HOW LAMINATES WITH EVAL™ EVOH FILM IMPROVE THE PERFORMANCE OF VIPS

Cynthia Teniers
Senior Business Development Engineer

EVAL Europe nv
Haven 1053
Nieuwe Weg 1 – Bus 10
2070 Zwijndrecht
Belgium

Tel. +32 3 250 97 33
Direct Tel. +32 3 250 97 21
E-mail cynthia.teniers@eval.be
www.eval.be

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ABSTRACT

The VIP market is a developing market. The majority of VIP applications are still for operating temperatures at or below ambient temperatures. To broaden the application field to higher volume applications with higher operating temperatures, moist conditions and a longer service life, the industry needs VIPs with an improved performance.

The performance of VIPs can be improved by the use of barrier envelopes with EVAL™ EVOH barrier films. EVAL™ EVOH films can be used as an intermediate layer and/or a sealing layer. They allow to: (1) minimize the thermal conductivity of the barrier envelope (minimal thermal bridging), (2) improve the resistance of VIPs to manipulation, (3) minimize the gas permeation through the skin of the envelope and (4) minimize the gas permeation through the seals of the envelope.

(*1) Minimize the thermal conductivity of the barrier envelope, increase the insulation performance of the VIP*
When you use an aluminium foil laminate on one side of the VIP and an EVAL™ VM-XL laminate on the other side, you can reduce the average thermal conductivity of the VIP by about half.

(2) Improve the resistance of VIPs to manipulation, maintain the insulation performance of the VIP during production, transport and installation
In Japan VIPs with EVAL™ VM-XL laminates are used for: refrigerators, cold shipping boxes, rice cookers and hot water cookers. Practice has shown that the insulation performance of these laminates is not reduced due to stresses during the production and installation process. Thanks to its excellent flex crack & pinhole resistance the barrier performance of EVAL™ VM-XL film is not reduced at the edges and corners of the panel. EVAL™ EVOH films can also be used in combination with other barrier technologies. They will act as a “back-up layer”, when one of the other barrier technologies is damaged during production, transport or installation.

(3) Minimize the gas permeation through the skin, increase the service life of the VIP
To further develop the market, the industry needs VIP barrier laminates that can withstand higher operating temperatures and have an improved gas & water vapour barrier. To meet these needs a new type of barrier film has been developed: EVAL™ TM-XL. This robust film with an increased gas & water vapour barrier was especially developed for applications with higher operating temperatures, moist conditions and a longer service life.

(4) Minimize the gas permeation through the seals of the envelope, increase the service life of the VIP
With ultra high barrier metallized films, the edge diffusion through 50 micron thick polyethylene sealing layers can be responsible for more than 50% of the gas permeation into the encapsulated panels. By the use of EVAL™ EVOH sealing layers the permeation through the seals can be reduced substantially which results in a longer service life.
In addition since EVAL™ EVOH films have melting temperatures (165-183°C) that are higher than those of polyethylene, the use of EVOH sealing layers can also improve the high temperature resistance of the VIPs.

ABOUT KURARAY AND EVAL EUROPE

Kuraray Co., Ltd. has long been a leader in high gas barrier technology and development. The company is the first and foremost producer of EVOH (ethylene vinyl-alcohol copolymer resins) under the name EVAL™ and the manufacturer of KURARISTER™. The company was established in 1926 in Kurashiki, Japan. Today, the Kuraray Group consists of about 70 companies, employing around 7,000 people worldwide.

EVAL Europe nv was founded as a wholly owned subsidiary in Antwerp in 1997 to supply the European, Middle Eastern and African markets with EVAL™. Backed by over three decades of experience, EVAL Europe nv serves European customers locally from its Technical and Development Centre. Deepening its commitment to the region, the first EVOH production site in Europe doubled its production capacity in October 2004 to 24,000 tons per year.

EVAL™ resins are used for food packaging, construction and building, automotive, industrial and cosmetics applications. EVAL™ EVOH is also available as film for lamination for technically demanding applications such as vacuum insulation panels (VIPs).

1. VIP MARKET NEEDS / TRENDS

The VIP market is a developing market that represents an interesting opportunity for the industry. The majority of VIP applications are still for operating temperatures at or below ambient temperatures. Refrigerator/freezer insulation and controlled temperature packaging remain the main applications.

At the moment the VIP industry is broadening the application field to higher volume applications with higher operating temperatures, moist conditions and a longer service life. This can be illustrated by recent developments in the Japanese market (Figure 1).

There VIPs are now also being used for:

- Apparel - about 35°C: rice cookers and hot water cookers
- Floor & wall heating systems - 40°C & life time of 20 years
- Tanks of hot water heaters - 60°C & moist conditions
- Refrigerated trucks - hot (sunlight)/cold
- Subway coaches – hot (sunlight)/cold
- Vending machines – hot & cold drinks
- Buildings – moist conditions & life time of 50 years

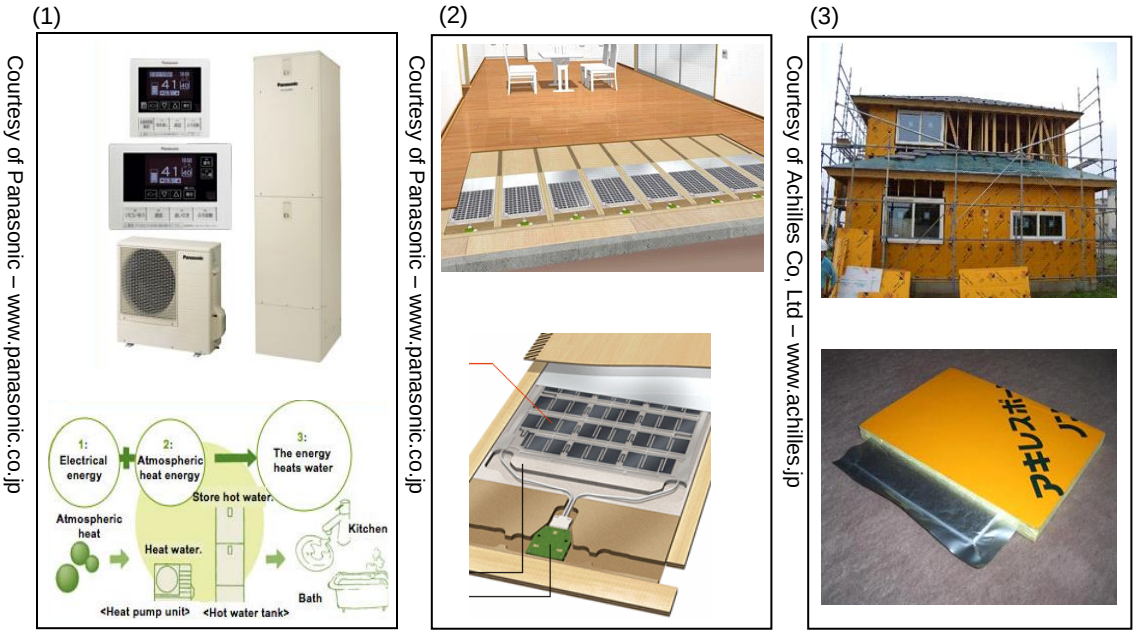

Figure 1 - Recent VIP successes in the Japanese market: (1) CO_2 heat pump for hot water heater (VIP around metal hot water tank with a volume of 460l or 370l), (2) floor heating system (VIP underneath floor heating elements), (3) building insulation boards (VIP integrated in a PUR-board to avoid damage during installation)

However to further develop the market, the industry needs VIP barrier laminates that can withstand higher operating temperatures and have an improved gas & water vapour barrier.

2. TECHNICAL CHALLENGES FOR VIP LAMINATES

The barrier envelope is critical for the insulation performance of the VIP. It sustains the required vacuum level for the desired lifetime of the panel. It should combine (Figure 2): (1) minimal thermal bridging (minimal thermal conductivity), (2) good resistance to manipulation (flex crack & pinhole resistance), (3) minimal gas permeation through the skin (barrier to oxygen, nitrogen & water vapour) and (4) minimal gas permeation through the seals (barrier to oxygen, nitrogen & water vapour).

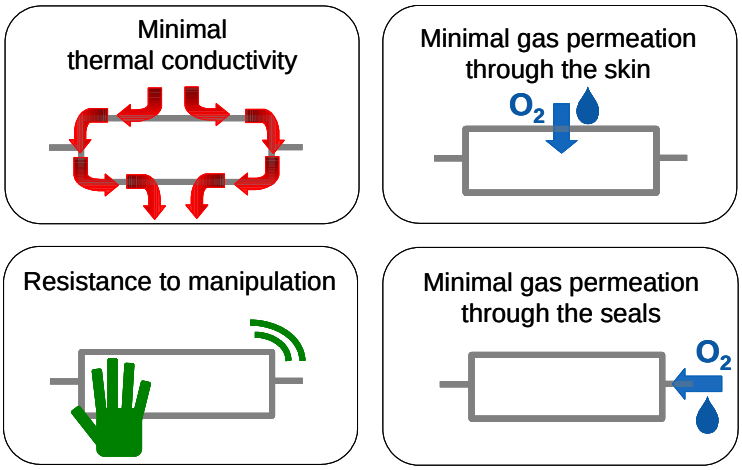

Figure 2 - Requirements for VIP laminates / envelopes

3. HOW EVAL™ EVOH FILMS CAN IMPROVE THE PERFORMANCE OF VIPS

EVOH is a random copolymer of ethylene and vinyl alcohol. It is a crystalline polymer that has a molecular structure represented by the formula mentioned in Figure 3.

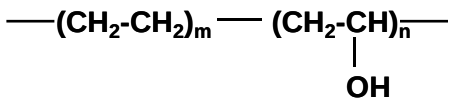

Figure 3 - Molecular structure of ethylene vinyl alcohol (EVOH)

EVAL™ EVOH films can be used as an intermediate layer in the VIP laminate and/or as a sealing layer (Figure 4). They are available as monolayer EVOH films as well as vacuum metallized EVOH films.

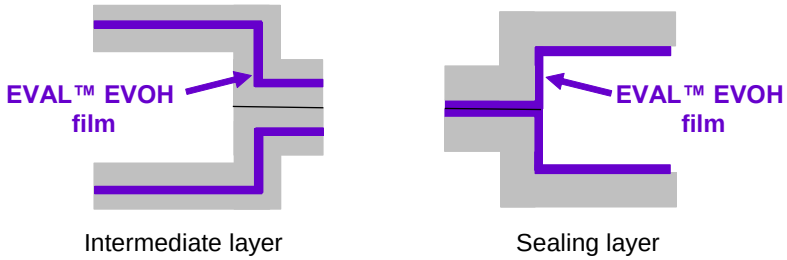

Figure 4 - EVAL™ EVOH film can be used as an intermediate layer and/or a sealing layer in the VIP laminate

The following paragraphs will discuss how EVAL™ EVOH films can be used to: (3.1) reduce the thermal conductivity of the barrier envelope, (3.2) improve the resistance of VIPs to manipulation, (3.3) minimize the gas permeation through the skin of the envelope and (3.4) minimize the gas permeation through the seals of the envelope.

3.1. Minimal thermal conductivity

Barrier laminates that contain aluminium foil (thickness: 6-8 micron) have very good barrier properties. The thermal conductivity of VIPs with an aluminium foil laminate on both sides is however high. The high thermal conductivity of the aluminium layer leads to heat bridges at the panel edges. This phenomenon is also known as thermal bridging or the thermal edge effect.

By the use of metallized films (Al thickness: nanometers) this thermal bridge effect can be minimized. Aluminium metallized EVOH films like EVAL™ VM-XL have a metallized layer that is thick enough to offer a sufficient barrier, but thin enough to have a minimal thermal conductivity.

When you use an aluminium foil laminate on one side of a VIP and an EVAL™ VM-XL laminate on the other side, you can reduce the average thermal conductivity of the VIP by about half (Figure 5). The use of EVAL™ VM-XL laminates on both sides of the VIP will result in an additional reduction.

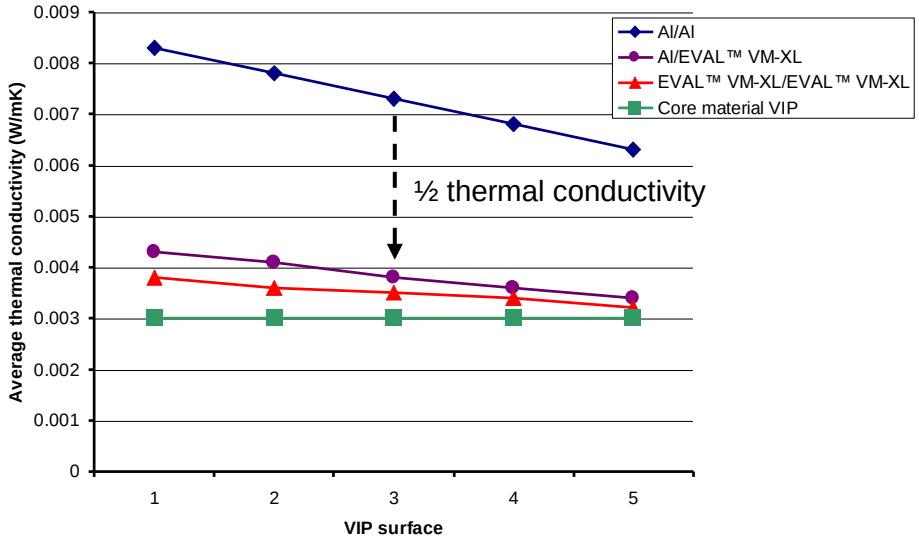

Figure 5 - Average thermal conductivity at 24°C (following JIS A 1412, based on ISO 8301) measured on VIPs composed of a core material and an envelope that contained: (1) aluminum foil laminate on both sides of the panel, (2) aluminium foil laminate on one side and EVAL™ VM-XL laminate on the other side as well as (3) EVAL™ VM-XL laminate on both sides of the panel. The thermal conductivity of the core material was measured as a reference.

EVAL™ VM-XL laminates reduce the thermal conductivity and thus increase the insulation performance of the VIP.

3.2. Resistance to manipulation

The amount of gas permeation through the VIP laminate is critical for the insulation performance of a VIP. This gas permeation depends upon the composition of the barrier laminate, but also on the resistance of the barrier laminate to manipulation during production, transport and installation.

During the production process the VIP laminate is exposed to stresses at the edges and corners of the panel, especially during the evacuation process. These stresses can damage the coating and/or deposited barrier materials on the barrier film, which results in an increased permeation at the edges & corners of the VIP and thus a decreased insulation performance.

In Japan VIPs with EVAL™ VM-XL films have been used for years. They are used for refrigerators, cold shipping boxes, rice cookers and hot water cookers. Practice has shown that the insulation performance of these VIPs is not reduced during production and installation, thanks to the excellent pinhole resistance of EVAL™ VM-XL films.

EVAL™ EVOH films can also be used in combination with other barrier technologies. They will act as a “back-up” layer when one of the other barrier technologies is damaged during production, transport or installation.

To quantify the resistance of EVAL™ EVOH films to manipulation, the oxygen transmission rate was measured after twisting by means of a Gelbo flex test (Figure 6) and compared to that of other barrier films.

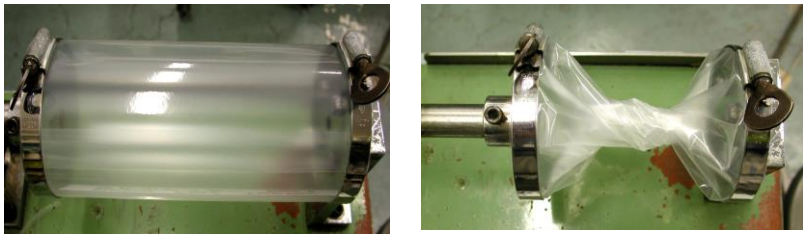

Figure 6 - Gelbo flex test

Figure 7 illustrates that after a couple of twist cycles the oxygen transmission rate drastically increases for the different barrier films except for the EVAL™ EF-XL (bi-oriented EVOH film) and VM-XL film (vacuum metallized EVOH film). These results show that EVAL™ EVOH films have an excellent flex crack resistance.

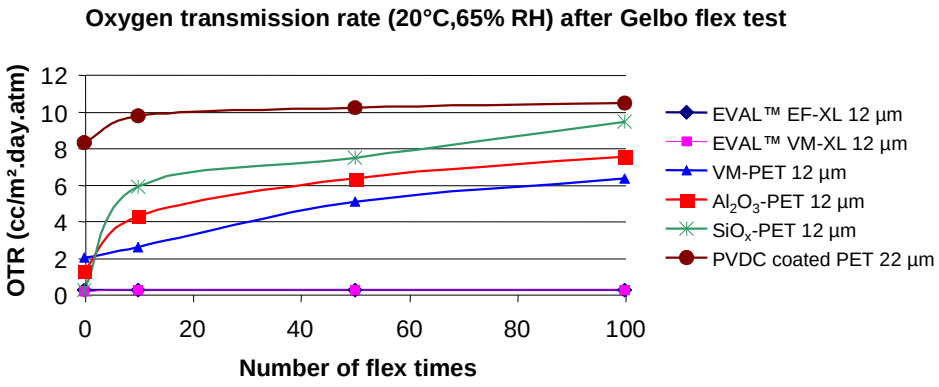

Figure 7 - Flex crack resistance of selected barrier films
OTR was measured on PET (12 µm)//barrier film//LLDPE (50 µm) laminates

EVAL™ EVOH films have an excellent flex crack and pinhole resistance and thus an excellent resistance to manipulation.

3.3. Minimal gas permeation through the skin

To further develop the VIP market, the industry needs barrier laminates that can withstand higher operating temperatures and have an improved gas & water vapour barrier.

To meet these needs Kuraray has developed a new type of barrier film called EVAL™ TM-XL. This film has an oxygen transmission rate of 0.01 cc/m².day.atm (40°C, 65% RH) & 0.2 (60°C, 90% RH) and a water vapour transmission rate of 0.1 g/m².day (40°C, 90%RH). The results in Table 1 illustrate that the barrier properties of EVAL™ TM-XL film are excellent and superior to other barrier films.

Table 1 - Barrier properties of EVAL™ TM-XL and other barrier films

Property	**Measuring method**	**Measuring conditions**	**Unit**	**EVAL™ TM-XL[(1)]**	**EVAL™ VM-XL**	**SiO_x/Al_3O_2-PET**	**VM-PET**	**PVDC-OPP**
Structure				New generation Al metallized bi-oriented EVOH film	Al metallized bi-oriented EVOH film	SiO_x/Al_3O_2 metallized PET	Al metallized PET	PVDC coated oriented PP
Thickness			µm	15	15	12	12	22
Oxygen transmission rate	ISO 14663-2	20°C, 65% RH	cc/m².day.atm	-	0.05	0.05-3	2-8	10-20
		20°C, 85% RH		-	0.05	-	-	-
		40°C, 65% RH		0.01[(2)]	0.05	-	-	-
Water vapour transmission rate	ASTM E96	40°C, 90% RH	g/m².day	0.1[(3)]	0.5	0.5-5	1-4	4-8

(1) Measured on PET//EVAL™ TM-XL//LDPE laminate (12//15//50 micron)
(2) Measured by OX-TRAN2/20, limit of detection = 0.01 cc/m².day.atm
(3) Measured by GTR-Tech, limit of detection = 0.2 cc/m².day.atm
(4) Measured by Permatran 3/33, limit of detection = 0.1 g/m².day

3.4. Minimal gas permeation through the seals

Each time that the barrier of the VIP skin is improved, the relative importance of gas permeation through the seals increases. With ultra high barrier metallized films, the edge diffusion through 50 micron thick polyethylene seal layers can be responsible for more than 50% of the gas permeation into the encapsulated panels, particularly by oxygen and nitrogen (Dr. Yoash Carmi - Hanita Coatings, IVIS 2007, Book of abstracts & proceedings p. 23).

The permeation through the seals can be substantially reduced by the use of EVAL™ EVOH film as a sealing layer (Figure 8). EVAL™ EVOH has outstanding gas barrier properties that exceed those of other plastics used today for barrier purposes (Table 2).

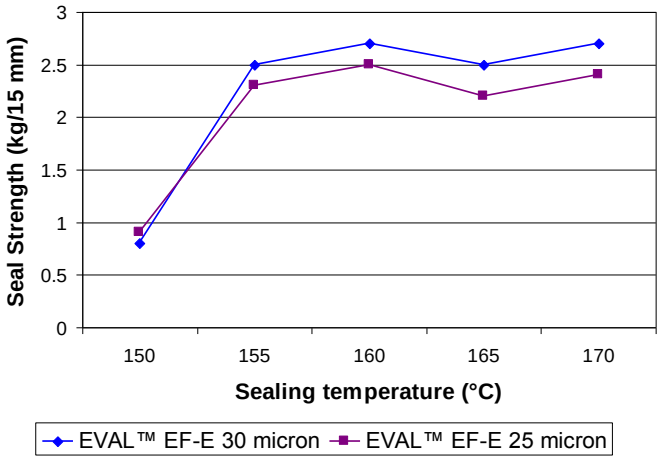

Figure 8 - Typical sealing temperatures for EVAL™ EVOH films
Heat seal curve measured on OPA//EVAL™ EF-E laminate
Seal conditions: force = 1kg/cm2, dwell time = 0.5 seconds

Table 2 - Gas transmission rates of selected polymers (measured following ISO 14663-2)

Films	**Gas transmission rates of selected polymers at 25°C and 0% RH (cc.20 µm/m².d.atm)**	
	N_2	**O_2**
EVAL™ EF-XL	-	0.15
EVAL™ EF-F	0.017	0.27
EVAL™ EF-E	0.13	1.23
OPP	730	3400
LDPE	3100	12000

Films	**Oxygen transmission rates of selected polymers (cc.20 µm/m².d.atm)**	
	20°C, 65% RH	**20°C, 85% RH**
EVAL™ EF-XL	0.38	0.75
EVAL™ EF-F	0.40	1.6
EVAL™ EF-E	1.6	3.4
CPP	3250	3250
LDPE	10000	10000

In addition the use of EVAL™ EVOH sealing layers, instead of polyethylene, can also improve the high temperature resistance of the VIPs (EVAL™ EVOH films have melting temperatures that vary from 165°C up to 183°C).

4. CONCLUSION

The insulation performance, service life and operating temperature of VIPs can be increased by the use of laminates with EVAL™ EVOH film. EVAL™ EVOH films allow to: (1) reduce the thermal conductivity of the barrier envelope, (2) improve the resistance of VIPs to manipulation, (3) minimize the gas permeation through the skin of the envelope and (4) minimize the gas permeation through the seals of the envelope. They can be used as an intermediate layer and/or a seal layer.

To meet the needs of the VIP market a new type of barrier film has been developed: EVAL™ TM-XL. This robust film with an increased gas and water vapour barrier is especially developed for applications with higher operating temperatures, moist conditions and a longer service life.