A Comparison of the Barrier Properties of VIP Laminates – New PST Technology

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Appendix:

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Goal:

To evaluate the gas and moisture barrier performance of different VIP laminates.

Both flat films and panels (150mm x 120mm with desiccant) were tested for each of the following laminates:

1. **V085HB1** – Bi-laminate of metallized PET and metallized EVOH with LDPE sealing layer
2. **V085HB3** – Bi-laminate of metallized PET with Avery Dennison Hanita's new Proprietary Surface Treatment (PST) technology with LDPE sealing layer
3. **V08621B** – Tri-laminate of metallized PET with LDPE sealing layer
4. **Asian 2nd generation MET EVOH** laminate - Bi-laminate of metallized PET and metallized EVOH with LDPE sealing layer
5. **Asian 3rd generation MET EVOH** laminate - Bi-laminate of metallized special PET and metallized EVOH with LDPE sealing layer
6. **V07941P** – Bi-laminate of metallized PET and Al foil with LDPE sealing layer

Test Procedure: *- see Appendix for a detailed explanation of all tests*

1. **Barrier to water vapor (MVTR)**, measured on flat film and on panels:
    1.1. Measurement of flat film (as produced without any mechanical stress) by Mocon PERMATRAN-W 3/31 with a detection level of 0.01 gr/m2*day: based on ASTM F-1249.
    1.2. Measurement of panels by the Water Intake (gravimetric) Technique: by weighing the panels before and during exposure to 40°C/90%RH for two months.
2. **Barrier to gas (GTR)**, measured on panels with fiberglass core materials and desiccant: The thermal conductivity increase rate was measured by a LaserComp while panels were stored under various conditions and the permeability [cc (STP)/year*m2 (panel)] of each laminate calculated on the base of measured results.
3. **Mechanical properties:** All mechanical properties (puncture resistance, heat seal strength and elongation) of the laminates were tested using a Lloyd Tensiometer Unit.

Results:

1. **Barrier to water vapor (MVTR)**
    1.1. The results of measuring MVTR for the flat laminates alone, using Mocon PERMATRAN-W 3/31 are shown in Figure 1 and summarized in Table 1.

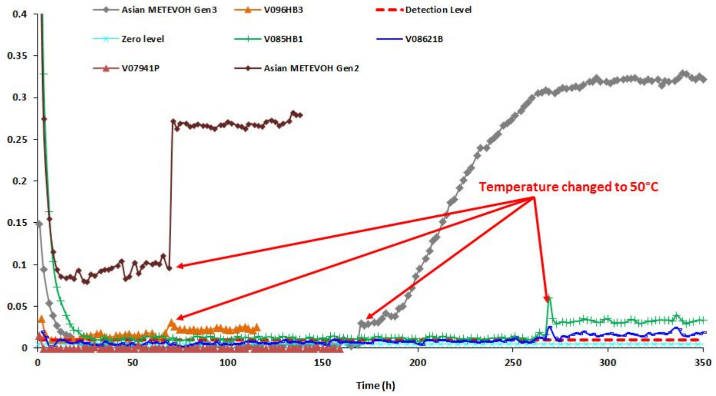


Fig 1 MVTR of laminates measured using Mocon PERMATRAN-W 3/31

Laminate	MVTR [gr/m2 day] 38°C/100%RH	MVTR [gr/m2 day] 50°C/100%RH
V08621B	<0.01	0.016
V085HB1	0.012	0.034
V085HB3 (PST)	0.014	0.03
Asian METEVOH Gen2	0.1	0.27
Asian METEVOH Gen3	<0.01	0.32
V07941P	<0.01	<0.01

Table 1 MVTR of laminates measured using Mocon PERMATRAN-W 3/31

1.1. The results of the Water Intake test made on panels at 40°C/90%RH measuring MVTR are shown in Table 2 below.

Laminate	MVTR [gr/m2 day]
V08621B	0.017
V085HB1	0.035
V085HB3 (PST)	0.029
Asian METEVOH Gen2	0.265
Asian METEVOH Gen3	0.103
V07941P	0.002

Table 2 MVTR of laminates measured using the Water Intake Test

2. **Barrier to gas (GTR)** was measured on panels with fiberglass core materials and desiccant using a Fox LaserComp:
The actual thermal conductivity test results for panels of 300x300x10 mm with 10g desiccant are shown in Table 3 and further illustrated in Figures 2 and 3.

Laminate	Ambient (22°C/50%RH)			80°C / Dry		
	Initial λ (mW/mK)	λ after 60 days (mW/mK)	Δ λ	Initial λ (mW/mK)	λ after 30 days (mW/mK)	Δ λ
V085HB1	1.56	1.8	0.24	1.6	3.56	1.96
V085HB3 (PST)	1.62	1.8	0.18	1.65	3.07	1.42
Asian METEVOH Gen 2	1.58	2.025	0.445	1.54	5.8	4.26
Asian METEVOH Gen3	1.58	1.8	0.22	1.71	4.37	2.66
V07941P (Al Foil laminate)	1.6	1.75	0.15	1.67	2.91	1.24

Table 3 Actual measurements of thermal conductivity under various conditions using LaserComp

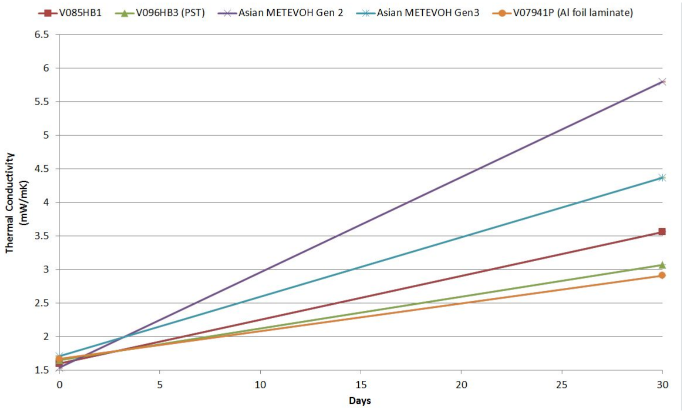
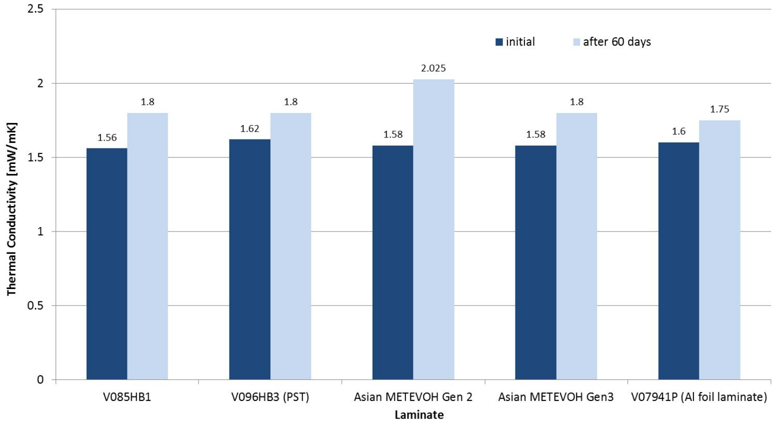


Fig 2 Thermal conductivity at 80o C, Initial and 30 days



Laminate	Permeability [cc (STP)/m2·year]					
	22°C/~50%RH	50°C/70%RH	50°C /dry	80°C	100 °C	120 °C
V08621B	6.7	24	24	80	200	500
V085HB1	1-2	8.5-10	8.5	42	90	295
V085HB3 (PST)	1-1.7	25	7.5	27*	60	210
Asian METEVOH Gen2	4	40 Failure after 40 days	9.95 (40°C)	85	210 *	475 *
Asian METEVOH Gen3	1.4	16	13	58	175	440
V07941P	1-1.4	7	6.5*	24	55	160

Table 4 Calculated GTR of panels measured using the LaserComp
**Values in red are expected values following an Arrhenius fit, see Fig 4 below.*

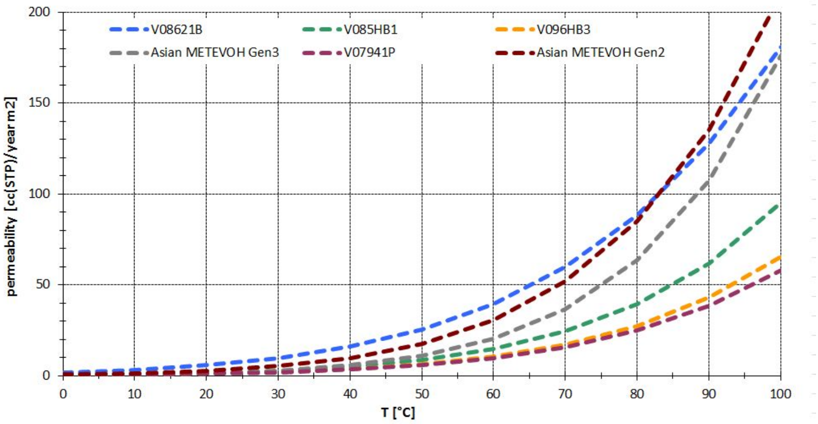


Fig 4 Expected GTR values after Arrhenius fit

3. **Mechanical Properties**
The mechanical properties tested by the Lloyd Tensiometer Unit are summarized in Table 5 below.

Laminate	Puncture Resistance [N]		Heat Seal Strength [N/mm]	Elongation [%]
	US method – FTMS 101C 2065	Japanese method – JIS Z1707	ASTM-F88 M 165°C, 4kg/cm2, 2 sec	ASTM D-882
V08621B	130	17	>3.5	**MD:** 100 **TD:** 90
V085HB1	135	18	>3.5	**MD:** 100 **TD:** 125
V085HB3 (PST)	125	17	>3.5	**MD:** 100 **TD:** 110
Asian METEVOH Gen2	160	21	>3.5	**NA**
Asian METEVOH Gen3	144	18	>3.5	**MD:** 120 **TD:** 140
V07941P	95	12	>3.5	**MD:** 125 **TD:** 80

Table 5 Lloyd Tensiometer Unit results

Conclusions:

1. Avery Dennison Hanita's V085HB3 laminate, which features a new proprietary surface treatment (PST) technology, shows superior performance in comparison to other existing metallized laminates, particularly at high temperatures and in dry conditions. Avery Dennison Hanita's V085HB1 laminate demonstrates superior MVTR in comparison to existing MEVOH laminates.

2. In dry conditions, V085HB3 (PST) has a similar GTR to foil laminate; in humid conditions, performance is stable.

3. Avery Dennison Hanita's new PST technology offers an economical and cost-effective ultra-high barrier solution.

Appendix

Testing Methods

1. Moisture permeation rate

Moisture permeation rate, also known as MVTR or WVTR, is measured by two different methods:

i. Measurement by Mocon PERMATRAN-W 3/31, according to ASTM F-1249 on flat film (as produced without any mechanical stress).

Method:

The sample of flat barrier film to be tested is mounted in a two-compartment permeation cell. A constant water vapor pressure is maintained on one side of the sample to keep the cell at 100% relative humidity. On the other side, the water molecules permeating through the sample are picked up by the extremely dry carrier gas (Nitrogen (N2)). The nitrogen then exits the cell and passes through the IR sensor. The amount of water vapor is measured by the sensor and the water transmission rate is calculated.

Fig 5 Mocon PERMATRAN-W 3/31

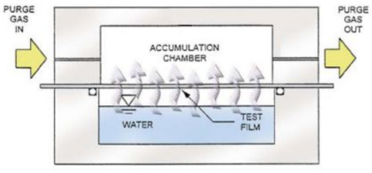


Fig 6 Schematic view of Mocon PERMATRAN-W 3/31

Credit: Mocon www.mocon.com

ii. The Water Intake (gravimetric) technique

The procedure starts with the preparation of small FG panels (~15cmx12cm) with a desiccant inside, as in Fig. 7. The panels are weighed using a micro-balance (Fig 8), and then held in a humidity oven at 40°C and 90%RH. Over the coming months, the panels are weighed once a week. The mass gain during this period is caused by the water molecules permeating and absorbed by the desiccant. Theoretically, the water permeation rate is about 1000 faster than the permeation rate of air, therefore the contribution of the weight gain of air permeation is negligible. At the end of the test period, the WVTR of the panel (depending on the type of the envelope only) is calculated by dividing the mass gain by test duration and the area of permeation.

Fig 7 Panels

Fig 8 Microbalance scale

2. Gas (Air) permeation rate

Gas (Air) permeation rate, which is also known as GTR, is tested by measuring the thermal conductivity of a 30cmx30cm glass fiber panels using a LaserComp machine. The panels are stored at a wide range of temperatures (23°C, 40°C, 50°C, 50°C/70%RH, 80°C, 100°C and 120°C), and the thermal conductivity of each panel is measured over at least 3 months. The pressure is then calculated using the known TC vs. P from the measured values of thermal conductivity, enabling a very accurate picture of the internal pressure increase throughout storage time. In the final stage, the air permeability [cc(STP)/year m2] of the laminate for a given temperature is calculated using the pressure increase rate and the panel dimensions (width, length and thickness), defined as the amount of air (cc(stp)) permeating through the envelope of a 1m2 panel in a year. Figure 9 below shows internal pressure as a function of test duration for Avery Dennison Hanita 3-ply laminate V08621B at 50°C/70%RH.

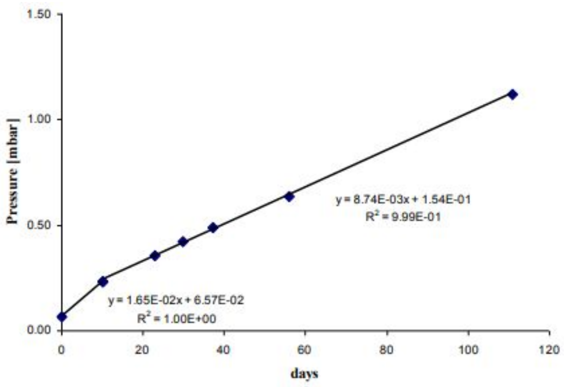


Fig 9 Internal pressure as function of test duration

The above Figure 9 clearly shows that the pressure increase rate at the initial stage is larger by a factor of ~ 2. This phenomenon refers to outgassing, which contributes substantially to the pressure increase rate in the first few weeks after panel production. This initial period of time should be excluded from the procedure of permeability calculation. Outgassing occurs at all temperatures; its duration is longer at lower storage temperatures. At ambient, it may take about two months before the contribution of outgassing to the pressure increase rate becomes insignificant and can be ignored. At that time, the pressure increase rate is determined solely by the steady state permeation rate of air through the envelope. In general, the permeability should be calculated using only the pressure increase after steady state has been reached, and the outgassing no longer affects the results.

It was found that the Arrhenius equation (Eq 1) can be used to model the dependence of permeability on temperature.

$$P(T) = P_0 \exp\left(-\frac{E_A}{RT}\right)$$

Eq 1

Where: P_0 is permeability at infinite temperature, $E_a[J]$ is activation energy and $R = 8.314\frac{J}{mol\,K}$ is ideal gas constant.

3. Mechanical Properties

All mechanical properties of the laminates are tested using a Lloyd Tensiometer Unit, as shown in Figure 10 below. The mechanical properties normally tested are:

i. **Lamination strength** – tested on each production roll at each lamination stage.

ii. **Tensile strength and elongation at break point** - tested on the final product, similar to ASTM D882.

iii. **Puncture resistance**- tested on final product, similar to FTMS 101C 2065 or ASTM D4833M.

iv. **Sealing strength** - tested on the final product, similar to ASTM F88M.

Fig 10 Lloyd Tensiometer Unit

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