



# Standard Test Method for Water Vapor Transmission Rate of Sheet Materials Using Dynamic Relative Humidity Measurement<sup>1</sup>

This standard is issued under the fixed designation E398; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers dynamic evaluation of the rate of transfer of water vapor through a flexible barrier material and allows conversion to the generally recognized units of water vapor transmission (WVT) as obtained by various other test methods including the gravimetric method described in Test Methods [E96/E96M](#).

1.2 *Limitations*—This test method is limited to flexible barrier sheet materials composed of either completely hydrophobic materials, or combinations of hydrophobic and hydrophilic materials having at least one surface that is hydrophobic.

1.3 The minimum test value obtained by this test method is limited by the leakage of water vapor past the clamping seals of the test instrument. A reasonable value may be approximately  $0.01 \text{ g}/24 \text{ h}\cdot\text{m}^2$  for any WVTR method including the desiccant procedure of Test Methods [E96/E96M](#) at  $37.8^\circ\text{C}$ , and 90 % relative humidity. This limit can be checked for each instrument with an impervious specimen such as aluminum foil. Calibration procedures can compensate for the leakage rate if so stated.

1.4 This test method is not suitable for referee testing at this time, but is suitable for control testing and material comparison.

1.5 Several other ASTM test methods are available to test a similar property. This test method is unique in that it closely duplicates typical product storage where a transfer of moisture from a package into the environment is allowed to proceed without constantly sweeping the environmental side with dry gas. Methods with constantly swept dry sides include Test Methods [F1249](#), [F372](#), and [F1770](#).

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

<sup>1</sup> 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. A previous version was under the jurisdiction of ASTM Committee C16.

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1.7 *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.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

- [C168 Terminology Relating to Thermal Insulation E96/E96M Test Methods for Water Vapor Transmission of Materials](#)
- [E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods](#)
- [E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method](#)
- [F17 Terminology Relating to Flexible Barrier Packaging](#)
- [F372 Test Method for Water Vapor Transmission Rate of Flexible Barrier Materials Using an Infrared Detection Technique \(Withdrawn 2009\)<sup>3</sup>](#)
- [F1249 Test Method for Water Vapor Transmission Rate Through Plastic Film and Sheeting Using a Modulated Infrared Sensor](#)
- [F1770 Test Method for Evaluation of Solubility, Diffusivity, and Permeability of Flexible Barrier Materials to Water Vapor \(Withdrawn 2004\)<sup>3</sup>](#)

## 3. Terminology

3.1 *Definitions*—For definitions of terms concerning the transmission of water vapor refer to Terminologies [C168](#) and [F17](#).

## 4. Summary of Test Method

4.1 The specimen is mounted between two chambers, one of relatively high relative humidity and the other of relatively low relative humidity. After conditioning and isolation of chambers, the rate at which the moisture increases within the

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

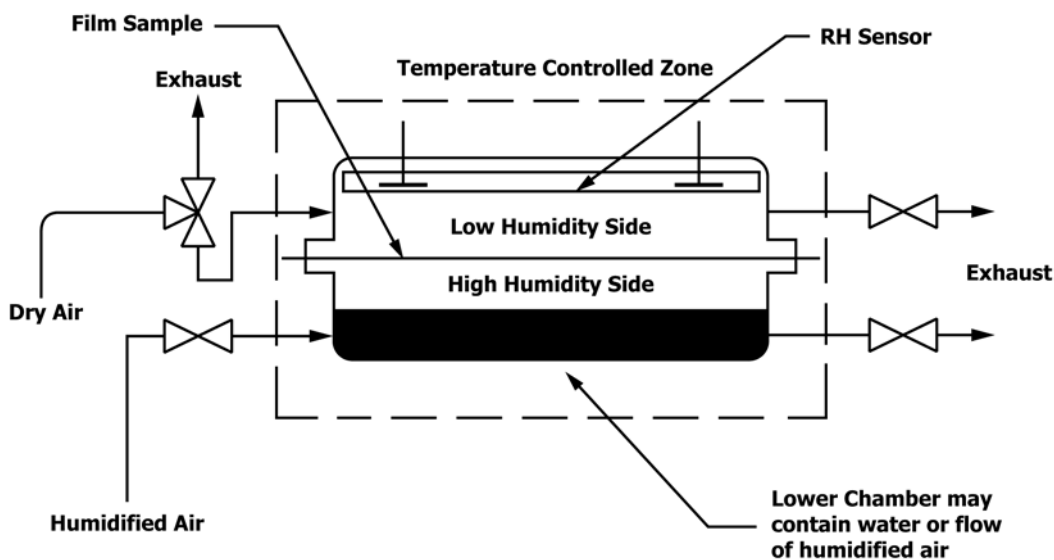


FIG. 1 Sectional Diagram of a Typical Test Chamber Using Relative Humidity Sensing

relatively low relative humidity chamber over a predetermined range of interest is measured. This rate is compared to the rate for a calibration sample (calibrated gravimetrically) and the WVTR is determined.

## 5. Significance and Use

5.1 No single set of test conditions can represent all climatic and use conditions, so this WVTR test method serves more to compare different materials at a stated set of conditions than to predict their actual performance in the field under any conditions.

5.2 The water vapor transmission rate, under known and carefully controlled conditions, may be used to evaluate the vapor barrier qualities of a sheet. Direct correlation of values obtained under different conditions of test temperature and relative humidity will be valid provided the barrier material under test does not undergo changes in solid state (such as a crystalline transition or melting point) at or between the conditions of test.

## 6. Apparatus

6.1 The apparatus employed should have the following elements:

6.1.1 *Test Cell*, designed to clamp a defined sample area sufficiently large to be representative of the sample (an area of 50 cm<sup>2</sup> has been shown to be satisfactory) between two chambers, one to contain an atmosphere of low relative humidity (sensor-side chamber), and the other an atmosphere of higher relative humidity (humidified chamber) (see Fig. 1).

6.1.2 *Clamping Arrangement*, to allow rapid insertion and removal of the test specimen equipped with gaskets against which the specimen is held to the dry chamber by a clamping force sufficient to resist leakage.

6.1.3 *Humidification Provision*, for maintaining humidity in the wet cell at the desired level. Where an atmosphere close to saturation is required, this may be achieved by means of a reservoir of water or a saturated sponge provided there is a

spacing 8 mm or less, between the water source and the specimen and yet no direct contact. Other levels of relative humidity may be obtained with saturated salt solutions or a stream of controlled humidified air.

6.1.4 *Air Source*—Air dried below the operating humidity range of the instrument (5 % relative humidity or less) shall be used as a purge for the sensor-side chamber. Various desiccants have been found satisfactory as drying agents.

6.1.5 *Sensor*, with rapid response and sensitivity capable of detecting changes in the moisture content of the gas within the dry chamber of 0.05 % relative humidity or less. This sensor may take any of a number of forms. For this purpose, the following have been described in the literature: an electrical resistance element,<sup>4</sup> an electrolytic cell,<sup>5</sup> and a beam of infrared radiation.<sup>6</sup>

6.1.6 *Data Collection*, a means to convert the sensor's moisture-change response into a signal that can be used to calculate the passage of moisture through the material under test. This may take the form of registering the time required for the signal to pass between two selected levels of relative humidity, or the change in signal over a given interval of time.

6.1.7 *Temperature Control*, a means of maintaining the test-cell purge air and the test specimen at a constant known temperature within  $\pm 0.1^\circ\text{C}$  is provided.

6.1.8 *Standard Films*, which have been calibration by gravimetric means. Various films have been found satisfactory with various thicknesses of PET most commonly used.

## 7. Test Specimens or Sample

7.1 Test specimens shall be representative of the sample.

<sup>4</sup> Ranger, H. O., and Gluckman, M. J., *Modern Packaging*, Vol 37, No. 11, July 1964, p. 153.

<sup>5</sup> Toren, P. E., *Analytical Chemistry*, Vol 37, 1965, p. 922.

<sup>6</sup> Husband, R. M., and Petter, P. J., *Tappi*, Vol 49, 1966, p. 565.

7.2 Where the test specimen is completely hydrophobic, no special conditioning procedure is required except that the surface exposed in the dry cell must not have visible free water present.

7.3 For specimens containing a hydrophilic layer, consideration must be given to its orientation. If the hydrophilic layer, such as paper, is facing the dry side of the test apparatus, false readings may result.

## 8. Testing Conditions and Instrument Test Range

8.1 The conditions for the test are selected. In the U.S.A., a standard condition of 37.8°C and 90 or 100 % relative humidity differential is commonly used, but the level can be whatever condition is of interest. If a different driving force is used in the test than is to be reported, a linear adjustment can be made if it has been demonstrated that the material does not undergo solid-state changes at these conditions. The use of such an adjustment is to be clearly stated in the report.

8.2 The instrument normally uses a reservoir of water to produce 100 % relative humidity in the high relative humidity chamber. The sensor-side chamber is purged with dry air prior to testing, but the relative humidity when measuring WVTR can be any level desired below the level of the wet cell and within the calibrated range. A dry cell level of nominally 10 % or 35 % is commonly used, but other levels can be used as desired. The final report will state the conditions of the wet and dry chambers. If 100 % for the wet chamber and 10 % for the dry chamber are used, this will yield a driving force of 90 % relative humidity (100 % versus 10 %). The driving force for other combinations of wet and dry chamber conditions shall be similarly calculated.

8.3 The instrument is set to record the time to change from  $0.1 \pm 0.05$  % below to  $0.1 \pm 0.05$  % above this nominal dry chamber condition. The actual relative humidity used for the end points will be known.

## 9. Calibration and Standardization

9.1 The response of the relative humidity sensor is calibrated with a NIST certified humidity sensor. This is accomplished either with (1) The instrument sensor in place and a means of exposing the certified sensor to the known humidified gas stream or (2) The instrument sensor removed from the instrument and calibrated. The relative humidity used for this calibration shall cover the range of actual relative humidity used during testing.

9.2 A standard, calibration film whose WVTR has been gravimetrically determined (referred in 10.7 as  $WVTR_C$ ) in accordance with the desiccant method of Test Methods E96/E96M is tested in the instrument as described below. The time for the relative humidity to change through the range selected is noted. (Referred in 10.7 as  $T_C$  = Time to move through humidity range for calibration film).

## 10. Procedure

10.1 Cut the specimen to the proper size for the test cell being used.

10.2 Orient the specimen appropriately.

10.2.1 In dynamic test procedures, the presence of a water-sensitive surface in the dry chamber may result in a reproducible but false reading due in part to edge effects. Tests in this orientation cannot reliably be made by this procedure.

10.3 Purge the dry chamber with the dried, purge air until the cell and exposed specimen surface are at equilibrium at a lower humidity condition than that employed for the test cycle.

10.4 Shut off the purge air and isolate the sensor containing chamber from the surrounding atmosphere. Allow the cell and specimen to begin to return to balance as moisture permeates through the film under test until the initial humidity desired to start the test is reached.

10.5 Measure and record the time for the relative humidity within the dry chamber changes from  $0.1 \pm 0.05$  % below the nominal dry condition to  $0.1 \pm 0.05$  % above the nominal condition. Conditions for the test samples must be the same as for the calibration sample.

10.6 Repeat steps 10.3 to 10.5 without removing the specimen until successive readings of the time to transverse the humidity range are uniform. The resulting value is taken as the test result for that specimen.

10.7 The WVTR for the sample under test is calculated by comparing its time to the time required for the calibration film.

$$WVTR_T = WVTR_C \cdot T_C \div T_T \quad (1)$$

where:

$WVTR_T$  = WVTR of sample under test,

$WVTR_C$  = WVTR determined gravimetrically,

$T_T$  = time to move through humidity range for sample under test, and

$T_C$  = time to move through humidity range for calibration film.

## 11. Report

11.1 The WVTR can be calculated as described in 10.7 and reported with appropriate significant figures.

11.2 When suitable test limits have been developed with samples of known acceptance, the dynamic test results in terms of seconds or humidity units may be reported directly, if desired.

11.3 Test conditions (including temperature, relative humidity) are reported along with a complete description of the instrument used.

## 12. Precision and Bias

12.1 The precision of this test method is based on an interlaboratory study of Test Method E398, Standard Test Method for Water Vapor Transmission Rate of Sheet Materials Using Dynamic Relative Humidity Measurement, conducted in 2012. Each of seven laboratories tested seven different materials. Every “test result” represents an individual determination, and all participants reported duplicate WVTR test results. Practice E691 was followed for the design and analysis of the data.

12.1.1 *Repeatability (r)*—The difference between repetitive results obtained by the same operator in a given laboratory

**TABLE 1 Water Vapor Transmission Rate (g/m<sup>2</sup> × day)**

Material	Average <sup>A</sup> $\bar{x}$	Repeatability Standard Deviation $S_r$	Reproducibility Standard Deviation $S_R$	Repeatability Limit $r$	Reproducibility Limit $R$
Polyvinylidene Chloride—White	0.424	0.019	0.157	0.053	0.440
Polyethylene Resin Vapor Barrier—Blue	0.656	0.034	0.246	0.097	0.690
Aluminum Foil, fiberglass, and polyester fabric	0.031	0.007	0.042	0.020	0.118
PET—1 mil	22.954	0.700	2.601	1.960	7.282
PET—5 mil	4.360	0.302	0.588	0.845	1.646
PCTFE homopolymer, high performance barrier film—1 mil	0.272	0.026	0.026	0.073	0.073
PCTFE homopolymer, high performance barrier film—4 mil	0.090	0.006	0.035	0.018	0.097

<sup>A</sup>The average of the laboratories' calculated averages.

applying the same test method with the same apparatus under constant operating conditions on identical test material within short intervals of time would in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

12.1.1.1 Repeatability can be interpreted as maximum difference between two results, obtained under repeatability conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

12.1.1.2 Repeatability limits are listed in [Table 1](#).

12.1.2 *Reproducibility (R)*—The difference between two single and independent results obtained by different operators applying the same test method in different laboratories using different apparatus on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

12.1.2.1 Reproducibility can be interpreted as maximum difference between two results, obtained under reproducibility conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

12.1.2.2 Reproducibility limits are listed in [Tables 1 and 2](#).

12.1.3 The above terms (repeatability and reproducibility limit) are used as specified in [Practice E177](#).

12.1.4 Any judgment in accordance with statements [12.1.1](#) and [12.1.2](#) would have an approximate 95 % probability of being correct.

### 13. Keywords

13.1 dynamic measurement; flexible barrier materials; relative humidity; sheet material; water vapor transmission

**TABLE 2 Days to Equilibrium (no replicate data reported)**

Material	Average <sup>A</sup>	Repeatability Standard	Reproducibility Standard	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	Deviation $S_r$	Deviation $S_R$	r	R
Polyvinylidene Chloride—White	1.11		0.67		1.87
Polyethylene Resin Vapor Barrier—Blue	1.20		0.83		2.34
Aluminum foil, fiberglass, and polyester fabric	2.03		1.72		4.80
PET—1 mil	0.77		0.41		1.16
PET—5 mil	0.95		0.39		1.10
PCTFE homopolymer, high performance barrier film—1 mil	1.63		0.94		2.64
PCTFE homopolymer, high performance barrier film—4 mil	2.39		1.63		4.58

<sup>A</sup>The average of the laboratories' calculated averages.

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