MVTR as a Function of Temperature and Relative Humidity in VIPs

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MVTR as a Function of Temperature and Relative Humidity

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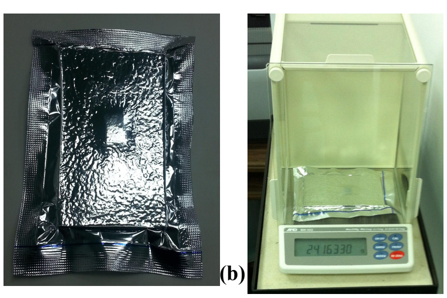
Goal:

To characterize the MVTR (Moisture Vapor Transmission Rate) properties of laminates under different conditions of temperature and relative humidity.

Test Procedure:

The Water Intake test is a simple but yet very effective test method. First of all, small panels (~15cm x 12cm x 5mm, Fiberglass + desiccant) were prepared and held in a humidity oven at different temperatures and humidity level. The panels were weighed once a week along the test duration of 1-2 months. Mass gained during this period referred to water permeation only; theoretically, water permeation through metallized laminates is greater than gas permeation by a factor of around 1000. At the end of the test, the WVTR (Water Vapor Transmission Rate) of the panel (which depends on the envelope film only) was calculated by dividing the mass gain by test duration and the surface area of the envelope.



(a) Small panel (~15cmx12cmX5mm) with glass fiber and desiccant

(b) Panel weighed by accurate analytic balance

The main advantage of the Water Intake test is the fact that the test is made at an application level.

Small ~15cm x 12cm VIP panels were prepared with different envelopes for MVTR measurement by the Water Intake method, using the following laminates:

i. V08621B - 3 metallized PET films with LDPE sealing layer.
ii. V07421 - 2 metallized PET films with LDPE sealing layer.
iii. V06221 – 1 metallized PET film with LDPE sealing layer.
iv. V08627 - 3 metallized (improved metallization) PET films with HDPE sealing layer.

Three panels of each type of laminate were stored at different conditions: 40°C/50%RH, 40°C/90%RH, 50°C/70%RH and 70°C/80%RH.

Test results for standard Avery Dennison Hanita 3- ply laminate V08621B at 40°C/90%RH are presented in Figure 1 and Table 1 below:

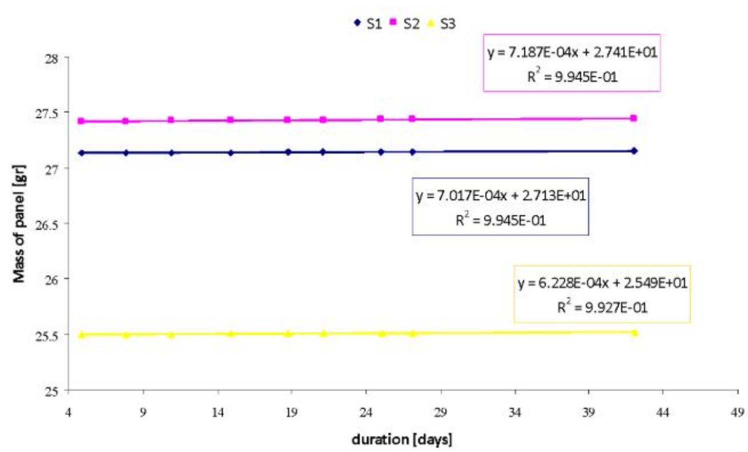


Figure 1: Water Intake test for Avery Dennison Hanita 3-ply laminate, 40°C/90%RH

Sample	A [m^2]	Δm [gr/day]	MVTR [gr/m^2·day]
S1	0.0403	7.017×10^{-4}	0.01741
S2	0.0416	7.187×10^{-4}	0.01728
S3	0.036	6.228×10^{-4}	0.01730
Average			0.01733

Table 1: Water Intake test for Avery Dennison Hanita 3-ply laminate, 40°C/90%RH

S1, S2 and S3 are different samples made from the same laminate, the results indicate that this is an accurate and repeatable test to determine MVTR properties of laminate under given conditions (temperature and relative humidity).

Results:

The calculated MVTR of each laminate under the different condition is summarized in Table 1 below:

MVTR [gr/m^2·day]				
Laminate	40°C/50RH	40°C/90RH	50°C/70RH	70°C/80RH
V08621B	0.00928	0.01745	0.02453	0.07828
V07421	0.01881	0.03389	0.04746	Adhesive failure
V06221	0.03625	0.06505	0.09121	0.29754
V08627	0.00861	0.01549	0.02164	0.06992

Table 2: MVTR measured under varying conditions for different laminates

The Saturation Pressure (P_S) of Water Vapor as a function of temperature is described by the following equation, Eq 1:

$$P_S(T)=6.11\times\exp\left(\frac{17.5\times T}{241+T}\right), P_S[mbar] and\ T[°C] \quad (1)$$

The general function that describes MVTR as a function of temperature and relative humidity is shown below in Eq 2:

$$MVTR(T,RH)=MVTR_0\cdot\frac{RH}{RH_0}\cdot\frac{\exp\frac{17.5\times T}{241+T}}{\exp\frac{17.5\times T_0}{241+T_0}}\cdot f_T \quad (2)$$

Where:

$MVTR_0$ - is the known MVTR at a specific condition,

RH_0 and T_0 - is the reference relative humidity and the reference temperature at which the $MVTR_0$ value is known,

$$\frac{\exp\frac{17.5\times T}{241+T}}{\exp\frac{17.5\times T_0}{241+T_0}}$$

- is the ratio between saturated water vapor pressure at the temperature under consideration and the saturated water vapor pressure at T_0. f_T - is the temperature factor affecting the permeation rate. Most of the measurements were made at 40°C/90RH, so the MVTR values at these conditions will be defined as $MVTR_0$, so the general equation (2) can be rewritten as :

$$MVTR(T,RH)=MVTR_{40°C/90RH}\cdot\frac{RH}{90}\cdot\frac{\exp\frac{17.5\times T}{241+T}}{\exp\frac{17.5\times 40}{241+40}}\cdot f_T=MVTR_{40°C/90RH}\cdot\frac{RH}{90}\cdot\exp\left(\frac{17.5\times T}{241+T}-2.49\right)\cdot f_T$$

Table 2 below presents the measured MVTR and calculated MVTR values without temperature factor (f_T=1), meaning that the general equation can be reduced to

$$MVTR_{40°C/90RH}\cdot\frac{RH}{90}\cdot\exp\left(\frac{17.5\times T}{241+T}-2.49\right)$$

Measurement Condition	Measured MVTR [gr/m2 day]	Calculated MVTR [gr/m2· day]	Ratio between measured and calculated	% of Difference (Δ) measured
V08621B				
40°C/50RH	0.00978	0.00971	1.00761	-0.76
40°C/90RH	0.01745	0.01745	1	0
50°C/70RH	0.02453	0.02276	1.07810	-7.24
70°C/80RH	0.07828	0.06605	1.18509	-15.62
V07421				
40°C/50RH	0.01881	0.01885	0.99779	0.22
40°C/90RH	0.03389	0.03389	1	0
50°C/70RH	0.04746	0.04419	1.07396	-6.89
70°C/80RH	No data			
V06221				
40°C/50RH	0.03625	0.03618	1.00196	-0.2
40°C/90RH	0.06505	0.06505	1	0
50°C/70RH	0.09121	0.08484	1.07514	-6.99
70°C/80RH	0.29721	0.24624	1.20701	-17.15
V08627				
40°C/50RH	0.00861	0.00862	0.99892	0.11
40°C/90RH	0.01549	0.01549	1	0
50°C/70RH	0.02164	0.02021	1.07091	-6.62
70°C/80RH	0.06992	0.05865	1.19206	-16.11

Table 3: Measured MVTR and calculated MVTR without the effect of the temperature factor (f_T=1)

Determination of f_T :

Table 3 below presents a summary of the "difference factor" between measured and calculated MVTR:

	Difference Factor (f_T)				
T[°C]	V08621B	V07421	V06221	V08627	Average
40	1	1	1	1	1
50	1.07810	1.07396	1.07514	1.07091	1.07453
70	1.18509	-------	1.20701	1.19206	1.19472

Table 3: Difference factor between measured and calculated MVTR

The following graph in Fig 2 below shows the value of f_T as a function of temperature:

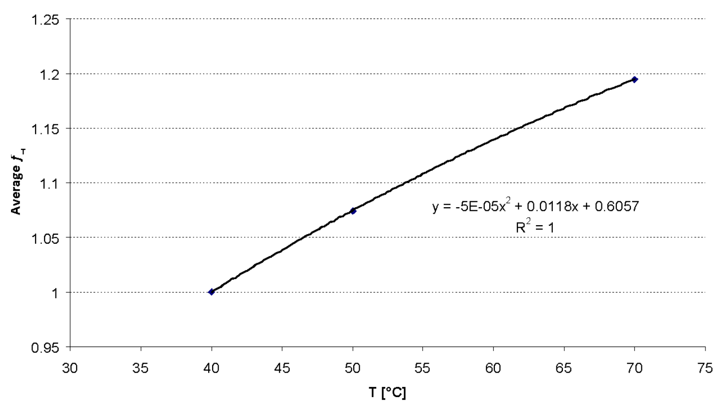


Figure 2: f_T as a function of temperature °C

Using the polynomial fit above, the general behavior of MVTR is

$$MVTR(T,RH) = MVTR_{40°C/90RH} \cdot \frac{RH}{90} \cdot \exp\left(\frac{17.5 \times T}{241+T} - 2.49\right) \cdot \left(-5 \times 10^{-5} \cdot T^2 + 0.0118 \cdot T + 0.6057\right), \quad T[°C]$$

Conclusion:

Based on the above work and formula (5), we can effectively predict the MVTR level of MetPET laminates at any given temperature and relative humidity.

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