

# Enhanced Water Vapor Permeability Tester for High Barrier Materials

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## ABSTRACT

Continuous developments in high barrier materials have extended beyond the lower measuring limits of commercially available permeability testers, necessitating improvements in measurement sensitivity. By applying relatively minor modifications to the Dynamic Relative Humidity measurement method for Water Vapor Permeability, significant improvements have been achieved, including a reduction of the lower measurement limit by one order of magnitude, faster testing cycles, and improvements in testing reproducibility and repeatability. In this presentation, we first review the Dynamic Relative Humidity measurement method and present the theory behind the changes made. We then provide some comparative testing data, which illustrates the improved sensitivity and faster measurements achieved for several high barrier films.

## INTRODUCTION

The newest developments of barrier materials for packaging of water vapor-sensitive food products and other specialized applications such as organic light-emitting diode (OLED) films have led to the achievement of lower water vapor transmission (WVTR) rates through the materials. The WVTR rates of these “ultra-barriers” are often below the detection limit of conventional permeability testers available on the market. As a result, there is a rapidly growing demand for improved water vapor permeation testers with higher measurement sensitivity.

In anticipation of the new market requirements, the Dynamic Relative Humidity Measurement method for WVTR testing was closely examined in order to identify possible areas of improvement or enhancement. A new design of testing chamber was developed for this purpose. In combination with minor changes to the humidity sensor, flow system and measurement software, the new test system achieved an improved measurement sensitivity of one order of magnitude compared to the conventional system, with a lower measurement limit of 0,003 g/m<sup>2</sup>/24 hr. In addition to the improvement in measurement sensitivity, the new system demonstrated faster measurement times for high-barrier materials, improved linearity of measurements, better reproducibility of measurements, and optimization of the intrinsic leak rate of the system. These characteristics make the new system particularly suitable for the measurement of high-barrier films and foils.

## MODIFICATIONS TO THE CONVENTIONAL SYSTEM

The improvements in measurement sensitivity have been achieved via the following modifications to various components of the testing system.

### Test chamber

The successful measurement of very low water vapor transmission rates using the Dynamic Relative Humidity method requires the accurate detection of small changes in relative humidity in the testing chamber during the measurement cycle. The new chamber design has a significantly reduced internal volume and an optimized geometrical configuration designed to minimise “dead space” and provide a direct path to the humidity sensor for the water vapor molecules permeating the film. The chamber is also designed to provide optimal flushing geometry for the dry-out step that occurs between each measurement cycle.

### Humidity Sensor

A new, resized humidity sensor has been implemented with an optimized location in the test chamber to minimise static air volume surrounding the sensor. As a result, the permeating water vapor from the lower chamber reaches the sensor more quickly, thereby providing a faster measurement response. In addition, the measurement range of the sensor has been narrowed by a factor 5 in order to increase the measurement resolution, thereby providing a corresponding increase in measurement sensitivity at very low water vapor transmission rates.

### Air Valves

During the dry-down step between measurement cycles, drying air is pumped into the chamber via special valves. It is therefore important to eliminate potential sources of water vapor leakage into the chamber and minimise “dead space” in the flow system. The new design utilizes special “micro-valves” positioned optimally on the chamber head, thereby minimizing “dead air” volume and possible sources of leakage from the ambient atmosphere.

### Chamber Interior Surface

One potential source of measurement inaccuracy at very low levels of water vapor permeation is the absorption/desorption effects on the surfaces of the system components. Molecules

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of water vapor can be absorbed into irregularities in the interior surface during a humidification step, and are then desorbed from the surface during a drying step. Such absorption/desorption mechanisms can significantly affect the measurement results, particularly for low-permeability materials. The new system design incorporates a special coating of all chamber interior surfaces, thereby minimizing surface adsorption/desorption effects during the measurement cycles.

### **Operating Software**

Another source of measurement inaccuracy at very low WVTR levels is electronic noise. In order to minimise the influence of noise on the measurement results, new tester software has been implemented, featuring an optimized measurement start-stop algorithm and better averaging of measurement results, thereby reducing variations caused by signal noise.

### **INFLUENCE OF SYSTEM MODIFICATIONS ON TESTING AND MEASUREMENT RESULTS**

The enhancements summarized above provide the following improvements in performance and measurement results, compared to the conventional system:

- Improved measurement sensitivity: the minimum detection range has been reduced by a factor of 10, from 0,03 g/m<sup>2</sup>/24 hr to 0,003 g/m<sup>2</sup>/24 hr
- Faster measurement times: the smaller chamber size and reduced dead volume in the enhanced system provide considerably faster measurement times for low permeability materials

- Improved stability and reproducibility of measurements: the reduction of system noise provides better measurement stability and reproducibility, and therefore more reliable test results
- Improved sensor response and resolution: the faster sensor response and better measurement resolution results in more accurate measurement results for high barrier films
- Faster equilibrium detection: more frequent measurements in a given time frame allow the faster confirmation of the attainment of steady state conditions over the sample film
- Optimization of the intrinsic leak rate: the reduction of intrinsic leak in the system reduces ambient effects and provides an improvement in measurement sensitivity

### **CONCLUSION**

The latest developments in barrier technology have created a need for improved water vapor permeability testers with higher measurement sensitivity. An improved version of the Dynamic Relative Humidity testing method for WVTR has been developed using modifications to the testing chamber design and other minor changes to some system components and software. This new system provides an improved measurement sensitivity of a factor 10 compared to the conventional system. In addition, the new system offers faster measurement times, and better repeatability and reliability of measurement results compared to the conventional system, thereby making it especially suitable for the testing of high barrier films and foils.