# Typology of Applications for Opaque and Translucent VIP in the Building Envelope and their Potential for Temporary Thermal Insulation

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Vacuum insulating systems are among the major recent innovations of building technology due to their very high efficiency. Their potential to be the most effective way of insulating the building skin is increasingly raising architects' interest mainly for two reasons:

- to reduce the thickness of insulating material needed and therefore allowing for slimmer wall constructions
- to increase or enable insulation in critical construction situations (for example in the area of thermal bridges).

Other motivations often include aesthetic or economic aspects.

It can be concluded that most common applications up to now are following the approach to replace ordinary insulating material (PS, mineral fibres, PU) within standard wall constructions by VIP and then modify the construction to make it function. A reverse approach is described in [Cremers 2005/1].

The systematic study of architectural applications for vacuum insulating systems intending to illustrate interrelations and further potential is subject of a running doctoral thesis at the Chair of Building Technology. Parts of the enterprise are presented in this paper.

## 1 Different Vacuum Insulating Systems

Fig. 1 shows different core and envelope materials that can be combined for vacuum insulating systems of different light transmittance [first published in Cremers 2005/2]. The illustration also differentiates between well known, available systems and those under current research and development. The latter especially applies to all translucent and transparent systems with the exception of 'vacuum-glazing' (glass envelope and no core material) where there is at least one product on the market already (Spacia® by Nippon Sheet Glass, Japan).

For opaque systems in the building market the main core materials are fumed silica. Here, systems with polymer foils are commonly subsumed as Vacuum Insulating Panels (VIP) and those with envelopes made of metal plates as Vacuum Insulation Sandwiches (VIS).

The potential future availability of non-opaque vacuum insulating systems will broaden the scope of possible architectural applications significantly.

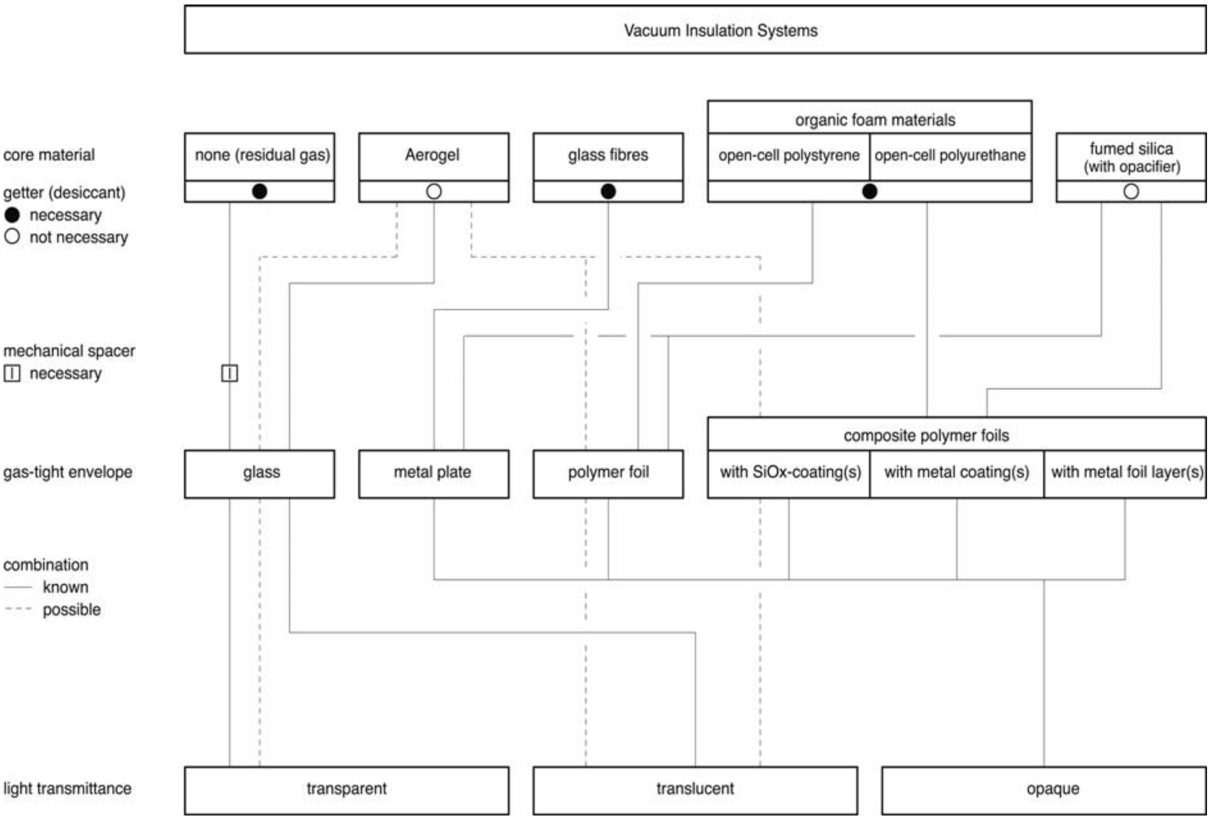



**Fig. 1: Components of vacuum insulating systems and relative opacity**

## 2 Typology of applications for vacuum insulating systems

Fig. 2 shows a typology of possible applications for opaque vacuum insulating systems which can be depicted in an analogue way for diaphanous systems [both first published and described in German in Cremers 2005,1].

The building envelope here is understood as the surface of the building exposed to the outer climate being separated into the facade and the roof. The envelope parts touching the ground are excluded in this study.

In the second level of examination the part of the envelope considered is differentiated between those with apertures and those without. Apertures here are understood to be areas permeable to solar radiation and/or air. This can be either windows, doors, ventilation sashes or even large glazed areas.

The third level deals with the question of whether the vacuum insulating system is mounted in a fixed or a movable part like a casement or a shutter for example. The latter case we call a 'manipulator' [Herzog 2004].

The fourth level addresses the relation between the vacuum insulated layer and the primary thermal break to differentiate between the following cases: If the vacuum insulating system coincides with the layer of the primary thermal break the relation is called 'identical' (e.g. an insulated opaque ventilation sash). Otherwise it will be referred to as 'additive' (e.g. an insulated shutter covering a regular aperture). The actual quality of the primary insulating layer is not of importance in this abstract analysis.

The last two levels introduce the case of temporary thermal protection to the typology whereby 'temporary' can refer either to the day/night period or even to seasons.

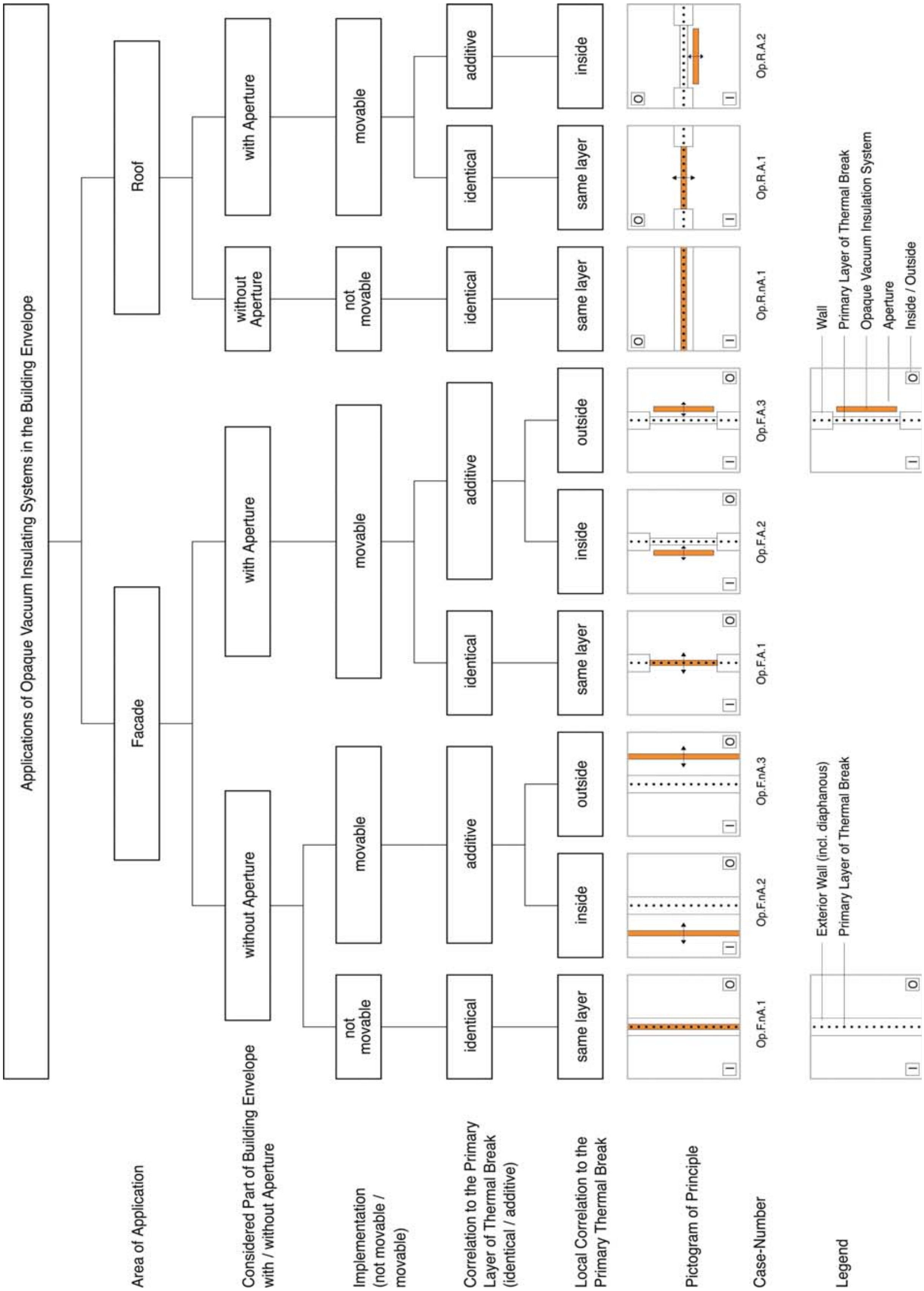



**Fig. 2: Typology of opaque vacuum insulating systems**

# 3 Study on the effect of temporary thermal protection

The typology in fig. 2 indicates the potential of an application for vacuum insulating systems for temporary thermal protection. To study the effect of such a measure (based on a day/night-period) a simplified scenario has been set up and examined by means of a thermal computer simulation:

A regular office room is fitted with a device for temporary thermal protection with different values of additional heat transmission resistance at night illustrated in fig. 4. The simulation carried out with HELIOS (developed by the EMPA) covered a complete heating period and all four major orientations.

Fig. 3 shows the effect on the transmission losses through the window (here: office room facing north) on four days in January. The energy-saving effect at night can clearly be seen from the stepped curves above the reference case without the protective device (QTr V1-0).

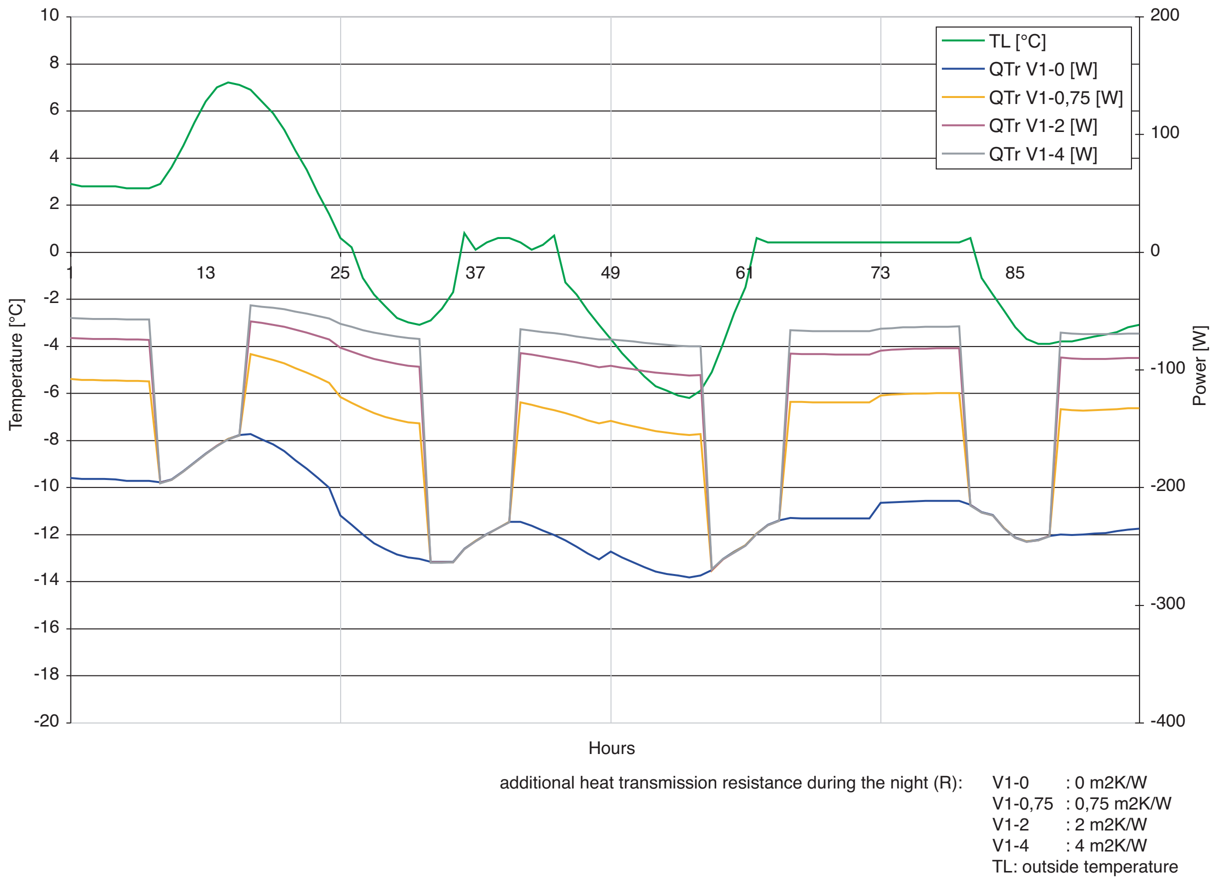



**Fig. 3: Transmission losses through aperture, orientation north, January 4-7**

The table in fig. 4 summarises the results and thereby shows the potential for highly effective temporary thermal protection as might be realised by the integration of vacuum insulating systems. However, it has to be emphasized that the relatively high values for the additional heat transmission resistance at night presuppose a tight connection on the edges free of thermal bridges.

It can also be concluded from the study that highly effective temporary thermal protection offers opportunities especially for mature buildings with low-quality glazing and for buildings with a constant demand for high interior room temperatures (e.g. hospitals) as transmission losses can be reduced significantly at night.

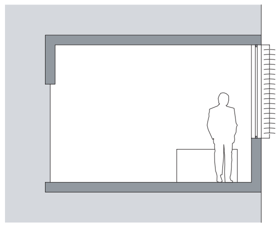
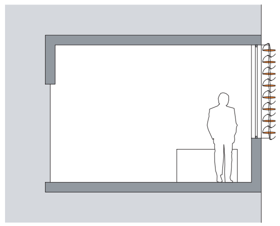
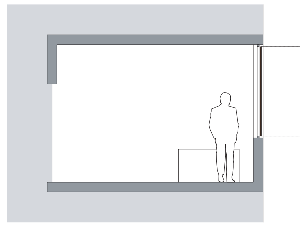
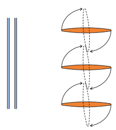
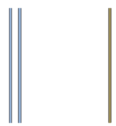
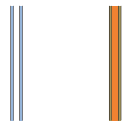
| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| schematic drawing of the examined scenario: a standard office room with a glazed aperture, all sides assumed to be adiabatic except for the facade - different solutions for temporary thermal protection at night | |  | | | |  | | | |  | | | | | | | |
| examined principle of temporary thermal protection | | reference: no temporary thermal protection | | | | insulating lamellae [1] | | | | simple wooden shutter (5mm) | | | | VIP-insulated shutter (5mm chipboard + 15mm VIP + 5mm chipboard) | | | |
| | |  | | | |  | | | |  | | | |  | | | |
| additional heat transmission resistance during the night [1] | | not existent | | | | 2,0 m²K/W | | | | 0,75 m²K/W | | | | 4,0 m²K/W | | | |
| $U_g$-value of the window (including temporary thermal protection) | | 1,66 W/(m²K) | | | | 0,35 W/(m²K) | | | | 0,72 W/(m²K) | | | | 0,22 W/(m²K) | | | |
| orientation of the office room | | north | east | south | west | north | east | south | west | north | east | south | west | north | east | south | west |
| annual transmission losses through the window | [kWh/a] | 751 | 766 | 775 | 765 | 413 | 429 | 439 | 428 | 512 | 528 | 538 | 527 | 365 | 381 | 391 | 380 |
| relation to reference (same orientation) | | - | - | - | - | 55 % | 56 % | 57 % | 56 % | 68 % | 69 % | 69 % | 69 % | 49 % | 50 % | 51 % | 50 % |

**fig. 4** **Summary of a Study of the Effect of Temporary Thermal Protection by the Computer-aided Thermal Simulation of a Standard Office Room. Simulation Tool used: HELIOS (EMPA)**

annotation: (1) Temporary thermal protection: Reduction of the U-value of the glazing at a solar radiation of 0 W/m $^2$ on the actual facade.

# 4 Two exemplary devices for highly effective temporary thermal protection

## 4.1 A membrane-covered, VIP fitted lamella

Fig. 5 shows the principle construction of a highly insulated lamella. The VIP core (a) is placed in the middle of a two-part aluminium grating (b) kept at distance and protected by polymer strips and brackets (c). The construction is completely separated locating the resulting thermal break exactly at the touching point if in the closed position (s. fig. 6). The subconstruction is stabilised by a protective thin ETFE-membrane being prestressed by finally applying an aluminium profile (e).

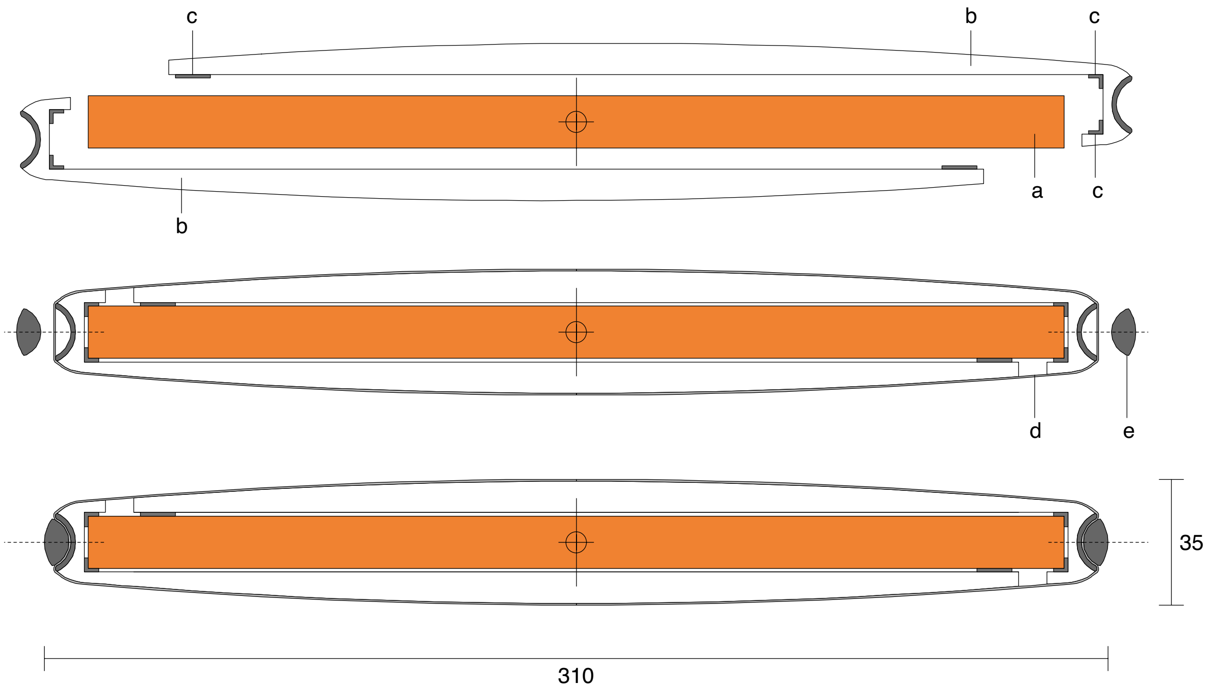



**Fig. 5: A membrane-covered, VIP fitted lamella: schematic drawing of the construction**

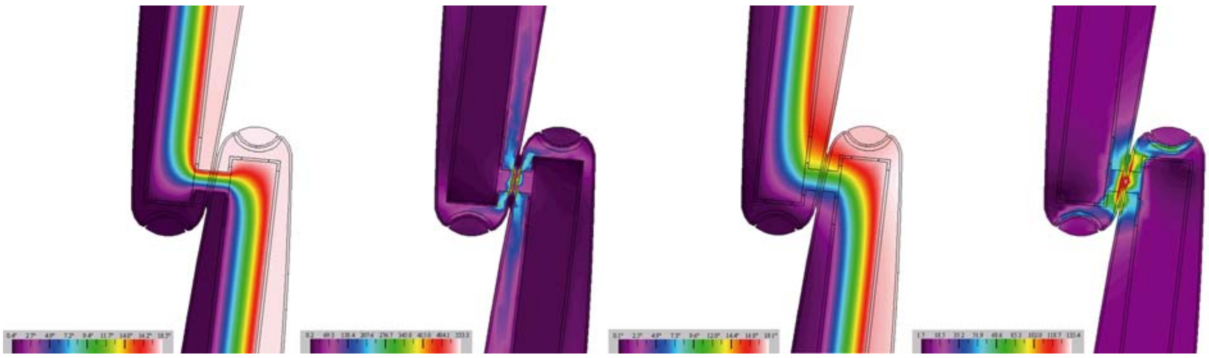


**Fig. 6: 2D-heat-transfer-simulation results, section through the alu-ribs (left) and between the alu-ribs (right). Each illustrated byisotherms (in °C) and maximum heat flux (in W/m$^2$)**

2D-Calculations (fig. 6, executed with THERM by LBNL, USA) provide a centre U-value of the closed lamella-curtain of 0,6 - 0,85 W/(m$^2$·K). Thus a $U_g$-value of a standard IGU of 1,7 W/(m$^2$·K) could be reduced during the night to around 0,5 to 0,6 W/(m$^2$·K) equivalent to 30-35%.

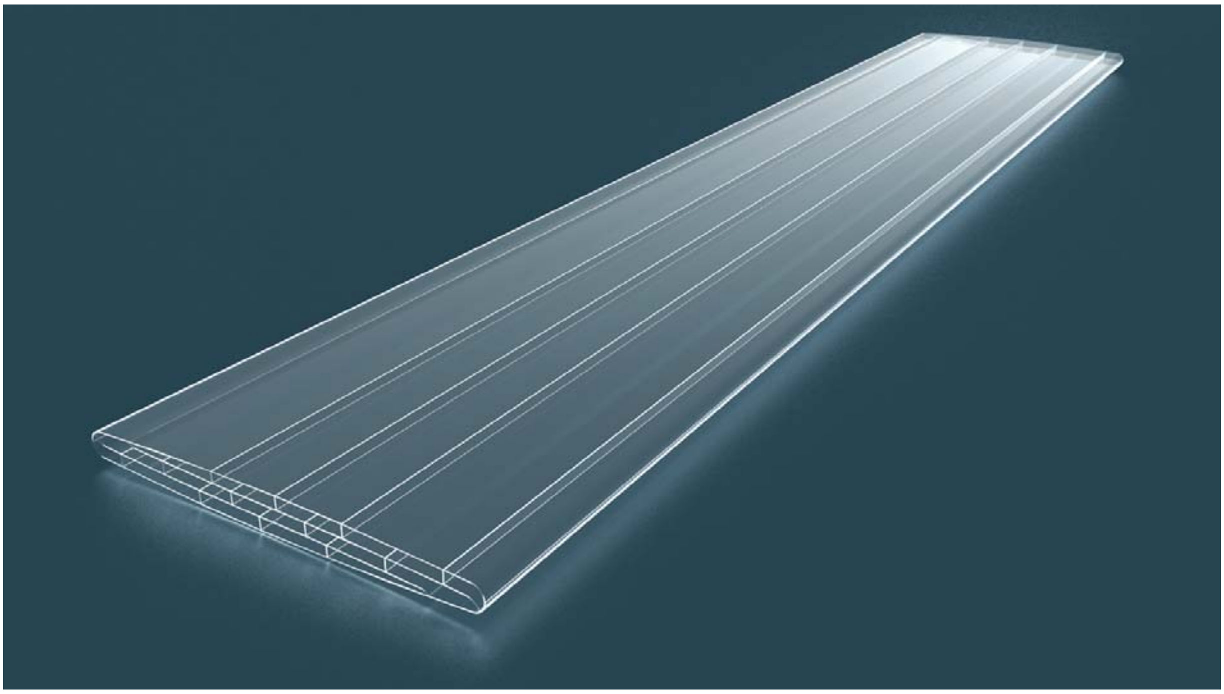


**Fig. 7: Rendering of the translucent polycarbonate lamella (unfilled)**

## 4.2 A translucent polycarbonate-profile lamella filled with aerogel

The second variant presented here follows up on the idea of having the PC-profile shaped by an extrusion process according to the optimal isotherms, i.e. prolonging the heat transmission path perpendicular to the isotherms at a maximum. The principle can be understood best from fig. 8 (top). Fig. 7 actually shows the empty profile whereas Fig. 10 displays a manufactured prototype built at the TUM which is filled with Aerogel-Granules (nanogel®).

This profile has also been calculated with THERM leading to the following results:

U-Value including joint: 0,9 W/(m$^2$·K)

for $\lambda_{Aerogel}$ = 18 mW/mK (ambient pressure)

U-Value including joint: 0,5 W/(m$^2$·K)

for $\lambda_{Aerogel}$ = 6 mW/mK (at 10 mbar)

It must be emphasised that the evacuated variant is currently hypothetical due to the unsolved demand for tightness of the profile but also because of the relatively large granules of the Aerogel used.

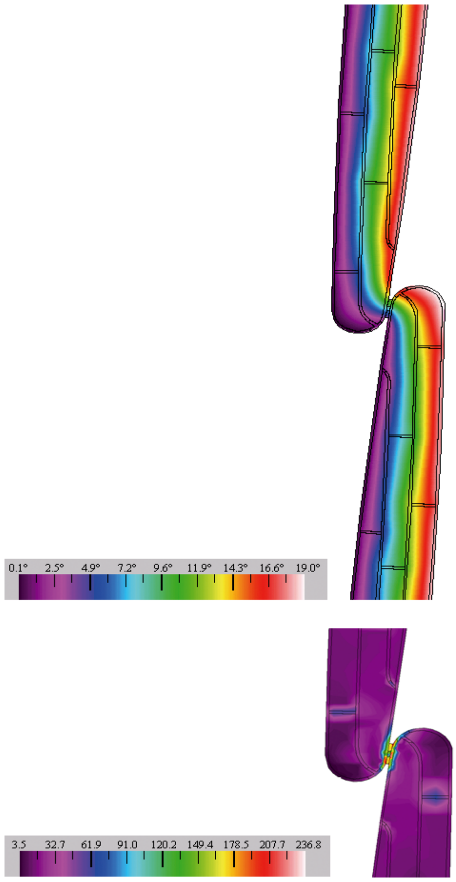



**Fig. 8: 2D-heat-transfer-simulation results, section through three-layer-variant, illustrated by isotherms (in °C) and maximum heat flux (in W/m2)**

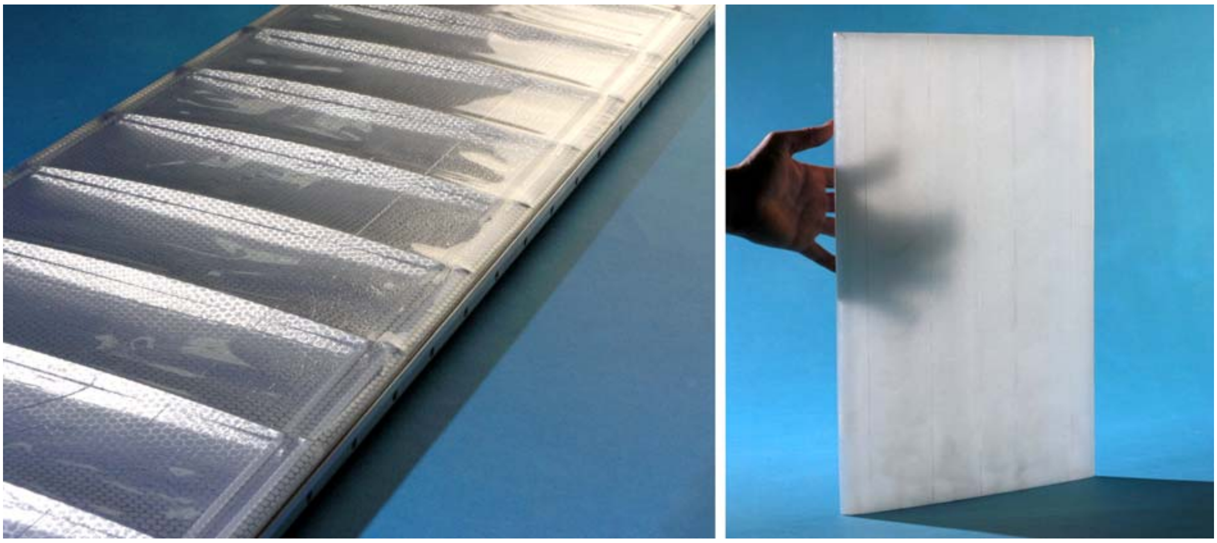


**Fig. 9 and 10: Prototypes of the described Lamellae**

Fig. 9 and 10 show the prototype status of the two proposed highly insulating devices for temporary thermal protection at the TUM. The membrane-lamella (fig. 9) is the only example known to the author where the vacuum insulating panel itself becomes part of the building appearance and is therefore giving clear and immediate evidence toward its potential.

The author expresses his gratitude to the following companies for generous support and sponsorship:

- va-Q-tec AG, Würzburg, Germany, www.va-q-tec.de
- Cabot Corporation (nanogel), www.cabot-corp.com/nanogel/

# 5 References

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