen Gas Transmission Rate, Permeability and Permeance at Controlled Relative Humidity Through Barrier Materials Using a Coulometric Detector[1]

This standard is issued under the fixed designation F1927; 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 rate of transmission of oxygen gas, at steady-state, at a given temperature and %RH level, through film, sheeting, laminates, co-extrusions, or plastic-coated papers or fabrics. This test method extends the common practice dealing with zero humidity or, at best, an assumed humidity. Humidity plays an important role in the oxygen gas transmission rate ($O_2$GTR) of many materials. This test method provides for the determination of oxygen gas transmission rate ($O_2$GTR), the permeance of the film to oxygen gas ($PO_2$), the permeation coefficient of the film to its thickness ($P''O_2$), and oxygen permeability coefficient ($P'O_2$) in the case of homogeneous materials at given temperature and %RH level(s).

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *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 precautionary statements are given in Section 9.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1898 Practice for Sampling of Plastics (Withdrawn 1998)[3]

D3985 Test Method for Oxygen Gas Transmission Rate Through Plastic Film and Sheeting Using a Coulometric Sensor

E104 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions

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

## 3. Terminology

3.1 *Definitions:*

3.1.1 *oxygen permeability coefficient* ($P'O_2$)—the product of the permeance and the thickness of the 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 mol/(m · s · Pa). The test conditions (see 3.1.4) must be stated.

3.1.2 *oxygen permeance* ($PO_2$)—the ratio of $O_2$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 mol/($m^2$ · s · Pa). The test conditions (see 3.1.4) must be stated.

3.1.3 *oxygen permeation coefficient* ($P''O_2$)—the ratio of $O_2$GTR to the thickness of the film. The SI unit of permeance is the mol/($m^2$ · s · cm). The permeation coefficient 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 transmission rate is known.

3.1.4 *oxygen transmission rate*—at a given temperature and %RH ($O_2$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 mol/($m^2$ · s). The test conditions, including temperature, %RH and oxygen partial pressure on both sides of the film must be stated.

3.1.5 *transmission rate* ($O_2$GTR)—a commonly used metric unit of $O_2$GTR is the $cm^3$ (STP)/($m^2$ · d) at one atmosphere pressure differential where: 1 $cm^3$ at Standard Temperature and Pressure (STP = 273.15K; $1.013 \times 10^5$ Pa) is 44.62 µmol and one day is $86.4 \times 10^3$ s. $O_2$GTR in SI units is obtained by

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[1] This test method is under the jurisdiction of ASTM Committee F02 on Flexible Barrier Packaging and is the direct responsibility of Subcommittee F02.10 on Permeation.

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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] The last approved version of this historical standard is referenced on www.astm.org.

multiplying the value in metric units by $5.165 \times 10^{-10}$ or the value in inch-pound units [($cm^3$(STP)/100 $in.^2 \cdot d$)] by $8.005 \times 10^{-9}$.

## 4. Summary of Test Method

4.1 The oxygen gas transmission rate is determined after the sample has equilibrated in a given temperature and humidity environment.

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 at a given temperature and %RH and the other chamber is purged by a stream of oxygen at the same temperature as the $N_2$ stream but may have a different %RH than the $N_2$ stream. In this case the environment would more closely simulate actual shelf conditions. 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 $O_2$GTR at a given temperature and %RH 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 purchaser and seller have agreed on sampling procedures, standardization procedures, test conditions and acceptance criteria.

## 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 diagramed in Fig. 1 and described following. Alternative systems need to be evaluated to ensure equivalent performance.

7.1.1 *Diffusion Cell,* consisting of two metal halves, that, when closed upon the test specimen, will accurately define a circular area. Typical acceptable diffusion cell areas are 100 and 50 $cm^2$. 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 sides of the cell. The diffusion cell shall be provided with a temperature measuring and controlling capability and a means to measure and control relative humidity.

7.1.1.1 Temperature control is critical because RH can vary as much as 5 % RH/°C in certain temperature regions. A compact design of the diffusion cell structure with associated controls would lend itself to better temperature control. The temperature should be controlled to ±0.5°C or better.

7.1.1.2 *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

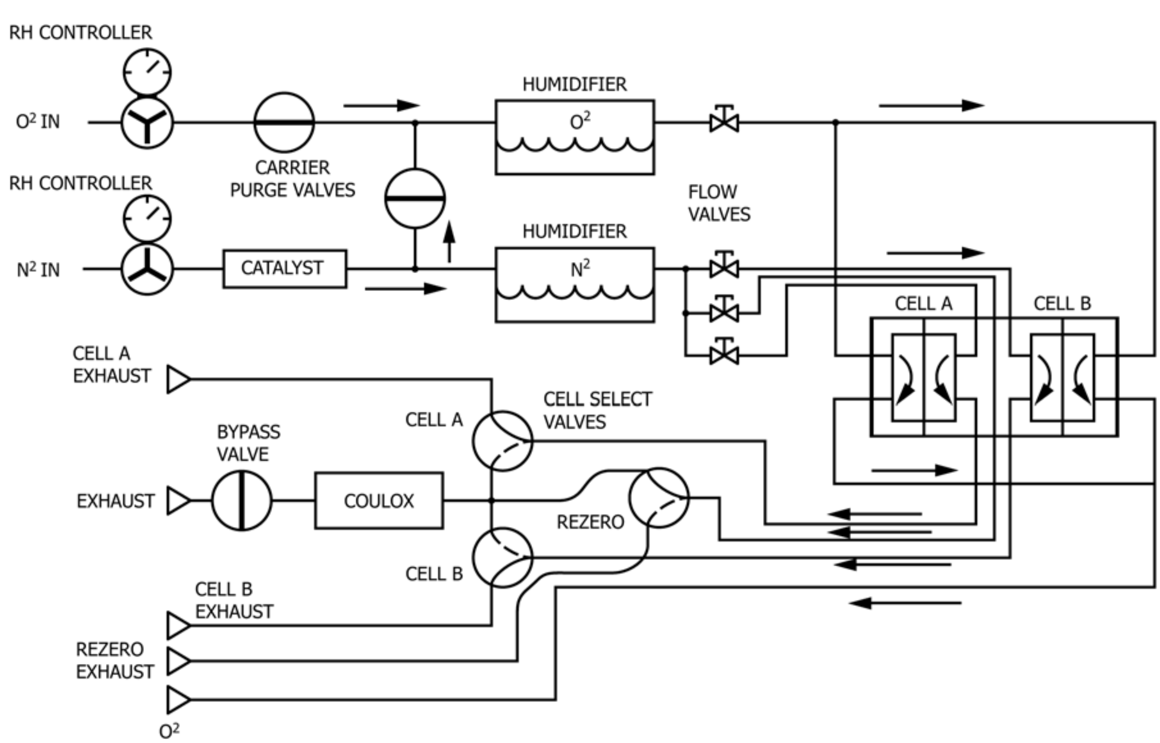


FIG. 1 A Practical Arrangement of Components for the Measurement of Oxygen Transmission Rate Under Precise Relative Humidity Conditions Using the Coulometric Method