EVAL™ Film for Vacuum Insulation Panels
A market towards more efficient energy use

The market for Vacuum Insulation Panels (VIP) is rapidly developing, creating new opportunities for improved design and more efficient energy use. The majority of VIP applications today are still for operating at or below ambient temperatures. To broaden the field to include higher volume applications, VIPs with improved thermal insulation performance and longer service life are required. Kuraray, leader in high gas barrier technology and development, has the answer: EVAL™ EVOH films. Performance can be improved by adding a layer of these ethylene vinyl-alcohol (EVOH) films to the multilayer laminate structures used to produce VIPs.

**EVAL™ EVOH in multilayer laminates for VIP**
EVAL™ adds value to VIP

EVAL™ EVOH resins are processed into monolayer or vacuum metallized films. These polymer based films are then combined with other barrier films to make a multilayer laminate structure, used as the outer shell of VIPs. The addition of EVAL™ EVOH can help prolong the VIPs service life (high gas barrier properties to maintain vacuum) and improve its overall insulation performance (low thermal conductivity).

Recent developments in the Asian market, especially in Japan, already show that VIP applications produced with laminates that contain EVAL™ EVOH, can be successfully applied in the retail sector.

VIP applications with laminates that contain EVAL™:

- Consumer refrigerators
- Consumer freezers
- Rice cookers
- Electric kettles
- Cold shipping boxes

There are still many VIP applications possible where EVAL™ can make a difference: consumer goods, building and construction industry (such as building insulation boards and floor & wall heating systems), the transport sector (such as insulated shipping containers, subway coaches), electronics and the industrial sector (such as piping).
**EVAL™ improves the performance of VIPs**

The barrier laminate envelope is critical for the insulation performance of the VIP. It must maintain the required vacuum level over the desired lifetime of the panel, without increasing thermal conductivity.

VIP performance can be improved by adding a layer of EVAL™ EVOH high barrier film to the laminate structure. There are two basic ways to do this, using EVAL™ either as an additional intermediate barrier layer, or as an interior sealing layer.

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**Location of EVAL™ EVOH in multilayer VIP laminate structures**

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**The benefits are many:**

1. Minimal thermal conductivity
2. Resistance to manipulation
3. Minimal gas permeation through the skin
4. Minimal gas permeation through the seals
1. Minimal thermal conductivity, increased insulation performance

Barrier laminates that contain aluminium foil have very good barrier properties. However, VIPs with an aluminium foil laminate on both sides will also have aluminium’s high thermal conductivity properties. This leads to heat bridges at the panel edges, a phenomenon also known as thermal bridging or the thermal edge effect.

By the use of metallized films this thermal bridge effect can be minimized. Vacuum 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.

Using an EVAL™ VM-XL laminate on both sides of a VIP significantly reduces its overall thermal conductivity. The VIPs insulation properties are effective not just in the centre of the panel, but also along the edges.

**Difference in thermal conductivity, centre and edges of VIP**
2. Excellent flex crack resistance, high 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, especially during the evacuation process at the edges and corners of the panel. These stresses can damage the coating and/or deposited barrier materials on the barrier film, which results in an increased permeation at the VIP edges and corners and thus a decreased insulation performance.

In Japan VIPs with EVAL™ VM-XL films have been used for years for refrigerators, cold shipping boxes, rice cookers and electric kettles. 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 (EVAL™ EF-XL or EVAL™ EF-E) 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 and compared to that of other barrier films. After a couple of twist cycles the oxygen transmission rate drastically increases for the different barrier films except for the EVAL™ EF-XL (bioriented EVOH film) and VM-XL film (vacuum metallized EVOH film). These results prove that EVAL™ EVOH films have an excellent flex crack resistance.
3. Minimal gas permeation through the skin

To further develop the VIP market, the industry needs barrier laminates that have an improved gas and water vapour barrier.

<table>
<thead>
<tr>
<th>Film type</th>
<th>Application</th>
<th>EVAL™ VM-XL 15 µm</th>
<th>EVAL™ EF-XL 15 µm</th>
<th>EVAL™ EF-XL 12 µm</th>
<th>EVAL™ EF-E 30 µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum metallized</td>
<td>Intermediate layer VIP laminate</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>bi-oriented EVOH</td>
<td>“Back-up” layer for other barrier technologies</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>film</td>
<td>like aluminium foil</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bi-oriented EVOH</td>
<td>Sealing layer VIP laminate</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>film</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Cast EVOH film</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Condition</th>
<th>EVAL™ VM-XL 15 µm</th>
<th>EVAL™ EF-XL 15 µm</th>
<th>EVAL™ EF-XL 12 µm</th>
<th>EVAL™ EF-E 30 µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTR*1</td>
<td>cm³/m².day.atm</td>
<td>20°C, 0% RH</td>
<td>&lt; 0.05*3</td>
<td>0.1</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20°C, 65% RH</td>
<td>&lt; 0.05*3</td>
<td>0.3</td>
<td>0.4</td>
<td>1.0</td>
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<tr>
<td></td>
<td></td>
<td>20°C, 85% RH</td>
<td>&lt; 0.05*3</td>
<td>1.0</td>
<td>1.3</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40°C, 90% RH</td>
<td>&lt; 0.05*3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>WVTR*2</td>
<td>g/m².day</td>
<td>40°C, 90% RH</td>
<td>0.5</td>
<td>29</td>
<td>36</td>
<td>18</td>
</tr>
</tbody>
</table>

*1 Oxygen Transmission Rate (ISO 14663-2), *2 Water Vapour Transmission Rate (ASTM E96), *3 Less than the measuring limit

Values determined by eliminating from the measured value obtained from laminated products using PET or polyolefin film, the influence of the moisture permeability of the PET or polyolefin film.
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. The permeation through the seals can be substantially reduced by the use of EVAL™ EVOH film as a sealing layer. EVAL™ EVOH has outstanding gas barrier properties that exceed those of other plastics used today for barrier purposes. 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).

<table>
<thead>
<tr>
<th>Films</th>
<th>Tₘ (°C)</th>
<th>Oxygen transmission rates of selected polymers (cm³.20µm/m².day.atm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>20°C, 65% RH</td>
</tr>
<tr>
<td>EVAL™ EF-E</td>
<td>165</td>
<td>1.6</td>
</tr>
<tr>
<td>CPP</td>
<td>150</td>
<td>3250</td>
</tr>
<tr>
<td>LDPE</td>
<td>110</td>
<td>10000</td>
</tr>
</tbody>
</table>

Conclusion

The insulation performance and service life 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 sealing layer. This way, they add value to a wide range of applications, and potentially open new opportunities for more efficient energy use with VIPs.
Environmental benefits of EVAL™ resins

As the impact we create on our environment becomes an ever greater concern, the world continues to look for solutions that are truly sustainable. EVAL™ EVOH films can help, providing valuable function that improves the performance of VIP insulation properties. The resulting energy efficiency with thin non-conductive structures and extended service life helps reduce the environmental impact of the product throughout its life cycle.

A one millimetre thickness of EVAL™ EVOH has about the same gas barrier properties as ten metres of LDPE. With such high performance, EVAL™ gives plastic structures the vacuum-retaining barrier performance that could previously only be achieved with metals.

Improved thermal insulation
Since EVAL™ is a plastic, not metal, thermal bridging or conductivity can be sharply reduced without compromising the overall barrier performance. Improved, highly effective insulation means more efficient product energy use.

Thinner structures, fewer materials
VIPs containing EVAL are so effective that they provide excellent insulation efficiency even in very thin structures. Thinner and light-weight insulation panels allow more freedom of design. Without compromising on performance, the functional volume can be increased or the total amount of materials used per unit can be reduced.

Energy recovery at end of life
A high proportion of energy is recoverable from EVOH, often reducing the amount of extra fuel necessary for the thermal disposal of sorted waste. Under perfect combustion, the few microns of EVAL™ in the structure emit only small amounts of CO₂ and water vapour.
Introducing Kuraray and EVAL™

Kuraray and EVAL™
Kuraray Co., Ltd. was established in 1926 in Kurashiki, Japan, for the industrial manufacture of chemical fibres. As the world’s largest producer of vinyl acetate monomer (VAM) derivatives, Kuraray has long been a leader in high gas barrier technology and development. Today the Kuraray Group consists of about 70 companies, employing around 7,000 people worldwide. Kuraray has been manufacturing and marketing ethylene vinyl-alcohol copolymers (EVOH) under the name EVAL™ since 1972, and remains the world leader in EVOH production and market development. EVAL™ is one of Kuraray’s core businesses and is produced globally in America, Japan and Europe. The sales and technical development of EVAL™ is supported by specialised local teams in each region.
EVAL™ the world’s leading EVOH

Europe
EVAL Europe nv (Antwerp, Belgium)
Capacity: 24,000 tons/year
Europe’s first and largest EVOH production facility

Americas
EVAL Company of America (Pasadena, Texas, USA)
Capacity: 35,000 tons/year
The world’s largest EVOH production facility

Asia-Pacific
Kuraray Co., Ltd. (Okayama, Japan)
Capacity: 10,000 tons/year
The world’s first EVOH production facility

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