How to Determine the Long-Term Performance of Vacuum Insulation Panels

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Vacuum Insulation Panels (VIPs)

- Ultra-thin, high-performing insulation
- Can be up to 20 times more effective than existing insulation products
- Rigid, highly-porous core material encased in a thin, gas-tight outer envelope, evacuated and sealed
VIPA International is the association representing the interests of the global vacuum insulation panel industry. Membership includes VIPs manufacturers, material and equipment suppliers and academia.

- Contribute to the standardisation process (funding of technical studies)
- Shape a better regulatory environment for VIPs
- Be a forum for discussion for the industry players
- Raise awareness and visibility to VIPs
- Dialogue with policy makers and stakeholders
Advantages of VIPs

• Thermal conductivity between 0.002 and 0.008 W/(m·K) after production
• Extremely low insulation thicknesses (10 mm to 40 mm)
• **Saving of valuable space**
• Stable, long-term thermal performance when installed correctly and protected from damage and penetration
Applications

Buildings

Transport

Appliances

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Where VIPs Can be Used in Construction

- VIPs are used where good insulation is required but little space is available
- VIPs can be used in new buildings and for renovation
- VIPs make more living space available
- VIPs can be part of a thin and elegant new construction
- VIPs can solve problems with heat or cold bridges

renovation of a balcony niche
Example: Facade refurbishment

requirement:
max. 30 mm incl. VIP Insulation and plaster on a massive brick wall
Example: Protection Layer

Protection layer: PUR foam 30 mm

Thin contact glue layer on VIP, glue layer on PU cover panel
General Application Instructions

Vacuum insulation panels need to be treated with great care.

Vacuum insulation panels (VIPs) should not be mechanically damaged. Sawing, drilling and scratching in particular must be avoided.

VIPs should not be exposed to high temperatures, high humidity levels and/or aggressive gases during storage or application.
General Application Instructions

VIPs can be fixed using non-alkaline adhesives like dispersions adhesives or 2-K adhesives, **no cement based adhesives**.

High temperatures and high humidity can degrade the service life of VIPs, especially high humidity. Condensed water on the panel surfaces should be avoided.

People working with VIPs should be adequately trained in advance.
How to Assess the Long Term Properties of VIPs

Slight increase of VIP thermal conductivity due to steady permeation of air and water vapour through the high gas barrier envelope.

VIPs based on fumed silica powder core:
maximum thermal conductivity if damaged and air-filled: \( 20 \text{ mW/mK} \)

Service life time of VIP is not easy to be defined in an unique way. If VIP is installed properly, no failing is to be expected.

=> mean thermal conductivity during specified time (25 years)
Standardisation of Monitoring the Ageing Process

• The development of reliable methods to measure the ageing process of VIPs in the building sector is of utmost importance for the industry.

• VIPA International is working together with the ISO (TC 163/SC3/WG11), the CEN (TC88/WG11) and the IEA-EBC (Annex65) on measurement methods for the ageing process of VIPs.
Declared Value of VIP Conductivity

Energy Performance Certificate of building needs information on VIP mean thermal conductivity during service life time.

⇒ declared value of thermal conductivity $\lambda_D$

which is calculated by

- initial thermal conductivity after production
- plus effective th. cond. due to heat bridges of VIP edges
- plus mean rise of thermal conductivity during service time
Aging of VIPs at Ambient Conditions

Long term monitoring of VIPs

Experimental results of EMPA/Switzerland:

20 mm Silica VIPs were stored for 10 years at 23°C and two different humidity conditions: $\varphi = 33\%$ and $\varphi = 80\%$

thermal conductivity was tested initially and after 10 years
### Results 10 years storage at 23 °C

<table>
<thead>
<tr>
<th>condition</th>
<th>φ rel. hum.</th>
<th>( \lambda ) initial</th>
<th>( \lambda ) after 10 years</th>
<th>( \Delta \lambda ) change</th>
<th>( \Delta \lambda / \Delta t ) yearly rate</th>
<th>mean increase 25 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>high hum.</td>
<td>80</td>
<td>3.9</td>
<td>6.1</td>
<td>2.2</td>
<td>0.22</td>
<td>2.75</td>
</tr>
<tr>
<td>dry</td>
<td>33</td>
<td>3.9</td>
<td>4.5</td>
<td>0.6</td>
<td>0.06</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Yearly rate of increase of thermal conductivity \( \Delta \lambda / \Delta t \) is very small
Not detectable during a reasonable time of test (max. half a year)

\( \Rightarrow \) **Acceleration of aging by e.g. higher temperature** (Arrhenius law)
Accelerated Aging

Annual increase of thermal conductivity of VIPs may be as low as 1 - 2% (results in 25 - 50% increase after 25 years)

⇒ Accelerated Aging necessary by e.g. elevated temperatures

CEN procedure:
• VIPs are stored at climate 50°C/70% r.h. for 6 months
• Thermal conductivity is measured every two months

Example 20 mm silica VIP:
– Annual thermal conductivity increase at accelerated aging conditions
Conversion to Standard Climate

Extrapolating aging results to standard climate for construction: 23 °C / 50 % r.h.

Climate may be different for other applications

Two cases:

• fumed silica powder without desiccant
• other materials (glass fibers, foams) with desiccant
Aging: Pressure Dependence of Thermal Conductivity

\[ \lambda(p) = \lambda_0 + \frac{26}{1 + \frac{p_{1/2}}{p}} \]

- \( \lambda \): thermal conductivity
- \( p \): gas pressure
- \( p_{1/2} \): typical gas pressure of core

For construction mainly VIPs with fumed silica core are used
Extrapolation to Standard Conditions

Example (schematic) for glass fiber VIP with desiccant:
Thermal conductivity increase measured at 50°C is scaled down to increase at 23°C by acceleration factor $f_{\text{air}}$ (here $f_{\text{air}} = 4$)
Silica VIPs without Desiccant

Fumed silica powder adsorbs moisture

Influence of moisture content on thermal conductivity
Water vapour permeation rate here is more important than air permeation rate

For scaling accelerated aging at 50°C/70% to 23°C/50%

scaling factor $f_v$ of water vapour is dominating

Typically, $f_v = 10$ for metallized barrier films
Mean Thermal Conductivity
Silica VIPs without Desiccant

Assuming linear increase through service life time $t_{\text{serv}}$ (e.g. $t_{\text{serv}} = 25$ years)

$$\lambda_{\text{mean}} = \lambda_0 + (d\lambda/dt)_0 \cdot \frac{1}{2} \cdot t_{\text{serv}}$$

Here

$$(d\lambda/dt)_0 = 0.79 \text{ mW/(mKyr)} \ @50^\circ \text{C}/70\%$$

with $f_v = 10$:

$$(d\lambda/dt)_0 = 0.079 \text{ mW/(mKyr)} \ @23^\circ \text{C}/50\%$$
Mean Thermal Conductivity
Silica VIPs

\[ \lambda_{\text{mean}} = 4.75 \text{ mW/mK} + 0.079 \text{ mW/mK} \cdot \frac{25 \text{ y}}{2} = 5.7 \text{ mW/mK} \]

typical declared value of silica VIP for construction:

\[ \lambda_D = 7 \text{ mW/mK} \]

(including heat bridges)
Conclusions

Conditions for evaluating long term performance of VIPs have been defined by CEN TC88 WG 11 committee.

Accelerated aging of VIPs at climate 50°C/70% most suitable
Change of thermal conductivity is measured during half a year
Mean thermal conductivity during service life then is calculated

Procedure is applicable both to silica and non-silica core materials
Besides construction any other application with specific climate and service life time can be included
Thank you very much for your attention!

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Extrapolation to End of Service Life Time

Initial change of thermal conductivity \((d\lambda/dt)_0\) is known

Extrapolation to end of service life time by:

\[
\lambda(t) = \lambda_0 + \frac{\lambda_{\text{air}}}{1 + \frac{\lambda_{\text{air}}}{(d\lambda/dt)_0 \cdot t}}
\]