Barrier films for vacuum insulation panels (VIP)

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1 Abstract

Vacuum insulation panels (VIP) have been used successfully for refrigerator insulation for 20 years. For about the same period of time, Wipak has experience with a wide range of high barrier films. During the last years however new application fields for VIPs have been found. Nowadays the range where VIPs are applied is huge, such as shoe- and tubing insulation and of course also within the building industry. On one side each of these groups has an identical primary task: the insulation, this means, the barrier film must have a high permeation barrier. On the other side the requirement to the VIP and therefore to the high barrier film as well are of completely different nature.

In the following paper several influence factors on the barrier will be discussed as well as the different requirements due to the application of the barrier film and how these requirements can be fulfilled with high barrier films from Wipak

2 Wipak Walsrode

Wipak Walsrode GmbH is part of the European Wipak Group, with approx. 1800 employees and several locations in Europe we produce high-quality films. Thus Wipak manufactures flexible and stable films for the packing of food as well as for medical and technical applications. Wipak and the North American sister company Winpak belong to the packing section of the Finnish company Wihuri Oy. In the area of the multi-layer films, particularly with barrier films, Wipak is technology leader. The film specialists develop with fresh ideas and the experience of decades film production and continue the tradition of the innovations. The range of the technical films is led under the name Covexx and within this range the barrier films for VIPs are a substantial field of work.

3 Requirements

The ranges of application in the building industry have partially completely own requirements. On one hand it is regulated by legal regulations and these regulations will be transfer as well to the film and on the other hand the boundary conditions compare to the conditions in the field of refrigerators are completely different.

3.1 Permeation

The requirements to the life time of VIPs in the building industry are much higher compared to VIPs in refrigerators. The life time of refrigerators is dedicated to approximately 15 years, but in the field of the

building industry a life time of 30 years if not 50 years is common. Because of this high requirement against life time in a general manner also a lower permeation is necessary by the barrier film.

The permeation of gases, in particular for non-polar materials, will be represented by the permeation of oxygen. This permeation is expressed in volume per area, for each day and difference of pressure, whereas the pressure difference means the partial pressure difference between the two sides of the film. Hereby it is to be noticed that in the literature and in various data the permeation rates vary in many kinds due to that the boundary conditions are different. It is important that permeation rates below 0,01 cm³/m²d are unrealistic as values for quality control. 0,01 cm³/m²d is at present the lower limit of the standard measuring devices that are used to measure the oxygen permeation in quality control. Only values down to this limit can be measured and supervised by the film manufacturer. All values below this value can be measured by complex measuring methods or interpolated, but then these values are only estimated, and they can never be secured as quality limit value. Beyond that the indication of the boundary condition (temperature, humidity) are important and necessary as well. For example the gas permeation increases due to an increase of the temperature, Figure 1. An increase of humidity has a negative effect on the oxygen permeation rates, the permeation will increase. For a rough estimation, a temperature rise of 1 °C increases the permeation about 5-7 % [Mo05].

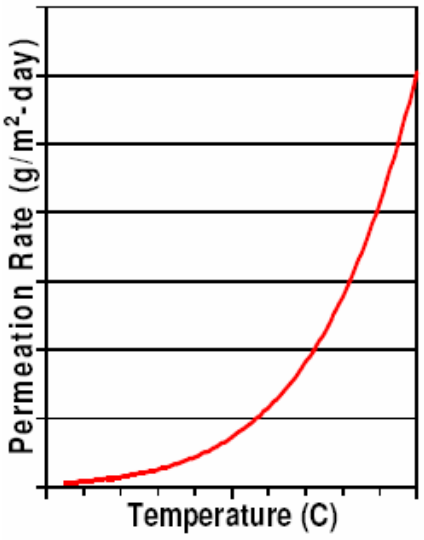

Fig. 1: Permeation rate vs. temperature

The second characteristic value is the water vapor permeation. This value is expressed in g/m²d and today's barrier film should have a value below 0,05 g/m²d at 38°C, 90 % r.H. The indication of temperature and air humidity is important since also the water vapor permeation will change with temperature and air humidity, see Figure 2. Further the water vapor permeation represents the symbolic value for permeation of polar materials through the material.

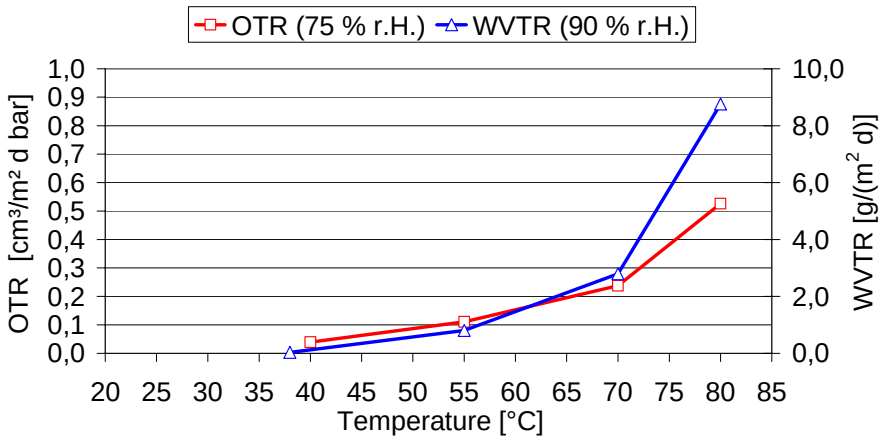

Fig. 2: Increase of the Permeation due to an increase in temperature for a non optimized high barrier film

The cause of the strong rise of the permeation values at higher temperature is to be justified with the fact that with reaching the glass transition temperature a change arises within the film. At this

temperature the transition of the energy elasticity range (= glass range) takes place to the entropy-elasticity range (= elastic range).

Only the combination of good barrier values against oxygen and water vapor guarantees a good overall barrier of the film. From this listing of the two crucial permeation values, also the simple conclusion can be drawn that barrier films for the building area must have another structure like barrier films for the Vacuum Insulation Panels in refrigerators. Since e.g. in the building industry importantly higher and varying temperatures prevail than in comparison to the refrigerator, where from a constant outside temperature of approx. 23°C can be proceeded.

However the increase of the permeation can be compensated even at higher temperatures to a minimum by a right choice of the single films, Figure 3.

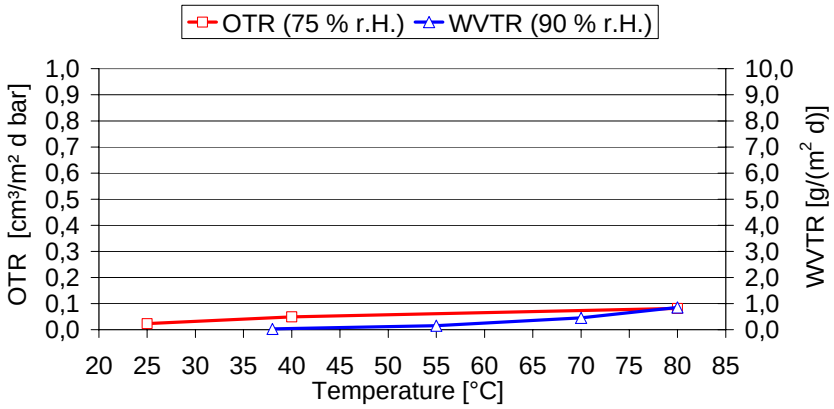

Fig. 3: Optimize barrier film for building application: Covexx BE M DL 165 B2

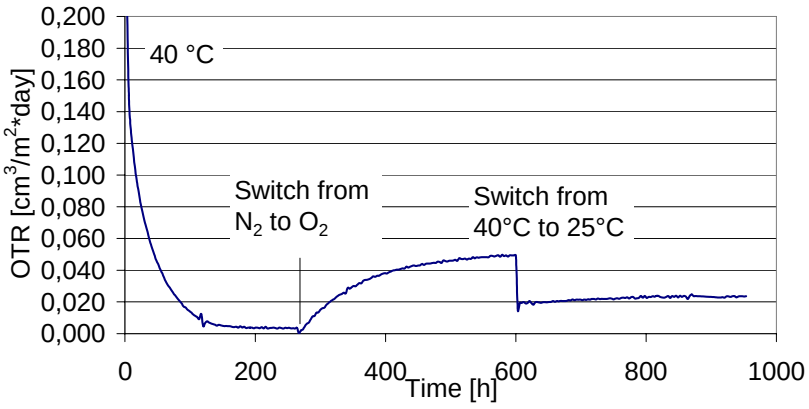

Fig 4: Monitoring of the OTR over several hours. It takes approx. 10 days to start the measurement and after 600 hours you receive one measurement point for one temperature

An obstacle during the development of further barrier films is the measurement of the permeability. Both the measurement of the water vapor transmission and also the oxygen permeability is a very time-intensive process (several days per temperature – Figure 4) which requires a high degree of experience. So it is to be noted e.g. that the sample has to be clamped in the same way as the expected conditions during the application. This means, that the outside ambient pressure (approx. 1 bar) and the appropriate humidity is applied to the outside of the film. This sounds banal, but it is however important and can influence the measurement. Several measurements have shown that different in the WVTR can occur up to 50%. Further, today's usual devices are at the limit of measurement for the production quality control.

3.2 Mechanical characteristics

Beyond the mechanical characteristics, apart from a good adhesion of the single layers, a proper sealing is necessary as well. In this part the experience of the processing plant plays a huge role further the selection of the sealing layer as well. Because of that the most of the VIP cores consist of pressed pyrogener silicic acid, which is dusty. It must be ensured at every time that no grains get in to the sealing layer (Figure 5). Otherwise a permeation increase could occur here, which is maybe visible only after several days or weeks. Furthermore the sealing layer should be sealable also in a broad temperature/ pressure and time window.

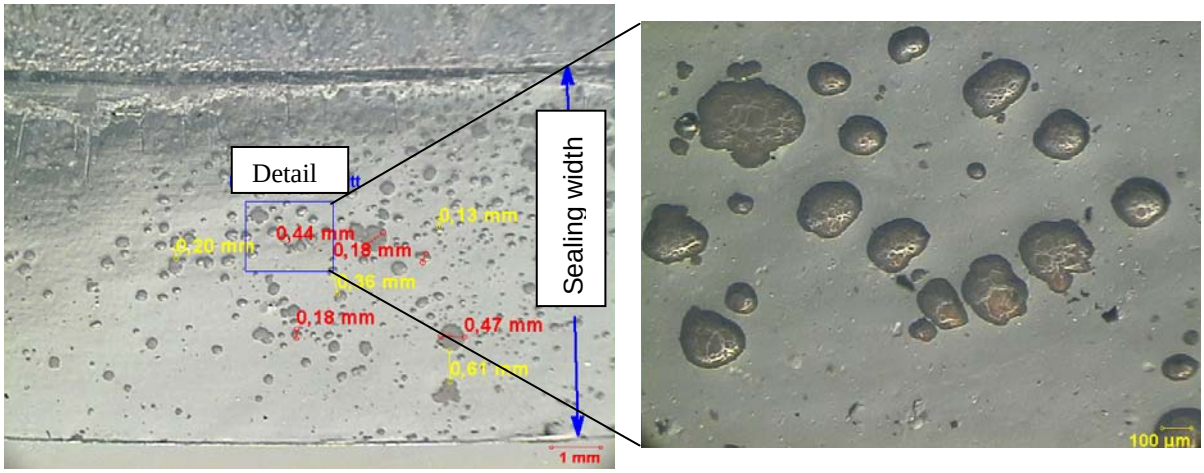

Fig. 5 Sealing layer of a VIP with embedded grains.

A further necessary characteristic is the achievement of sufficient puncture resistance. Here it is to be noted that the measurement has to take place from the outside to the inside of the film, since a damage occurs primarily from outside as e.g. by scratches or impacts (Figure 6).

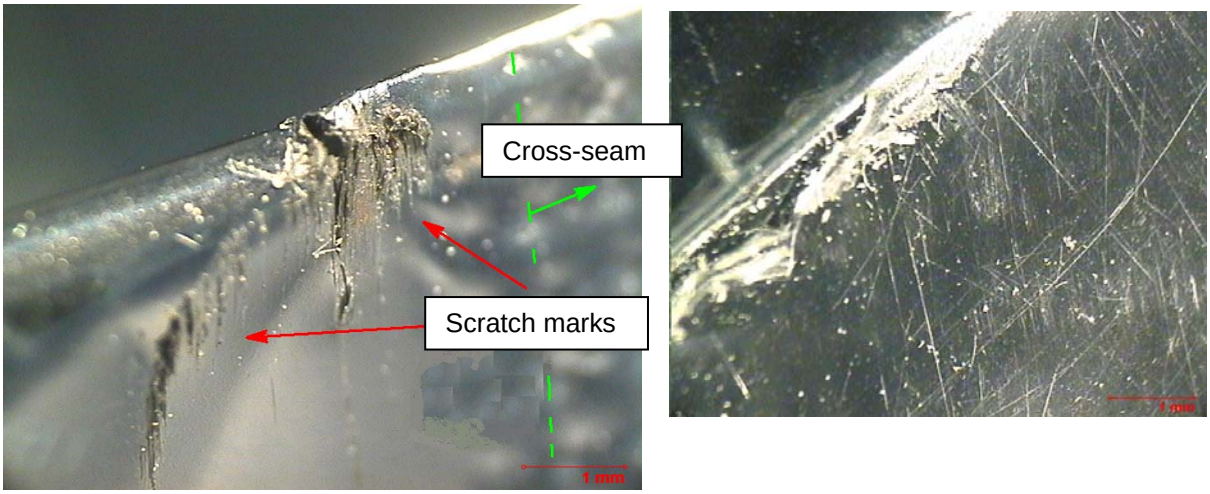

Fig. 6: Scratch marks at a VIP film

3.3 Building material class B2

A huge difference are the requirements for high barrier films in the building industry in contrast to the requirements for using them in a refrigerator is the fulfillment of the building material class B2 according to DIN 4102 [NN98]. Here it is to be noted that not the barrier film is tested alone, the complete VIP is examined. If the barrier film would be tested alone, then the fulfillment of the building

material class B2 wouldn't be a problem. However if the complete VIP is examined, then other boundary conditions are present. Due to the fact that the core of the VIPs is a bad thermal conductor, the developed heat will not dissipate and remains locally in place. Thereby the films receive a lot higher thermal stress in comparison to a test without the core material.

The examination of a VIPs turns out quite simply, in such a way that a defined flame size is directed toward the most sensitive place (edge flaming) at the VIP. This flame is directed 15 seconds toward the VIP and in the next following 20 seconds the flame point may not cross a defined height.

In the course of numerous test series, Wipak developed a film, which fulfills the requirements of the building material class B2 according to DIN 4102 (Covexx M DL 165 B2). At this high barrier film no compromises were made to the further demand characteristics such as permeability (see Figure 3) and life time. It concerns rather a further development of a state of the art successfully high barrier film with the ad on to fulfill the building material class B2.

3.4 Alkaline / Acidic Environment

Since in the building sector also strongly alkaline environments can be present, this must be considered during the development of the films. Cement can have a pH value of up to 14. In this case the critical point is the join/cutting edge of the film due to a (possible) penetration of the cement dissolution into the metallized layer where delamination of the film can take place. This can be avoided by a simple turn over of the cutting edges, whereby first installations pointed out the success of this simple alternative.

Important is in addition also the compatibility with other building materials (adhesives, finery...). Also the question is, how the VIP will be fixed at the wall. These are for the moment still questions that must be coordinated by intensive communication between users, VIP producer and film supplier.

3.5 Heat conductivity

Beside the core material the heat conductivity of the VIPs is also determined by the film. Today, there are three different main film concepts:

- Barrier film which contains an aluminum foil of approx. 5 – 12 µm
- Barrier films containing only polymeric barriers layers
- Barrier films containing one or multi SiO_x, Al_xO_y or metallized layers
- In some cases, as well hybrid barrier films

Barrier films with aluminum always contain an aluminum layer as is indicated by the name. This aluminum foil has got a thickness between 5µm and 25µm, typically between 7µm and 12µm. This type of barrier laminate exhibits nearly perfect barrier properties, but has the problem of thermal conductivity within the aluminum layer, which can lead to heat conduction all around the panels edges, which is known as the thermal edge effect in VIPs. With a metallized barrier film several individual (up to three) metallized films are laminated together. In this case the total thickness of the metallized layer is approx. 100-300 nm. Due to these thin metallized layers a sufficient barrier is obtained and nowadays most of the used panels are using metallized film structures.

Barrier films on purely polymer basis, have the advantage that they are suitable for thermoforming and exhibit an optical transparency, however the disadvantages are found in the high thicknesses of the films to reach the necessary barrier and in the strong rise of permeation at increased temperature and air humidity.

3.6 Structure of the films

The principle structure of the films, did not change in the last years and can be found in appropriate literature [Ja03, Br02]. Independent if the functional barrier layer is either metallized, an aluminum foil or a polymer film, the structure can simplified as follows. On the outer side of the barrier film is a substrate, which is the responsible link to the surface of the object that has to be insulated. This can be among other things polyester, polypropylene or also polyethylene, whereby here the boundary conditions are very important. As a sealing layer a polyethylene with the requirements as before described are usually used.

3.7 Manufacturing

The manufacturing of high barrier films requires a high potential of technical know-how. During the lamination on the one side the metallized films may not be subjected to high tension, but on the other side the web tension must be adjusted carefully so that winding without crinkles is possible. However it cannot be denied, that through each converting stage a damage of the film occurs. If this would not be the case, then the total permeation of the laminated film has to be the result of a simple addition of the single permeation rates. Thus the total permeation could be calculated according to a series connection from the electro-technology.

Today's high barrier films for VIPs represent the upper class in the area of laminated films, since the requirements are very complex. All this leads to the fact that there is not the one VIP film. It must be looked rather exactly on the requirements. Wipak Walsrode offers user-specific high barrier films, which apply in some cases for many years within different application areas (Table 1). However it is, as in nearly each technical application, first to define the application profile before choosing the special high barrier films.

Table 1: Different high barrier films from Wipak Walsrode for VIP applications

COVEXX	Properties/ Application	Sealability	WVTR [g / m² d] (38 °C, 90 % r.h.)	OTR [cm³ / m² bar d] (23 °C, 0 % r.h.)
BE M DL 105	long term longevity VIPs e.g. refrigerator	a/a	0,05	0,01
BE M DL 110	medium term longevity VIPs e.g. cooling box	a/b	0,07	0,05
BE M DL 165	long term longevity VIPs, a/b sealable	a/b	0,03	0,01
BE M DL 165 B2	long term longevity VIPs, fire resistance class B2	a/b	0,04	0,01
BE M DL 165 S	long term longevity VIPs high temperature stability	a/b	0,03	0,01
BE M DL 135 I	long term longevity VIPs high adhesion to EPS-foams	a/a	0,04	0,01
AL P 85	Aluminum containing VIP film	a/a	n.m.	n.m.

n.m.: not measurable, a: VIP inner side, b: VIP outer side

4 Summary

Within the range of high barrier films for VIPs important steps could be made during the last years. Thus by continuous development the permeability was decided lowered even at higher temperatures and therefore new application fields could be found. By fulfilling important laws (building material class B2 according to DIN 4102) a further important step was done, to establish VIPs also in the building area. However it now also requires an implementation of these new VIPs films in the appropriate areas of application.

Wipak Walsrode has a high knowledge in the area of high barrier films, which was developed due to the experience of many years in this area. In the future Wipak Walsrode will continue to develop new high barrier films for different applications. Due to the already installed VIPs, this market is a chance for the future and Wipak believes in that innovative, and at the same time interesting, insulation material.

5 Literature

[Br02] Brandt, R. Vakuum-Isolations-Paneele eine anspruchsvolle Anwendung für Sperr-schichtfolien?, SKZ-Fachtagung, Würzburg, 24.-25. September 2002

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[NN98] N.N. Brandverhalten von Baustoffen und Bauteilen, Teil 1: Baustoffe – Begriffe, Anforderungen und Prüfungen, DIN 4102-1, Beuth Verlag, Berlin