

WHICH WVTR TEST METHOD IS RIGHT FOR YOUR APPLICATION?



AMETEK MOCON

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Abstract

Water vapor transmission rate (WVTR) is an important factor across many industries and applications. From breathable healthcare and personal protective equipment (PPE) to high-barrier electronics and solar panels, the rate of transmission for water vapor through materials greatly impacts quality, performance and safety.

Introduction: Why is WVTR Important?



Compostable packaging plays an important role in protecting the environment

Food Packaging

The packaging used to protect food plays a critical role in achieving the desired shelf life of the product. Poor performing barriers will allow food to spoil sooner creating both waste and unhappy customers. Films and coatings that are commonly used to provide water vapor protection need to be closely checked and monitored to ensure they are properly applied to achieve the desired performance.

Goals:

- Preservation: Low WVTR packaging keeps moisture out, preventing spoilage and microbial growth.
- Crispness: Maintaining proper humidity levels in packaging helps preserve the texture and freshness of fruits, vegetables and snacks.



PPE needs to be breathable

Healthcare

Healthcare is about safety and comfort. As an example, the purpose of PPE is to keep the user safe from harm or sickness. Airborne pathogens are common concerns in this industry, so PPE needs to be designed and tested to let the user's breath and their body humidity escape, but to block microbes and pathogens from getting through to the person. For diapers, the barriers need to hold or repel water yet let humidity pass through to protect the skin from direct moisture contact.

Medical Packaging

One of the primary purposes of medical packaging is to keep the contents clean and microbe free after it has been sterilized. These barriers have a different level of breathability than PPE or diapers.

Goals:

- Sterility: Low WVTR in medical packaging (like implants, syringes) is crucial to maintain sterility and prevent contamination.
- Drug Efficacy: Some medications are moisture-sensitive and require precise humidity control for stability and effectiveness.
- Drug Stability: Many pharmaceuticals degrade in the presence of moisture. Low WVTR packaging ensures their potency and shelf life.
- Controlled Release: WVTR can be carefully controlled in drug delivery systems (like patches) to regulate medication release.



Increased permeability of polymer versus glass syringe barrels changes barrier properties

WHY WVTR TESTING IS IMPORTANT



Construction Materials

Vapor barriers used in the construction industry need to allow water vapor to transmit through but block liquid water. Barriers used in soil erosion control, roofing, house wraps, and insulation are among the most common that are tested for water vapor transmission rate (WVTR).

Goals:

- Building Materials: Understanding WVTR of building materials helps prevent moisture buildup, which can lead to mold, rot, and structural damage.
- Insulation: Proper WVTR in insulation materials is essential for maintaining energy efficiency and preventing condensation.



Tyvek® wraps allow moisture to escape while protecting from bulk water

Tyvek® is a registered trademark of affiliates of DuPont de Nemours, Inc.

Electronics

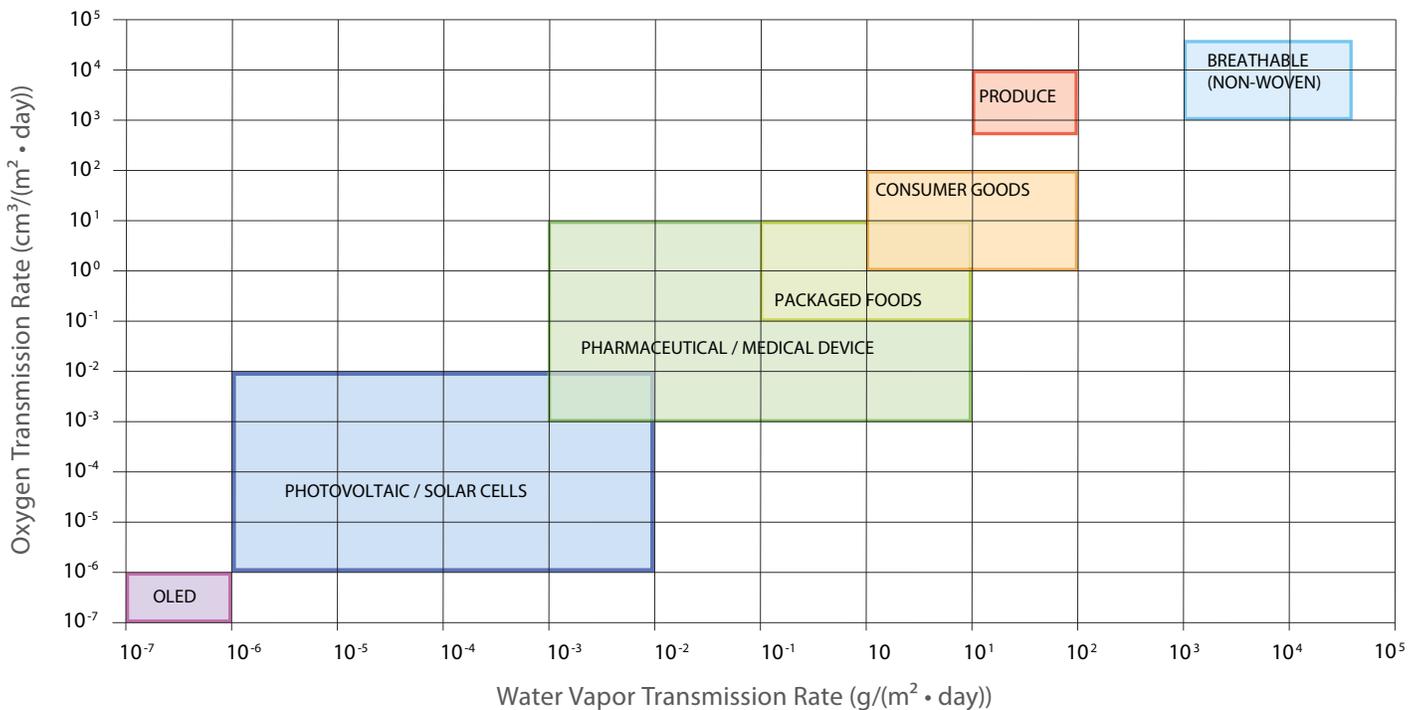
Electronics, photovoltaic panels and organic light-emitting diodes (OLED) are sensitive to moisture ingress. The coatings, encapsulations and barriers that are used to protect them are critical to their performance and lifespan.

Goals:

- Corrosion: Moisture can cause corrosion of electronic components, leading to malfunctions. Low WVTR in packaging and enclosures protects sensitive electronics.
- Performance: High humidity can affect the performance of electronic devices. Controlled WVTR helps maintain optimal operating conditions.



Photovoltaic panels



WHICH MEASUREMENT IS BEST FOR MY APPLICATION?

To measure the wide range of transmission rate levels across these industries, there are four unique primary ASTM standards. Each standard utilizes a different measurement technology and technique that is best for a target detection range. In most cases, the best method is the one capable of testing at the level of your material.

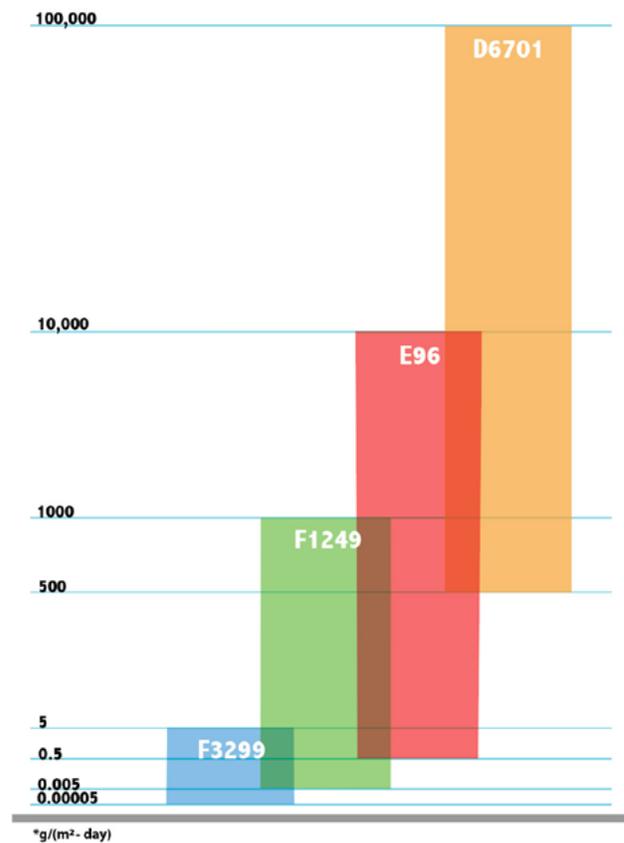
At many test levels, there are several options. Choosing the best method for each application depends on several factors such as; common standards required within an industry, speed of testing results, accuracy of the testing results, the level of the transmission rate, sample type, shape or configuration, technical ability of the staff and many more.

ASTM standards for WVTR testing are chosen based on the material's barrier properties to ensure accurate and reliable results. Different industries and applications have different needs.

- **ASTM D6701** is suitable for very high transmitting materials due to its high humidity sensor and unique apparatus that ensures great lab to lab repeatability.
- **ASTM E96** is a versatile method suitable for a wide range of materials, from high to moderate transmitters.
- **ASTM F1249** is specifically designed for moderate to good barrier materials, offering higher sensitivity and accuracy in this range and overall faster test times than the gravimetric ASTM E96 method.
- Finally, **ASTM F3299** apparatus engineered by MOCON® for extremely high barrier materials provides the sensitivity and precision required for accurately measuring very low WVTR values down to 0.05mg/(m² · day).

In essence, each standard offers a balance of sensitivity, accuracy and practicality for a specific range of WVTR. Using the appropriate standard ensures that the WVTR measurement is both meaningful and reliable.

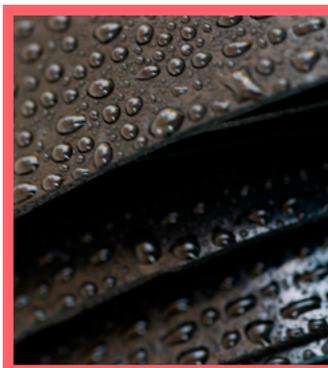
WVTR ASTM Standard Test Method Permeation Ranges



D6701 Breathable barriers



E96 Moderate barriers



F1249 Food and medical barriers



F3299 High barriers





ASTM D 6701

Equivalent to EDANA/INDA NWSP 070.4.R0 and NWSP 070.5.R1

Polymer non-woven and other porous polymer membranes play a major role in PPE, personal care and construction membranes. These unique materials are designed to allow moisture to transmit through at relatively high rates but prevent liquid or droplets of water from passing through.

ASTM D6701 is an instrumental method utilizing a modified inverted cup and guard film concept with a precision RH sensor. This design eliminates the variable air gap issue that can affect the transmission rate during an E96 test. The unique design allows measurement of True Permeation through the samples that reflect real-life situations for high-transmitting moisture barriers.

The only instrument complying with ASTM D6701 is the MOCON PERMATRAN-W® 101K (Fig 1). By measuring moisture concentration, carrier gas flow and temperature, it can measure WVTR between 500 and 100,000 g/(m² · day). Compared to the gravimetric E96 method, the D6701 method involves far less time and labor making it ideal for quality control testing. Additionally, the PERMATRAN-W 101K is designed to test six samples simultaneously, instead of just one sample as in the manual E96 cup method.

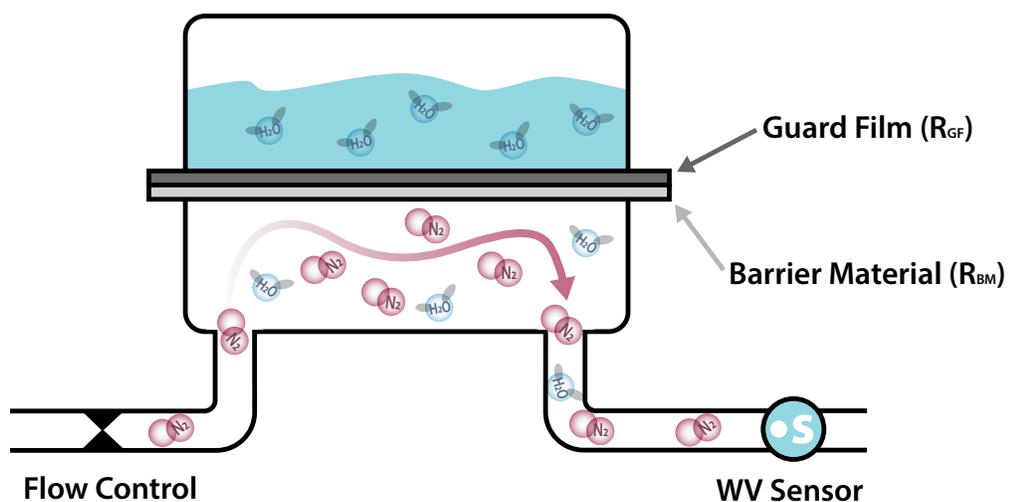


Fig1. ASTM D6701 Inverted Cup with Guard Film Concept.

Learn more about [ASTM D6701](#).

Learn more about [PERMATRAN-W 101K](#).



ASTM E96

Equivalent to ASTM D1653, TAPPI T 448, T 464, ISO 2528, JIS Z0208, GB/T 1037, DIN 53122-1

ASTM E96, also called the gravimetric or cup method, is a common method used to determine the WVTR of high-transmitting plastic barriers or non-woven materials. The cup method (Fig 2) involves placing a test material on top of a dish filled either with water (to test the WVTR going out of the dish) or a desiccant (to test the WVTR going into the dish). The test dish is placed into a temperature and humidity controlled chamber and periodically weighed. The weighing duration can range from days to weeks. An analysis of the weight change over time is used to calculate the materials WVTR.

The main disadvantage of E96 compared to D6701 or F1249 is the speed of the test. E96 testing usually takes days or weeks to obtain repeatable, accurate measurement data. Additionally, due to the limited sensitivity of the balance, this method is generally only considered suitable for testing high to medium WVTR materials.

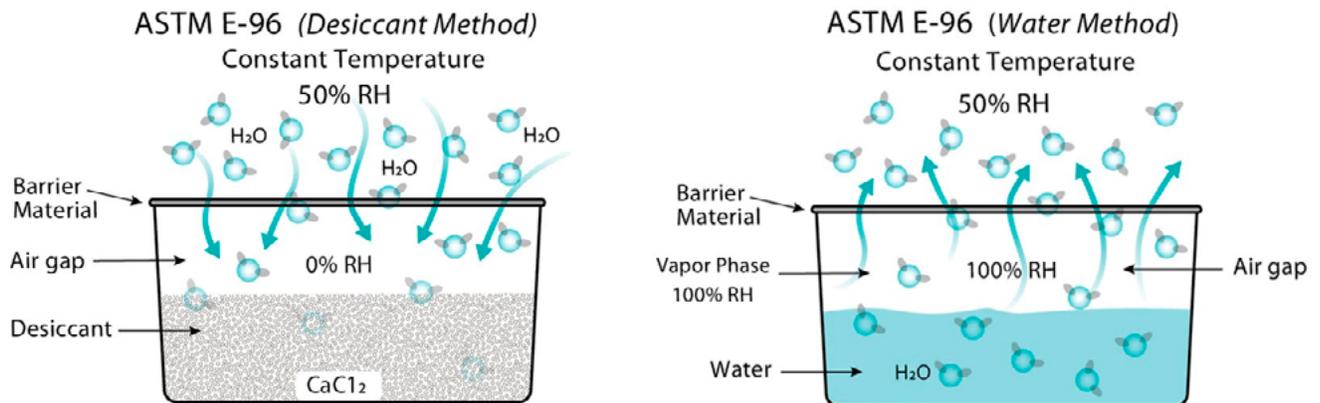


Fig 2. ASTM E96 Cup Test

Learn more about [ASTM E96](#).

INFRARED DETECTION METHOD



ASTM F1249

Equivalent to TAPPI T 557, ISO 15016-2, JIS K 7129-2, GB/T 26253, 31355

ASTM F1249 is a standard test method for measuring WVTR through plastic film sheeting using a modulated infrared sensor (F1249 was initially published in 1990). This test method is suitable to test flexible barrier films and sheets consisting of single and multilayer natural or synthetic polymers and foils, including coated materials.

As illustrated in Fig. 3, this method, uses a dry chamber separated from a wet chamber of known temperature and humidity by the barrier material to be tested. The dry chamber and the wet chamber make up a diffusion cell in which the test film is sealed. Water vapor transmitting through the film mixes with the gas in the dry chamber, which flows through a pressure-modulated infrared sensor. This sensor measures the fraction of infrared energy absorbed by the water vapor and produces an electrical signal, the amplitude of which is proportional to the water vapor concentration. The amplitude of the electrical signal produced by the test film is then compared to the signal produced by measurement of a reference film of known WVTR. This information is then used to calculate the rate at which moisture is transmitted through the material being tested.

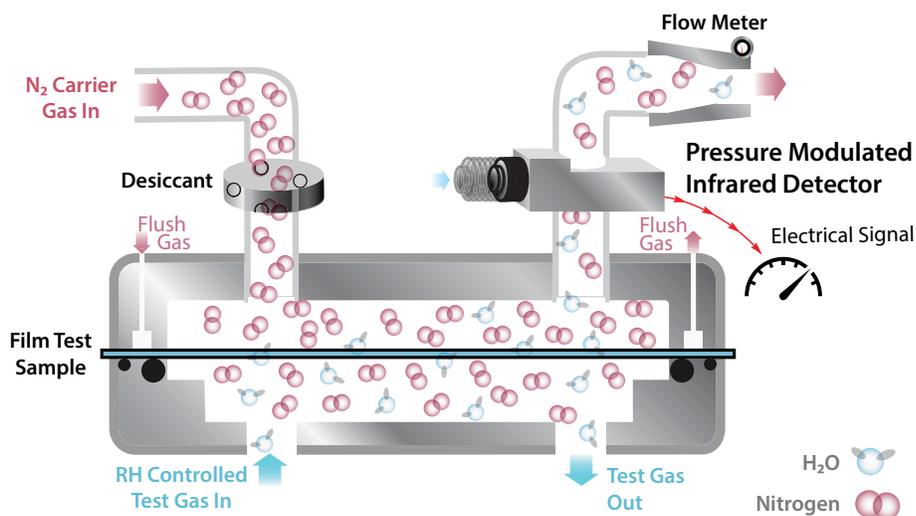


Fig. 3 ASTM F1249 Diffusion Film Test Cell

Learn more about [ASTM F1249](#).

Learn more about the [AQUATRAN 3/34](#), [AQUATRAN 3/38](#) and [AQUATRAN 3/40](#) instruments.



ASTM F3299

Equivalent to ISO 15106-3, JIS K 7129-3, GB/T 21529, DIN 53122-2

ASTM F3299 is a standard test method for measuring WVTR through barriers using an electrolytic detection sensor (Coulometric P_2O_5 sensor).

This test method, analogous to ASTM F1249, mounts a test film between a dry and wet chamber at a specified temperature and humidity level. As water permeates from the wet side to the dry side, the N_2 carrier gas sweeps the transmitting water vapor to the instrument's P_2O_5 detector. Within a P_2O_5 detector, current dissociates water into hydrogen and oxygen. The current produced by this process directly correlates to the molecules of water vapor dissociated. By counting each water vapor molecule, the ASTM F3299 MOCON AQUATRAN® 3 instrument has 100X more sensitivity than the F1249 apparatus.

To achieve accurate sensitivity at these low levels of detection, the MOCON ASTM F3299 instrument tests do innately take longer to reach a steady state since the baseline leak rate of the instrument must be evaluated in between every test cell (i.e., sample) reading, thus decreasing the frequency of data collection. With the longer test times and best low-level sensitivity, the MOCON AQUATRAN 3 used with research and development (R&D) of high-barrier materials.

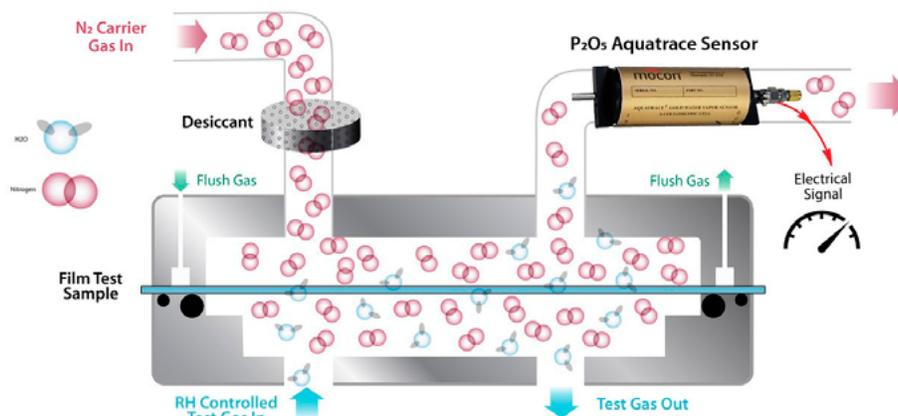


Fig 4. ASTM F3299 Film Diffusion Test Cell

Learn more about [ASTM F3299](#).

Learn more about the [AQUATRAN 3](#) instrument.

MOCON has the expertise to help you decide.

It takes more than specialized equipment to accurately determine barrier and package performance. With nearly 60 years of permeation expertise, our AMETEK MOCON ISO 17025 accredited permeation testing laboratory leads the way with industry-recognized and custom test methods, purpose-built instruments and experienced Applications Specialists. Our testing helps our clients to:

- Extend and validate shelf-life claims
- Address problems that have arisen during R&D
- Obtain the data to develop more sustainable packaging solutions
- Provide third-party material verification

Industries we serve:



Food & Beverage



Consumer Products



Healthcare



Pharmaceutical



Packaging & Converters

Water Vapor Transmission Rate (WVTR) Testing Services

Test Method	Typical Samples	Analysis Range g/(m ² · day)
ASTM F1249 – WVTR of film materials using a modulated IR detector Note: Our MOCON laboratory offers a modified version of this test to analyze package samples.	Food, pharmaceutical, medical device and electronics packaging Research materials including: compostable & recyclable blends	0.005 to 1000 Note: Package WVTR test range from 0.00003 to 0.5 g/day
ASTM F3299 – WVTR of high barrier film materials utilizing a P ₂ O ₅ detector Note: Our MOCON laboratory offers a modified version of this test to analyze package samples.	Electronics, pharmaceutical, medical device and high-barrier materials	0.00005 to 5.0 (0.05 to 5000 mg/(m ² · day)) Note: Package WVTR test range from 0.0003 to 25.0 mg/day
ASTM E96 – WVTR of film materials using a gravimetric methodology	High transmitting, porous and perforated films, and coated paper	
ASTM D6701 – WVTR through high transmission rate materials	Breathable and non-wovens materials, such as building wraps and skin contact products	500 to 100,000 g/(m ² · day)

Training Overview

The better you understand how to run our instruments, the more accurate and useful your permeation tests will be.

In response to customer feedback, we offer advanced permeation training. We've drawn on our decades of testing experience to create a comprehensive new advanced permeation training course. Over a few days at either your laboratory or our headquarters, we will guide up to four people through accurate and reproducible film and/or package permeation testing techniques. You'll also receive a classroom session on permeation basics that you can use to teach your colleagues.

Learn more about [Advanced Permeation Training](#).



TEST METHOD COMPARISON



Key Features	ASTM D6701	ASTM E96	ASTM F1249	ASTM F 3299
Samples				
Test Concept	RH level of test gas in carrier gas stream	Weight change of water or desiccant	Infrared measurement of water molecules	Absolute coulometric sensor for water molecules
Sensor Type	Precision RH probe	Weight balance	Pressure modulated IR sensor	MOCON precision P ₂ O ₅ sensor
Test Cell	Diffusion cell	Weighing dish	Diffusion cartridge	Diffusion cartridge
Test Cell Setups	Inverted cell, dry on carrier gas side	Wet cup; dry cup; inverted cup	Dry on carrier gas side	Dry on carrier gas side
Test RH	100%	10%-90%	10%-90% & 100%	10%-90% & 100%
Test Temp	20-50°C	20-40°C	10-40°C	5-50°C
WVTR Determination	Calculated from flow and RH of carrier gas	Least squares regression on weight-time relationship slope	Calculated from sensor signal and flow rate	Direct coulometric determination from current output of the sensor
Test Duration	Very short - hours	Long - days to weeks	Short - hours to days	Long - days to weeks
Measurement Level	Very high transmitters Range: 500 to 101,000 g/(m ² · day)	Moderate to high transmitters Range: 0.5 to 10,000 g/(m ² · day)	Moderate to high barriers Range: 0.005 to 1,000 g/(m ² · day)	High to very high barriers Range: 0.00005 to 5 g/(m ² · day)
Benefits	Fast measurement of breathable barriers	Simple and cost-friendly	Great sensitivity and accuracy, with shorter test times	Very high accuracy at ultra-low WVTR levels
Applications	Healthcare; personal care products; non-woven breathables	General packaging; building materials; clothing; healthcare	Foods; pharmaceutical; electronics	Electronics
Other global standards	NA	ISO 2528; JIS Z 0208; DIN 53122-1; GB/T 1037	ISO 15106-2; JIS K 7129-2; GB/T 26253 (film), GB/T 31355 (package)	JIS K7129-3, ISO 15106-3, GB/T 21529, DIN 53122-2
MOCON Instrument	PERMATRAN-W® 101K 	PERMATRAN-G® 5/09 & 5/12 	AQUATRAN® 3/34, 3/38 & 3/40 	AQUATRAN® 3 

Comparing ASTM Methods for WVTR Testing

Selecting the right ASTM method for WVTR testing depends on your specific application—whether it's high-throughput, quality control, or precision-driven research and development. Each method offers distinct advantages in terms of speed, sensitivity and suitability for different material types.

- ASTM F1249 is ideal for fast, repeatable results in both R&D and production applications.
- ASTM F3299 with the MOCON® AQUATRAN® 3 method delivers unmatched sensitivity for ultra-low WVTR applications in high-barrier materials and coatings.
- ASTM E96 provides a simpler, more accessible approach for medium to low-barrier materials.
- ASTM D6701 is uniquely suited for highly permeable non-woven materials.

WVTR Test Methods: Pros & Cons to guide your selection

Test Method	Pros	Cons
ASTM D6701	<ul style="list-style-type: none"> - Only method for highly permeable non-wovens (>10,000 g/(m² • day)) - Proven lab-to-lab repeatability - Fast test results 	<ul style="list-style-type: none"> - Limited to specific high-permeability materials - Test results not readily convertible to other testing methods
ASTM E96	<ul style="list-style-type: none"> - Simple setup with a balance, environmental chamber and cups - Useful for large datasets on medium to poor barriers 	<ul style="list-style-type: none"> - Long test duration and less precision and sensitivity when analyzing barrier materials - Labor-intensive compared to automated instrumental methods
ASTM F1249	<ul style="list-style-type: none"> - Infrared detection, along with automated and precise temperature and humidity controls contribute to excellent repeatability - Faster results and greater sensitivity than ASTM E96 	<ul style="list-style-type: none"> - Best suited for materials with a range between 0.05 and 1000 g/(m² • day) - Method has less sensitivity than the MOCON AQUATRAN 3 (ASTM F3299) instrument
ASTM F3299	<ul style="list-style-type: none"> - The MOCON AQUATRAN 3 has industry-leading sensitivity and accuracy - Absolute sensor is very accurate and repeatable at PPB levels of detection 	<ul style="list-style-type: none"> - Best suited for materials with WVTR between 0.00005 and 5 g/(m² • day) - Samples generally have long outgassing time making tests longer than ASTM F1249

We go beyond industry-leading instruments and accessories

Since 1966, we have set the industry standard in precision gas permeation and package testing instrumentation. Our dedicated team and innovative products offer the best value with an extensive range of solutions. Trusted by companies worldwide, we deliver the most accurate and repeatable results to ensure and enhance the quality and integrity of product packaging.



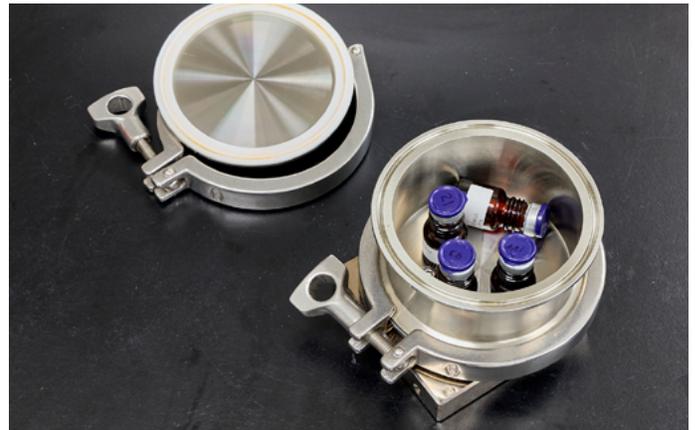
The world's largest permeation testing lab



Comprehensive advanced permeation testing training



Over 70 patents developed in our instrument solutions



Custom application development and lab testing services for healthcare, packaging, food & beverage and electronics industries