# Vacuum Insulation Panels for Buildings and Technical Applications

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## ABSTRACT

Vacuum insulation panels, which may be applied in buildings and technical applications are presented. A possible solution of the protection of vacuum panels is shown, it is demonstrated that also complex 3-dimensional forms of vacuum panels can be manufactured and examples of quality control of vacuum panels are given.

## KEYWORDS

Vacuum insulation panel, building insulation, pyrogenic silica, high gas barrier films, gas pressure measurement, quality control

## INTRODUCTION

First application tests of vacuum insulation panels (VIPs) for buildings took place in Germany and Switzerland in 1998 / 1999. In the following years within several national and international projects the quality of the vacuum panels were improved and different methods for applications in buildings tested. The combination of microporous silica as core material and special high barrier films with double or triple metalization proved to be the best choice. The rate of gas pressure increase was measured and it was estimated that including water vapour transmission through the envelope a life time of up to 50 years could be achieved with this kind of vacuum insulation panels. Furthermore simple measurement methods for testing gas pressure and monitoring the quality of the panel have been developed (Caps 2005b).

Nowadays several ten thousands of square meters of vacuum panels are produced for application in buildings. Still further improvements of the vacuum panels are necessary to make an even wider distribution of vacuum panels in the building industry and other applications possible. In the following several examples of developments made at va-Q-tec are presented. A possible solution of the protection of vacuum panels is shown, it is demonstrated how complex 3-dimensional forms of vacuum panels can be made and examples of quality control procedures are given.

# COMPONENTS OF VACUUM INSULATION PANELS

## Silica Core Material

Today microporous silica is the preferred core material for VIPs which may be used for building applications. The pore diameters of the silica core are well below 1 µm, thus the thermal conductivity of air within this structure even is partially suppressed at 1000 mbar atmospheric pressure. In Fig. 1 the thermal conductivity of silica vacuum panels as function of their gas pressure is depicted. At gas pressures below 5 mbar the thermal conductivity is as low as 4 mW/mK. The increase of thermal conductivity of this panels series with gas pressure can be described by the equation

$$\lambda = \lambda_0 + 26/(1 + p_{1/2}/p_{gas}) \qquad (mW/(mK)) \qquad (1)$$

with $p_{1/2}$ = 675 mbar. At low gas pressure the increase of thermal conductivity $\lambda$ is proportional to the gas pressure increase: $\Delta\lambda$ = 26 mW/mK $*$ $\Delta p/p_{1/2}$ = 0.0385 mW/mK $*$ $\Delta$p/mbar.

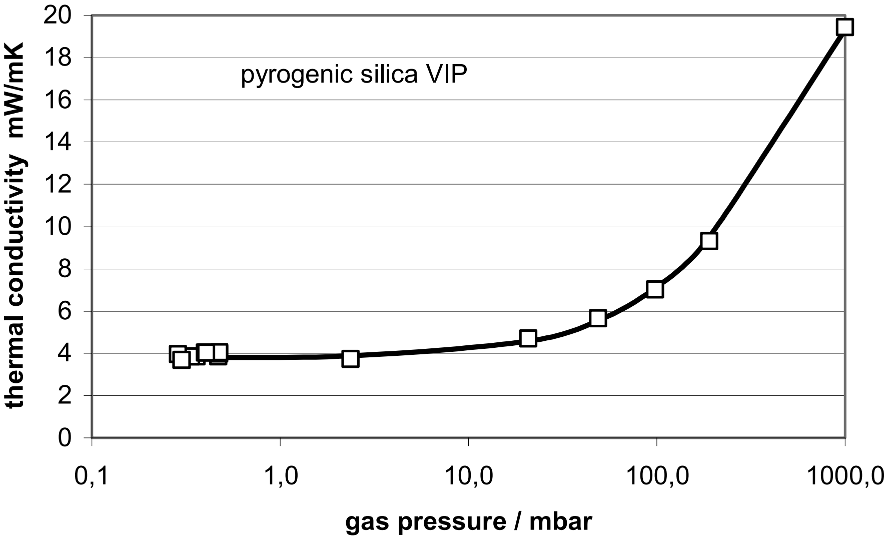

Fig. 1: Thermal conductivity as function of gas pressure

### Gas Barrier Film

Using a high quality metallised film the increase of gas pressure within a 20 mm thick silica board is about 1 mbar per year (Caps 2005b), which includes both the increase due to diffusion of air and water vapour through the envelope. This leads to an increase of thermal conductivity after 50 year life time in the order of 3 to 4 mW/mK. The increase could be reduced by a factor of ten if a high quality aluminium foil would be used. Only large vacuum panels, however, should be equipped with an aluminium foil, as the heat losses around the edges may be considerable. A possible solution to this problem is to combine a metallised film with an Al foil in such a way that the edges are free of aluminium and only the surfaces are covered with it (Caps 2005a).

## PROTECTION OF VACUUM INSULATION PANELS

An important requirement for the practical application of foil based VIPs in buildings is the protection of the envelope against damage and fire protection. An outer cover made from a glass fiber textile can fulfil both requirements. Edges and corners are protected in such a way that the glass fiber textile has an overlap of about 3 mm on both sides (Fig. 2). The glass fiber envelope either is fixed by an adhesive which covers the whole surface of the high barrier film or one or two double adhesive bands. These kind of protected VIPs can be used for all kind of building applications.

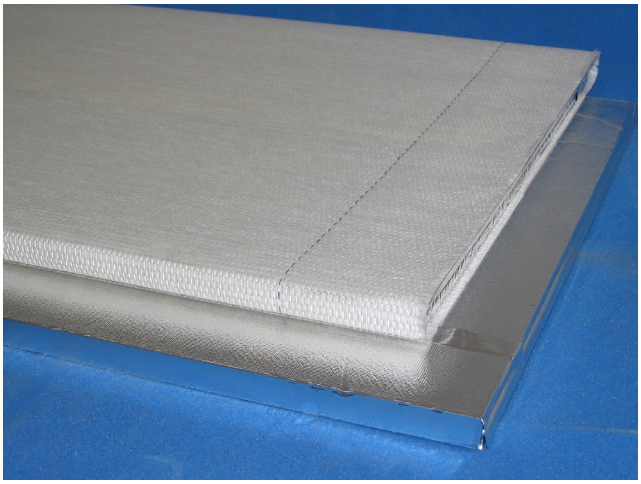

Fig. 2: Vacuum insulation panel with glass fibre textile as cover on top of blank panel

## COMPLEX FORMED VACUUM INSULATION PANELS

Flat evacuated insulation elements are already an established product. They also may be bent to a cylindrical form. General objective of a recently finished EU project “VACI” was the development and refinement of methods to manufacture complex, 3-dimensional curved vacuum insulation panels for different applications. It could be demonstrated successfully that the manufacturing of vacuum insulated complex shapes e.g. pipes, elbows or T-pieces is possible. An example is depicted in Fig. 3.

Fig. 3: Vacuum insulations forming a 90° bow

The art of obtaining the desired shape lies in highly precise calculations of the cutting of the core material, which subsequently leads to the exact shapes required.

It could be demonstrated that the vacuum insulation technique exhibited extremely low heat fluxes, thereby permitting a considerable reduction in insulation thickness. The objective of 60 mm vacuum insulation instead of 160 mm conventional insulation around pipes was actually improved even further. The total thickness of the vacuum insulation of about 50 mm has the same insulation performance as a conventional polyurethane foam insulation of 160 mm thickness. Thus the overall diameter of an insulated DN200 pipe is reduced from 520 mm to 300 mm, the overall cross section even is reduced by a factor of three. Application temperatures may vary between cryogenic conditions and temperatures of up to 90 °C.

## QUALITY CONTROL

### Control of Core Thermal Conductivity

The thermal conductivity of the evacuated silica core may depend on different parameters like composition of the powder mixture and density of the pressed powder board. Therefore it is important to control the thermal conductivity of the evacuated core material regularly. In Fig. 4 the thermal conductivity values of two series of 20 different silica panels have been measured. The overall mean of thermal conductivity here amounts to 4.17 mW/mK with a standard variation of 0.08 mW/mK. Thus a high uniformity of thermal conductivity values of the vacuum panels is guaranteed.

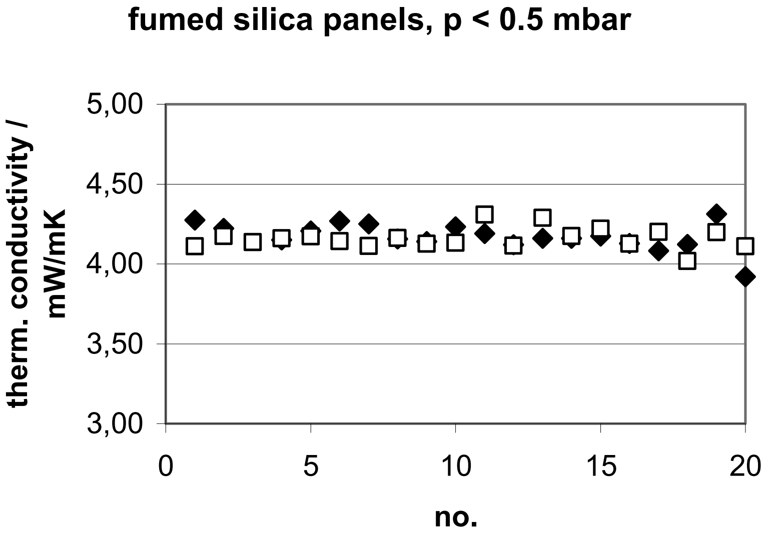

Fig. 4: Variation of thermal conductivity of 40 different vacuum insulation panels

### Control of Gas Pressure

The control of the vacuum is the most important issue for producing and applying vacuum panels. Several methods are possible with and without modifying the vacuum panel for the gas pressure measurement. va-Q-tec has found a simple and cost efficient way to include a sensor into the vacuum panel and measure the thermal, gas pressure dependent property of this sensor externally. The sensor consists of a thin metal plate (0.5 mm thickness) which is covered by a porous thin glass fiber fleece. The overall thickness of the sensor device is just 0.8 mm, the diameter 30 mm (Fig. 5). An external measurement head is heated to a steady temperature of about 70 °C and pressed onto the vacuum panel where the internal sensor plate sits below the envelope (Fig. 6). The heat flow measured by the external measurement head after several seconds waiting time is proportional to the thermal conductivity of the glass fibre fleece, which also is a function of the internal gas pressure of the panel. Measurement times of 5 to 10 s can be achieved within a gas pressure range of 0.02 to 10 mbar.

Fig. 5: Metal sensor chip integrated into a vacuum insulation panel

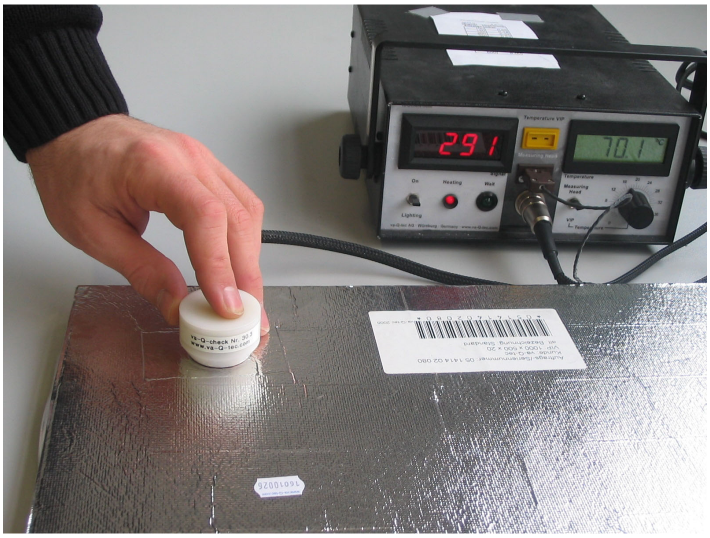

Fig. 6: Measurement of gas pressure with “va-Q-check”

Fig. 7 shows a typical variation of gas pressures achieved for a production lot of 350 vacuum panels. All gas pressures are below 2 mbar. The mean gas pressure is 0.5 mbar. Consequently even small increases of gas pressure in the range of 0.5 mbar can be detected for these silica panels. If two measurements are 1 week apart, a gas pressure increase of 0,5 mbar or 25 mbar per year can be verified. Even lower gas pressure increases induced by very small leaks can be detected if the silica panels are stored within a helium atmosphere for one or two days at elevated temperatures of 30 or 40°C (Caps 2005b).

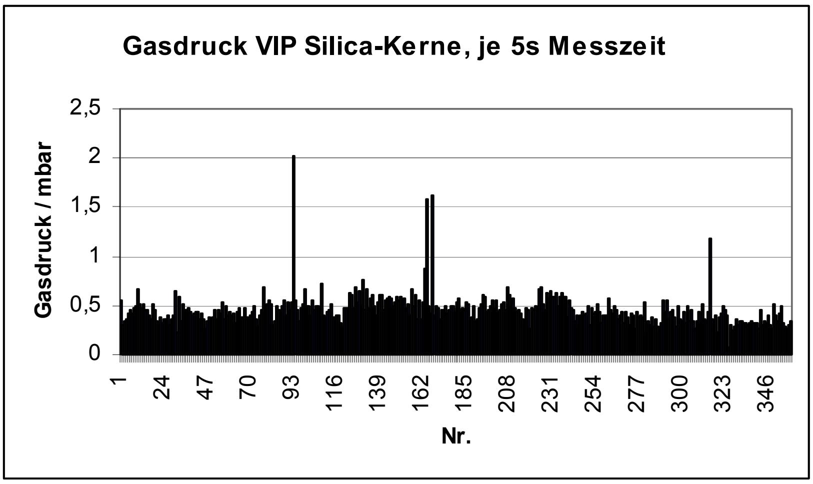

Fig. 7: Variation of gas pressure of evacuated silica panels; acceptable gas pressure is 3 mbar

With a modification of the glass fibre fleece of the sensor even a gas pressure range of up to 100 mbar is achievable. As for higher gas pressures there is a significant increase of temperature of the thin metal disk during measurement, for an extension of measurement range it is recommended to choose a thicker metal plate (2 mm instead of 0,5 mm) as heat sink.

The use of the "va-Q-check" system for monitoring gas pressure has helped to improve the quality of vacuum panels significantly. Not only for silica VIPs but also for vacuum panels with other core materials the check system has proved to be very valuable for quality assurance.

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