Calculating Thermal Bridge in VIPs

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Table of Contents

Calculating Thermal Bridge in VIP Panels

A guide to selecting the right core material, and the right envelope

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Introduction:

The vacuum insulation panel (VIP) industry primarily uses two types of core materials - glass fiber (fiberglass or FG) and fumed silica (FS). Because fiberglass panels degrade quickly even under a low build-up of pressure, they require the extremely high barrier that Aluminium foil (Al foil) based laminates provide. Although the center of panel conductivity of FG panels is about 50% smaller than that of fumed silica, they show poor initial insulation performance due to the high heat conductance of the Aluminium foil, known as the *thermal bridge effect.*

Fiberglass panels are relatively inexpensive, but the performance of fiberglass panels with Al foil can be poorer than that of fumed silica panels with metallized laminates. This inferior performance is true from the moment of evacuation, and due to the quicker degradation of fiberglass panels, it becomes even more pronounced throughout the panel's service life. However, when fiberglass is the core of choice, then the thermal bridge effect can be ameliorated by using much thinner layers of Al foil.

Demonstration:

To illustrate this difference in insulation efficiency, Avery Dennison Hanita has built a simple Excel tool to calculate the effective thermal conductivity of combinations of core materials and envelope laminates. By comparing the insulation performance of vacuum panels with different Al-foil envelopes to panels with metallized envelopes, it is easy to calculate the effect of the extra heat conductivity through the envelope containing Al foils, and its negative effect on the overall thermal insulation performance of the panel. This calculation is based on the most comprehensive research made on the thermal bridge effect by the Swiss Research Institute in Zurich, EMPA[1].

We have applied their idea of calculating the effect of the thermal bridge by modifying the λ of the panel in the standard formula for calculating the amount of heat transferred through a panel. This formula shows the increase in thermal conductivity of the panel λ of the center of panel to λ-effective so that the overall amount of heat transferred from the warm side to the cool side in a second can be calculated by the standard formula which is the product of λ-effective multiplied by the surface area of the panel multiplied by the temperature difference divided by the thickness of the panel. In summary:

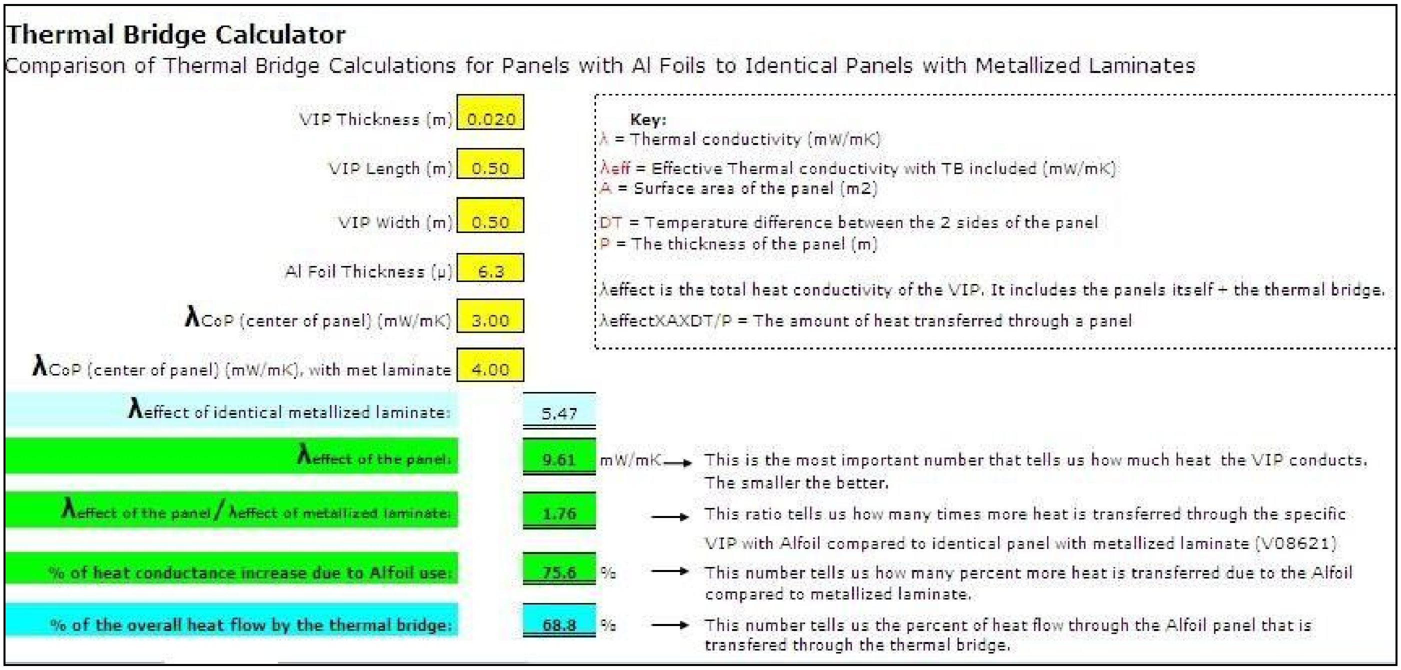
- **The amount of heat transferred through a panel**

  = λeffective X A X ΔT/P

Avery Dennison Hanita has taken this formula and created a simple Excel calculator that enables the calculation of the effective thermal conductivity of almost any combination of core material and envelope laminate.

The Thermal Bridge Calculator

In the six yellow cells, insert the dimensions of the panel in meters, the thickness of the Aluminium foil in microns and the center of panel thermal conductivity in mW/m^{2}K. The calculator will present the value of λ-effective of the panel and compare it with the result for an identical panel with metallized, non-foil laminate. It will also provide the percentage of heat transferred through the envelope for the panel under consideration. Note the effect on the thermal conductivity when different thicknesses of Al foil are used.



Thermal Bridge Calculator

Comparison of Thermal Bridge Calculations for Panels with Al Foils to Identical Panels with Metallized Laminates

VIP Thickness (m)	0.020
VIP Length (m)	0.50
VIP Width (m)	0.50
Al Foil Thickness (μ)	6.3
λCoP (center of panel) (mW/mK)	3.00
λCoP (center of panel) (mW/mK), with met laminate	4.00
λeffect of identical metallized laminate:	5.47
λeffect of the panel:	9.61 mW/mK → This is the most important number that tells us how much heat the VIP conducts. The smaller the better.
λeffect of the panel / λeffect of metallized laminate:	1.76 → This ratio tells us how many times more heat is transferred through the specific VIP with Alfoil compared to identical panel with metallized laminate (V08621)
% of heat conductance increase due to Alfoil use:	75.6 % → This number tells us how many percent more heat is transferred due to the Alfoil compared to metallized laminate.
% of the overall heat flow by the thermal bridge:	68.8 % → This number tells us the percent of heat flow through the Alfoil panel that is transfered through the thermal bridge.

Key:
λ = Thermal conductivity (mW/mK)
λeff = Effective Thermal conductivity with TB included (mW/mK)
A = Surface area of the panel (m2)
DT = Temperature difference between the 2 sides of the panel
P = The thickness of the panel (m)
λeffect is the total heat conductivity of the VIP. It includes the panels itself + the thermal bridge.
λeffectXAXDT/P = The amount of heat transferred through a panel

What do the results show?

For example, the calculator tells us that for a square panel of dimensions 0.5m, using a 9μ thick Al foil envelope, panel thickness 0.018m and center of panel thermal conductivity of 3 mW/mK, the effective thermal conductivity will be 11.37 mW/mK - almost four times higher than the center of panel thermal conductivity. The λ-effective of this panel is 114% higher than the λ-effective of an identical panel produced with fumed silica and metallized laminate! However, if Avery Dennison Hanita 6.3 micron Al foil laminate had been used, the thermal conductivity would have been lower, at around 72% more than that of a panel with metallized film envelope.

Comparison of thermal bridge calculations for panels with Al Foils to identical panels with Metallized Laminates

VIP Thickness (m)	0.018
VIP Length (m)	0.5
VIP Width (m)	0.5
Al Foil Thickness (μ)	9
λCoP (center of panel) (mW/mK)	3
λCoP (center of panel) (mW/mK), with met laminate	4

Key:
λ = Thermal conductivity (mW/mK)
λeff = Effective Thermal conductivity with TB included (mW/mK)
A = Surface area of the panel (m^2)
DT = Temperature difference between the 2 sides of the panel
P = The thickness of the panel (m)

λeffect is the total heat conductivity of the VIP. It includes the panels itself + the thermal bridge.
λeffectXAXDT/P = The amount of heat transferred through a panel

λeffect of identical metallized laminate:	5.32336		
λeffect of the panel:	11.37281	mW/mK	This is the most important number that tells us how much heat the VIP conducts. The smaller the better.
λeffect of the panel/λeffect of metallized lamintate:	2.136		This ratio tells us how many times more heat is transferred through the specific VIP with Alfoil compared to identical panel with metallized laminate (V08621)
% of heat conductance increase due to Alfoil use:	113.6	%	This number tells us how many percent more heat is transferred due to the Alfoil compared to metallized laminate.
% of the overall heat flow by the thermal bridge:	73.6	%	This number tells us the percent of heat flow through the Alfoil panel that is transferred through the thermal bridge.

Summary:

The Thermal Bridge Calculator gauges the effect of thermal bridge on the insulation performance of different core and envelope material combinations. The tool demonstrates that fumed silica panels with Avery Dennison Hanita's metallized laminate show a minimal thermal bridge effect in comparison to glass fiber/Al foil panels. The calculator clearly shows that when using a fiberglass core with a thinner Aluminum foil laminate, the thermal bridge effect, and the overall heat conductance of the panel will be substantially smaller. Thanks to the very low heat conductance through the envelope, fumed silica panels with metallized laminate, although they are more expensive than glass fiber VIP products, provide far better overall insulation performance from the beginning of panel life to its end.

References:

[1] EFFECTIVE THERMAL CONDUCTIVITY OF VACUUM INSULATION PANELS Authors: K. Ghazi Wakili; R. Bundi; B. Binder
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To receive a copy of the calculator, please contact barrier.laminates@eu.averydennison.com