真空隔热系统

——可能的应用领域及其设计要点

Vacuum Insulation Systems – Possible Applications and Design Considerations

Jan Cremers

1 位于 Erlenbach(ZAE) 的一家医院采用的 VIP 材料建成的建筑立面外观图
2 真空隔热板（VIP 板）的通用结构和部件示意图
3 目前可用的各种真空隔热系统
4 真空隔热系统、材料组成和透光率

1 external view of the VIP facade of a hospital in Erlenbach (ZAE)
2 general structure and elements of a vacuum insulation panel (VIP)
3 different available vacuum insulation systems
4 vacuum insulation systems, combinations and light transmittance


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真空隔热系统是目前建筑界最重要的创新领域之一，正在受到各方面越来越多的关注。相对于建筑领域使用的其他多数产品来说，它们是高度复杂的系统，因此可能会带来众多的使用错误问题，这需要设计者和使用人员具有较高的能力。在传统的隔热材料中，热传递中的 20% ~ 30% 经由热辐射实现，另外 5% ~ 10% 的热传递经由结构框架材料实现，而剩余的约 65% ~ 75% 的热传递则由隔热材料周围的空气完成。因而，各类真空隔热系统共同的工作原理是：减少通过这些热传递途径中最重要的一环——空气传递热量，即通过将隔热系统抽成真空，减少热量传递。为了在这类隔热系统中维持长时间的真空状态，必须采用密封套将这一真空空间包覆起来。这些密封套可由玻璃、金属、塑料或合成塑料薄膜等构成。这一被包覆的空间可以是完全空无一物的，也可以填充上芯材，但那些芯材的组成单元必须是完全开孔的，这样能被抽成真空。系统还必须要能抵抗相当高的大气压（最大约为 10.3tonnes/m^2），具体情况取决于该系统的真空等级。


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图 4 给出了有关真空隔热系统、单个构成部件及它们可能的组合使用情况的总体介绍；同时它还介绍了有关各类真空隔热系统所能达到的透光率方面的情况。

芯材

在建筑界，当前我们主要关注于具有微孔隔热芯材的不透明真空隔热系统。这类隔热系统中的绝大部分芯材由玻璃纤维增强结构和熏硅组成，图 2 给出了建议结构样式。

正是因为这类材料具有极高的多孔性，且这些微孔足够小，因此它们能够极大地降低空气的导热作用。因而，即使是在标准大气压下，该材料的导热系数也仅约为 0.018W/m^{2}K。此导热率明显低于环境空气约为 0.026W/m^{2}K 的导热。这一导热率关系还具有进一步的影响，在相对较低的真空条件下该材料的导热也能显著下降，几乎逼近该材料在 10mbar 气压下的极限导热率 0.004W/m^{2}K。这样，生产过程的技术要求将显著降低，隔热系统也能够容忍其密封套材料和连接处（即胶封或焊接接缝处）相对较高的气体渗入率。最重要的是，由于该类产品的使用寿命取决于系统可能接受的最高内部气压升高值，所以此特点能使得该类产品具有更长的预计使用寿命。

密封套材料

人们一般在该领域使用两类材料，这两类材料的不同最终将促生两类极为不同的真空隔热系统：其中一类是金属塑料合成贴箔；而另一类是不锈钢板。专业文献中一般将第一类隔热产品称为金属隔热板（简称 VIP），将另一类产品称为真空隔热夹层（简称 VIS）（具体参见表 7）。

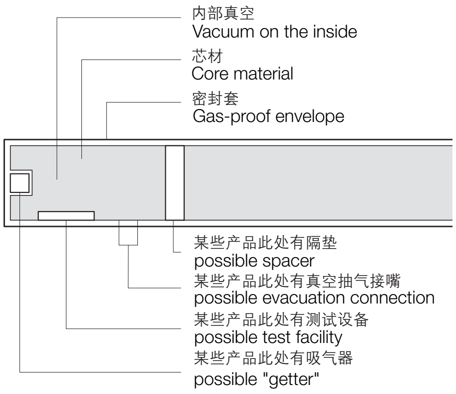
当前，隔热值较高的、覆有氧化硅层的透明化学聚合物薄膜尚不能满足必要的导热率要求。但其正处于进一步开发之中。

质量控制

真空隔热系统的导热率主要取决于其内部气压及其介质芯材的湿度。倘若某系统内部的初始气压和湿度为已知的话，那么原则上可采用这两个物理量来进行质量控制。如果忽略系统内部作用（如气体自行生成等）的话，可能发生的任何内部气压升高都主要取决于密封材料与边沿隔垫材料的质量。由于通过肉眼无法发现隔热板的气密破损，特别是在它们安装并被覆盖以后更是如此，那么采用相应的技术手段测量系统内部气压是质量控制惟一可行的手段。对于真空隔热系统，这一检测需求将带来特殊的困难：即使只是为了进行具体的质量保证，检测工序也必须贯穿整个的产品供应链——起始于制造过程，同时还需包括运输、仓储以及安装过程等。由于多次检测需要在不同地域进行，因此必须采用一种能够快速得出测量结果且便于操作的检测手段。那些无需穿透系统，且当隔热板仅能提供数个特定检测点时也能使用的检测方法是较为适用的。原则上，安装后的隔热系统工作性能也能通过使用热图像记录技术进行验证。对于不锈钢密封类隔热系统产品来说，取出单个的隔热板也是一种可行的辅助检测手段。

导热分类

目前，尚没有任何一类真空隔热系统产品得到批准可以在建筑工程中使用。一般来说，制造商仅能提供隔热板的中央处无干扰条件下的导热率值。而特别需要指出的是，隔热板安装后导热率无法达到该理想指标。可实现的 *U* 值（亦即平均导热



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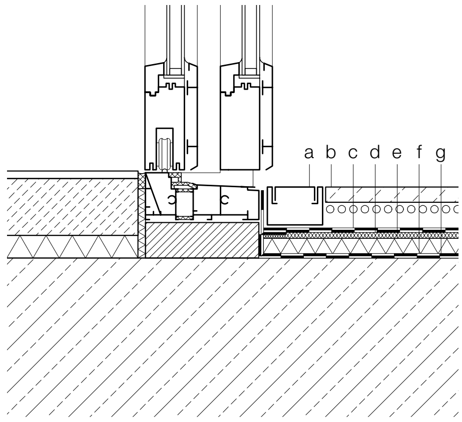


采用高性能真空隔热系统的无窗台的露台结构
a 有 50mm 栅栏的排水沟
b 有碎花贴面的 52mm 厚混凝土板
c 2mm 厚毛毡衬层
7mm 厚沥青防水层
d 8mm 厚建筑保护垫
e 20mm 厚高性能金属隔热板（VIP）
f 5mm 保护垫
g 3mm 沥青隔汽层

sill-free terrace construction through the use of high-performance insulation
a drainage channel with 50 mm grating
b 52 mm concrete slab with chippings
c 2 mm fleece underlayer
7 mm bituminous water barrier
d 8 mm building protection matting
e 20 mm high-performance insulation VIP
f 5 mm protective matting
g 3 mm bituminous vapour barrier

率）取决于隔热系统的几何外形、制作材料及边沿处所采用的成形和连接工艺。

环境工程学评估

在目前的认知条件下，我们能得出如下结论：相对于该系统较高的节能功效来说，其原材料开销较小。在建筑部门目前所使用的各种该类系统中，硅质材料板占绝大部分比重（VIS 系统中使用的不锈钢材料除外）。如密封用不锈钢材料，就可以轻易回收使用。在这些系统拆离后，无需多大难度就可以将它们拆散为构成部件。此时，它们将不再含有任何复合材料，于是可以被分类回收。目前使用的合成材料薄膜不能被立即回收使用，但是它们所占比重较小，且可以部分循环使用。

系统的设计注释

安装工艺要求

采用密封薄膜封装的隔热板在机械强度上尤为脆弱，因而，在建筑工地没有保护措施就安装该类隔热板是不可以的。高水平的预制使得它们能在有保护措施的可控条件下安装，当然该种方式也是更为可取的。此外，采用纤维板和泡沫材料薄层一类的软质包装层保护隔热板表面更为有利。我们应始终牢记真空隔热系统绝对不能被刺破，并要求这类系统在没有任何拉应力的条件下安装，极其严格地限定安装时的固定工艺。需要进一步向使用者强调的是，在后续过程中，不能通过打孔或钉入钉子在隔热系统的安装区域附加任何建筑材料。

热桥

每个出现的热桥，都将意味着系统的平均隔热值下降。这同样也将升高建筑的能源消耗，同时带来水汽凝结的风险。因为其几何外形的缘故，同时由于系统单元的边沿处总具有比其中部高的导热率，真空隔热系统将不可避免地产生热桥。系统接缝位置处此种效应的大小，严格取决于隔热系统的加工成形方法、系统的几何外形和尺寸，同时还特别取决于系统的安装位置。高性能隔热系统的使用将使得热桥效应变得更加突出，因为降低了隔热系统的厚度并使中部导热率最小化。这使得相对于传统隔热材料来说，热桥效应的解决在此类系统中具有更为重大的意义。即便如此，由于它们本身具有绝佳的防水汽性能，真空隔热系统内自身并不会产生水汽凝结。正是由于该系统本身的特点，才造成了其连接处会出现更多的薄弱点。在这个问题上，我们有必要注意详细论证非破坏性水汽的扩散现象。

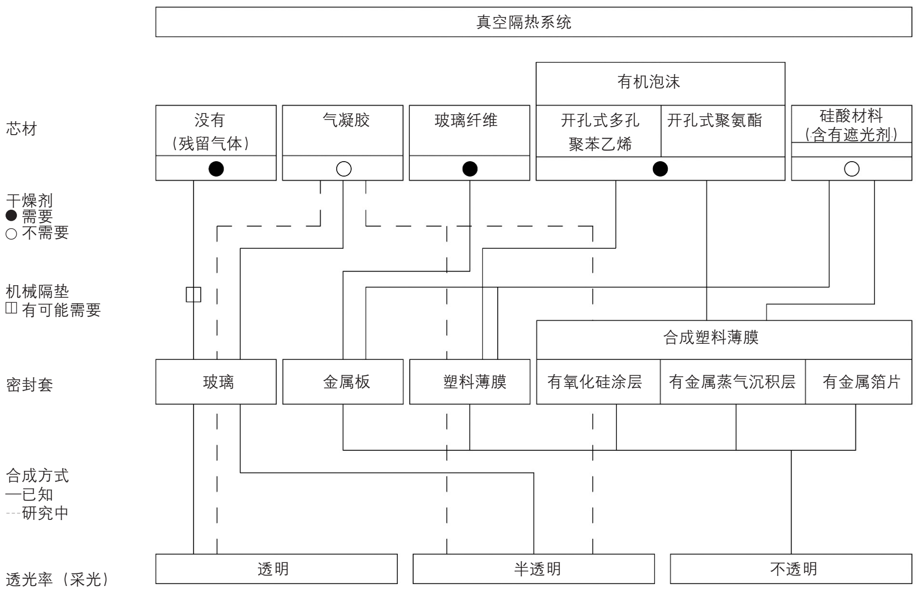
隔热系统样式

首选隔热系统样式是矩形隔热板式样，它们的直角边具有最为精确的几何精度。不过，其他类型的外形样式也是可行的，虽然它们通常会带来巨大的制造费用，同时也将降低产品的预期使用寿命。所有真空隔热系统的基本特征就是，它们的板材形状一旦制造完成就不能更改，即它们不允许任何后续的形状修改。此问题在产品设计阶段考虑制造公差时极为重要。由于热桥效应带来的尖锐问题，对于真空隔热系统的应用来说工程尺寸的精确设定要求是极高的。需要进一步考虑的是工程预算方面的压力，这使得工程仅能采用少量的适用样式。

采用标准的产品样式能够提供进一步的优势，在此种情况下，由于它们在仓库中已有大量存货而无需临时制造，所以在简要通知后即能获得额外的产品供货。

可替换性／可接触操作

因为相对于传统的隔热材料来说，真空隔热系统易于损坏，所以如果它们能够不太费劲地进行更换的话会更为有利。因



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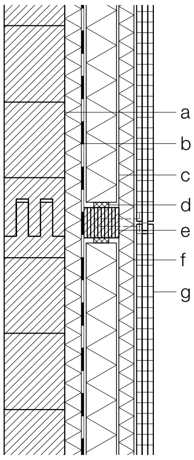

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而此类结构必须以下面几种方式构建：要么能够取下单个的隔热板，要么能够拆卸固定它们的子系统。

一个工程实例：

用于立柱气窗立面的隔热板

仅需较小的难度，就能将真空隔热系统安装到现有的立柱气窗系统之中。同样，由于完工后的隔热系统的厚度极其接近常用的多层隔热玻璃，这两者也可以互换。相对于具有较大厚度的传统隔热板来说，此处采用将玻璃窗覆盖的办法也是特别适当的——即将隔热系统安装于玻璃窗内立面。约 32mm 的单元厚度足以在板材中部达到 $0.16W/m^2K$ 左右的 U 值。相对于当前所使用的最好的多层隔热玻璃（该玻璃中部的 U 值约为 $0.65W/m^2K$）来说，U 值也已降低了约 75%。由 ZAE–Bayern（即巴伐利亚实用节能研究中心）为位于 Erlenbach 的一家医院开发的隔热板（见图 1），给出了这种安装前后呈现出的不同效果的实例。

在这类工程应用中，建筑立面整体的 U 值很大程度上取决于隔热板的大小，及隔热板边沿处尺寸与其平面区域的相对比例（如使用隔圈的隔热板时及立柱／横梁结构中）。由于这类隔热板能在工厂中预制完成且在制成以后就能开始给予保护，所以此类真空隔热系统需大量采用与夹层面包一样的机械保护措施。这极大地简化了整个产品的加工及安装流程。另一方面，在它们被包覆于保护层内后，将不能使用现有的测试方式来快速检测 VIP。在装配完成后，现有的技术仅能通过热量图实现对该类产品的检测。对该系统这一不足的惟一补救办法就是在 VIP 的运输和装配过程中尽力避免损坏其气密性。此类隔热板相对于传统隔热板来说，有产品质量轻及所占空间减小的额外优势。这些优点主要体现在它们安装之后，但在运输和安装过程中也稍有体现。

经济性

人们不能期望真空隔热材料普遍替代传统的隔热材料。这些高性能隔热系统的主要特征是拥有最好的隔热效果和最小的厚度。如果这些特性能够在功能、设计、经济性或审美方面带来足够的优势，以证明其目前相对较大的先期投资是值得的话，那么该类隔热系统的应用指日可待。在众多的建筑工程中，它们的应用区域将是建筑中特定的重要区域。只有在极少数特殊工程中，它们才大面积使用在建筑上，如那些有必要应用这些材料的范围特别大

		VIP	VIS
密封金属		金属化程度（铝贴板 1μm）	0.6 ~ 4mm 不锈钢板
芯材		熏硅	熏硅
边沿隔垫		薄膜密封	0.20 ~ 0.27mm 不锈钢焊接箔膜
抽成真空工序		在真空室内制造	使用真空凸轮抽成真空
厚度	[mm]	10 ~ 50（典型 20）	10 ~ 40
导热（板中心处）	[mW/(mK)]	4.2	5.3
内部气压	[mbar]	<5	1
边沿隔垫处的热桥效应		低	高
放气后的导热率	[mW/(mK)]	20	20
精确的导热率	[kJ/(kgK)]	0.8（芯板）	0.8（芯板）
密度	[kg/m³]	160 ~ 180	160 ~ 180（+ 密封金属）
连续工作温度范围	[℃]	– 30 ~ 80	– 200 ~ >1000
连续工作湿度范围	[% 相对空气湿度]	0 ~ 60℃（40℃）	取决于合成金属
可接受的最高工作温度（短时间暴露，<15min）	[℃]	80 ~ 120（取决于密封薄膜）	>1000
可承受压力荷载能力		150 ~ 160kPa（在 10% 变形时）	>7.5t/m²
挠曲强度		无	较高，具体取决于金属板厚度
厂商提供的使用年限	[年]	没有数据	3 ~ 50 年，若可在现场抽空则 >100 年
机械敏感性		非常高	较低
可维修性		不可以	可以，如果可以接触到的话
防火等级分类	根据 DIN 4102 – 6 标准	（最大值为 B2 级）	A1 级
普通建筑的应用许可证		在办理之中	在办理之中
最大尺寸（长 × 宽）	[mm]	2200×1000（取决于制造真空室大小），标准尺寸为 1000×500/1000×600	8000×3000（取决于金属板大小）
制造公差，l 或 b/s	[mm]	– 5 ~ +2/±1	±2

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5 位于慕尼黑的住有两户人家的楼房
建筑师：Florian Lichtblau
6 采用真空隔热材料的墙体结构
a 80mm 厚实心云杉木墙体
b 22mm 厚软质木纤维板
c 40mm 厚真空隔热材料
d 环绕压缩带
e 40/45mm 厚胶合板木质承重托
f 20mm 厚软质木纤维板
g 22mm 厚三合板
7 真空隔热系统的对比（VIP 与 VIS）

5 two-family house in Munich,
Architect: Florian Lichtblau
6 Wall structure with vacuum insulation
a 80 mm solid spruce wooden wall
b 22 mm soft wooden fibre board
c 40 mm vacuum insulation
d surrounding compressible strip
e 40/45 mm laminated wood bearers
f 20 mm soft wooden fibre board
g 22 mm three-layer board
7 Comparison of vaccum insulation systems
(VIP and VIS)

的那些场所。这类材料将在新建筑中大量使用，但对于建筑翻修工作来说，它们也同样重要。因为在建筑翻修中，通常会出现若使用传统隔热材料，安装空间将不足以安装足够的隔热材料的情况。

本文作者是一位建筑师，他在建筑学教授 Thomas Herzog 博士（罗马人）的领导下参与了慕尼黑大学的科研工作。前不久，他参加了一项推广工程，这是一项有关真空隔热系统在建筑上可行的应用方式的推广工程。

杨鹏鲲 译／王宝民 审

Vacuum insulation systems are currently one of the most important fields of innovation in the construction sector, and are receiving more and more attention from all quarters. In contrast to the majority of products used in the construction field, they are highly complex systems. Using them therefore presents the risk of a number of possible mistakes; they call for a high level of competence from both the designer and the user. Within a conventional insulating material, thermal transport is typically made up of 20–30 % thermal radiation, 5–10 % thermal conduction through the material of the framework, and about 65–75 % thermal conduction through the enclosed gas. The common operating principle of vacuum insulation systems is therefore to minimise the transmission of heat through the most important of these routes, the gas, by evacuating the unit. In order to maintain the vacuum in this kind of insulation system over a long period, it is necessary to surround the evacuated space by a gas-proof envelope consisting, for instance, of glass, metal, plastic or a composite plastic membrane. The enclosed space can either be empty, or it can be filled with a core material whose cells are entirely open and which can therefore be evacuated. Depending on the level of induced vacuum, the system must be capable of resisting a significant proportion of atmospheric pressure (equivalent to up to about 10.3 tonnes/m^2).

Ill. 4 provides an overview of the individual components and their possible combinations, and of the light transmission offered by the various insulation systems.

Core material

In the construction sector we are concentrating, at present, primarily on opaque systems with micro-porous insulation cores. Most of these consist of glass-fibre reinforced, fumed silica, and have the sort of structure suggested by ill. 2. This is because this group of materials has a very high porosity combined with a pore size that is itself small enough to strongly suppress the gas conduction effect. Even at atmospheric pressure, therefore its thermal conductivity, approx. 0.018 W/m^2K, is significantly below that of the surrounding air at approx. 0.026 W/m^2K. These relationships have the further effect that the thermal conductivity drops sharply even at relatively soft vacuums, already coming close to its minimum of 0.004 W/m^2K at approx. 10 mbar. Thus, the demands on the manufacturing process are reduced, and higher gas permeation rates can be tolerated in the envelope material and the joints (seals or welded seams). This therefore leads, above all, to a longer potential functioning life, since this is determined by the maximum acceptable pressure rise in the system.

Envelope material

Two groups of materials are being used here, and they lead to two very different systems: metallised plastic composite foil, and stainless steel plate. The literature generally refers to the first group as Vacuum Insulation Panels(VIP),and to the second as Vacuum Insulating Sandwiches (VIS) (ill. 7). Transparent high-barrier membranes, based entirely on polymers and coated with SiOx, do not yet achieve the necessary permeation rates, but are under further development.

Quality control

The thermal conductivity of a vacuum

insulation system depends primarily on the internal gas pressure and on the moisture content of the core material. The first physical magnitude can therefore, in principle, be used for quality control, provided the initial gas pressure and the moisture in the system are known. If internal effects such as the evolution of gas are neglected, any pressure rise that occurs depends, in the first place, on the quality of the envelope material and of the edge spacer. Since it is almost impossible to detect leaking panels by purely visual means, in particular when they have already been fitted and have been covered, procedures for measuring the internal pressure offer the only possible method of quality control. The particular difficulty associated with this for vacuum insulation systems is that the checks – even for concrete guarantee reasons – must cover the production chain from beginning to end, starting with manufacture and including transport, storage and fitting. Because of this necessity for multiple checks to be carried out at various locations, there is a particular need for procedures that give quick results and that are uncomplicated. Methods that do not require penetration of the envelope, and which can be used even if the panel is only accessible at certain points, are preferable. In principle, the function of vacuum insulation systems that have been fitted can also be demonstrated using thermographic recording techniques. Supplementary evacuation of individual panels is also possible on systems with stainless steel envelopes.

Thermal conductivity groups – classification
No products from the vacuum insulation systems sector have yet been approved for use in construction. Generally speaking, manufacturers only quote thermal conductivity values that apply to the undisturbed panel surface in the centre of the panel. In practice, however, this figure will never be achieved when the panel is fitted. Achievable U-values (and therefore "average" thermal conductivity figures) are primarily determined by the geometry, the choice of material, and the way in which the edges are formed and joined.

Ecology
In the light of the present state of knowledge, the following can be said: the total material expense is relatively small, due to the high efficiency. In the systems used so far in the construction sector, the silica boards (apart from the stainless steel in VIS) represent the major weight. Like the enveloping stainless steel, it can be reused without difficulty. Once the systems have been vented, they can be dismantled into their component parts without great difficulty. They then contain no composite materials, and can be recycled. The composite membranes used so far cannot be immediately re-used, but they represent a low proportion of the weight, and can be partially recycled.

		VIP	VIS
Envelope material		metallised high (Al-layer 1 µm)	0.6–4 mm stainless-steel plate
Core material		Fumed silica	Fumed silica
Edge spacer		Membrane seal	Welded stainless-steel foil 0.20–0.27 mm
Evacuation process		Manufacture in vacuum chamber	Via evacuation flange
Thickness	[mm]	10–50 (typically 20)	10–40
Thermal conductivity (Centre of panel)	[mW/(mK)]	4.2	5.3
... at an internal pressure	[mbar]	< 5	1
Thermal bridging effect of the edge spacer		low	high
Thermal conductivity when vented	[mW/(mK)]	20	20
Specific thermal capacity	[kJ/(kgK)]	0.8 (core plate)	0.8 (core plate)
Weight	[kg/m³]	160–180	160–180 (+ envelope material)
Temperature range for-continous use	[°C]	–30 to 80	–200 to > 1000
Air humidity range for continous use	[% rel. air hum.]	0 bis 60 (bis 40 °C)	depending on alloy
Acceptable peak temperature-(short exposure, <15 min)	[°C]	80–120 (depending on membrane)	> 1000
Pressure loading capacity		150–160 kPa (at 10% deformation)	> 7.5 t/m²
Flexural strength		not available	high, depending on plate thickness
Quoted functioning life	[years]	No data	3–50 years, > 100 years, if it can be evacuated in situ
Mechanical sensitivity		very high	low
Repairable		no	yes, if accesible
Fire protection classification	in acc. with DIN 4102-6	(B2 is maximum possible)	A1
General Buildings-Inspectorate Approval		under preparation	under preparation
max. dimensions, l × w	[mm]	2200 × 1000 (depending on vacuum chamber), standard 1000 × 500/1000 × 600	8000 × 3000 (depending on plate size)
Manufact. tolerance, l or b/s	[mm]	–5 to +2 / ±1	± 2

Design notes

Sensitivity
Panels with membrane envelopes, in particular, are extremely mechanically delicate. The handling of unprotected panels on the building site is therefore critical. A high level of prefabrication permits them to be fitted under protected, controllable conditions, and is therefore preferable. It is, moreover, advantageous to protect the panel faces with adjacent soft layers, such as soft fibreboard or thin layers of foam material. It must also be borne in mind that vacuum insulation systems must never be penetrated. This, together with the further requirement that they are fitted without being subjected to tension, radically restricts the possible methods of fastening. It is also necessary to explain to the user that nothing can be attached to the affected areas by drilling or nailing at any later stage.

Thermal bridges
Every thermal bridge means that the average thermal insulation figure is reduced. It also increases the energy requirement, and presents a risk of condensation. Because of their geometry, vacuum insulation systems themselves cannot help but create thermal bridges, since their edges always have higher thermal conductivity than the centres of the system units. The magnitude of the effect at these potential joint locations depends on exactly how the edges of the system are formed, on the geometry and dimensions, and on the particular situation where the system is fitted. The use of high-performance insulation makes the problem of thermal bridges more acute: the significantly lower insulation thickness in combination with the minimisation of thermal conductivity across the main area gives every thermal bridge a greater significance than it would have with conventional insulating materials. Even though condensation cannot form within the vacuum insulation system itself, since they are absolutely vapour-proof, it is the nature of the system that the joints represent even more significant weak spots. The non-destructive diffusion behaviour must be demonstrated here in detail with the necessary care.

Format
The preferred format is that of rectangular panels, whose right-angle edges have the most accurate geometry possible. A range of other shapes is nevertheless also possible, although these are usually associated with considerable expense in manufacture as well as with a reduction in the expected service life. A fundamental

feature of all vacuum insulation systems is that the format of panels that have once been manufactured cannot be changed. Later modifications are impossible. This is of particular importance at the design stage when the tolerances are considered. Because of the more acute problem of thermal bridges, the demand for accurate dimensioning is particularly high for the application of vacuum insulation systems. A further aspect is the economically-driven pressure to have only a small number of possible formats. Standard formats offer a further advantage, in that additional supplies can be delivered at short notice, since they can be stocked in a warehouse and do not have to be specially manufactured.

Exchangeability / accessibility

Because, in contrast to conventional insulating materials, vacuum insulation systems can fail, it is helpful if they can be exchanged without too much difficulty. The structure must therefore be built in such a way that it is possible to access either the individual panels or the sub-system that holds them.

An example application:
Panels for stanchion-transom facades

Vacuum insulation systems can be fitted into existing stanchion-transom systems with relatively little difficulty. They can also be exchanged, since the thickness of the resulting system is quite similar to that of the usual thermally-insulating multiple glazing. It is of particular relevance here that with these systems – in contrast to conventional insulating panels that are significantly thicker – it is possible for the glazing to be flush – mounted on the inside of the facade as well. Unit thicknesses of approx. 32 mm are enough to achieve U-values of approx. 0.16 W/m²K in the centre of the panels. This is a reduction of about 75 % in comparison with the best thermally-insulating multiple glazing currently available (where the *U*-value in the centre of the glass is approx. 0.65 W/m²K). The panels developed by ZAE-Bayern (Bavarian Centre for Applied Energy Research) for a hospital in Erlenbach provide an example of such a variant. (ill. 1)

In this kind of application, the *U*-value of the facade as a whole depends heavily on the size of the panels, and on the relative proportions of the edges (edge spacer panels and stanchion/transom construction) to the flat areas. In the same way as other sandwich solutions, a large measure of mechanical protection is given to the vacuum insulation system because the panels can be fabricated at the factory and are protected from then on. This greatly simplifies handling throughout the whole process chain, up to and including fitting. On the other hand it is no longer possible, using existing test methods, to check the VIP quickly after it has been mounted between the protective layers. Present technology only permits determination of the thermal image when assembled. Compensation for one disadvantage of the system is offered by the possibility of almost entirely ruling out damage (venting) to the VIP during transport and assembly. An additional advantage can be seen in the reduction in weight and space offered by these panels as compared with conventional insulation panels. This not only applies to them when they are fitted, but to a lesser extent also during transport and assembly.

Economy

A general replacement of conventional insulating materials by vacuum insulation materials can certainly not be expected. These new, high-performance systems will, however, find applications wherever their primary feature – maximum insulating effect with minimum thickness – brings enough functional, design, economic or aesthetic advantage to justify what, so far, has been a significantly higher initial investment. In many cases this will be particular locations of special importance within a building. Only in unusual cases will it involve the entire building shell, for instance in locations where useful area is extremely expensive. It will be used in new constructions, but will also become important to renovation work, where there is often insufficient room for adequate insulation to be installed when conventional insulating materials are used.

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