Thermal conductivity of VIP silica core at different levels of vacuum and external pressure

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Robust and Durable Vacuum Insulation Technology for Buildings
KTH
Div. of Building technology

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Thermal properties of core materials

Studies and evaluation of aerogel as core materials for VIP's with aim to:

- investigate new alternative core materials that may reduce the market price of the VIPs
- evaluate newly developed nanoporous silica, at different levels of gaseous pressure and mechanical loads
- modify the available measuring methods for testing thermal conductive properties of VIP core at different levels of gaseous pressure combined with mechanical loads

Materials

Sample ID	S_{BET} (m^2 g^{-1})	PS (nm)	V_{tot} (cm^3 g^{-1})	ρ_b (g cm^{-3})	Porosity (%)
A (P-100)	686	26	3.5	0.085	96.1
B	241	12	0.5	0.08	96.4
C	427	5	0.8	0.054	97.6

S_{BET} – BET specific surface area, PS- Pore size centred on maxima peaks in DFT pore size distribution, V_{tot} - total volume of pores between 1nm and 100 nm, ρ_b - tapped density, porosity is calculated on the basis of a skeletal density of 2.2 $g{\cdot}cm^{-3}$.

<u>Sample A</u>

Commercially available silica aerogel material
Visually translucent spherical aggregates

Actual density: 0.074 $g{\cdot}cm^{-3}$
Particle size: 0.01 - 4.0 mm
Pore size: Of about 20 nm

<u>Sample B and C</u>

New types of precipitated silica “powders”
Opaque particles

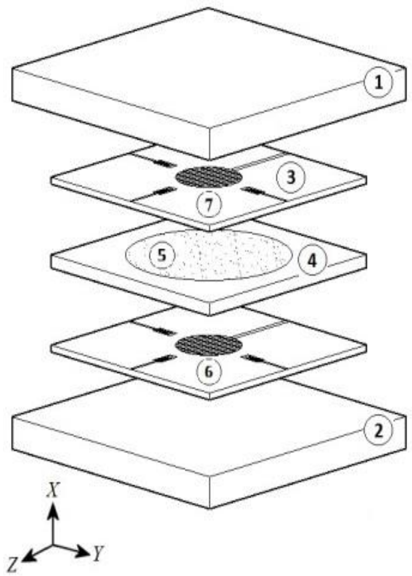
Actual density: 0.08 and 0.09 $g{\cdot}cm^{-3}$, respectively
Particle size: 1.0 – 100 µm (0.001 – 0.1 mm)
Pore size of 10 – 25 nm.

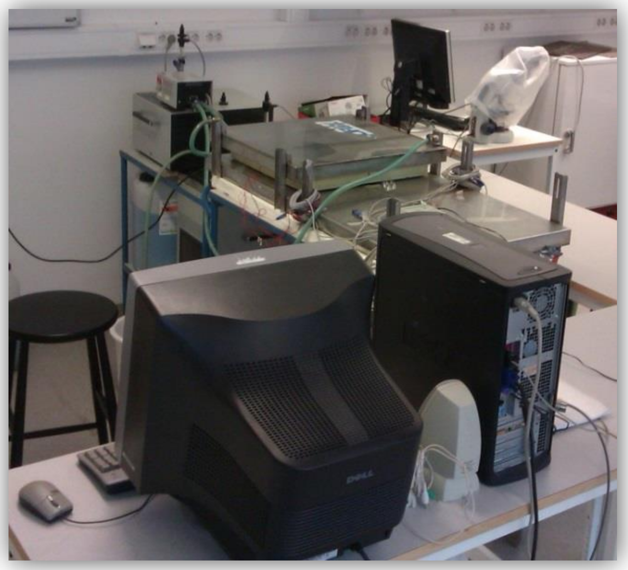
Measuring methods

A Transient Plane Source (TPS) method

A Transient Hot Bridge (THB) method

A stationary method with a hot plate apparatus



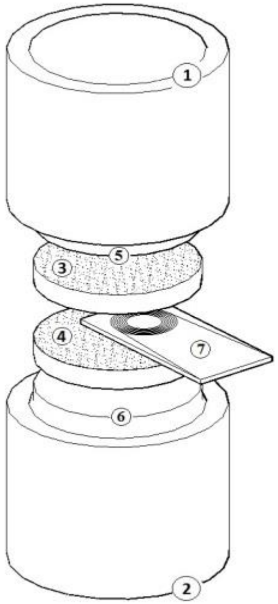


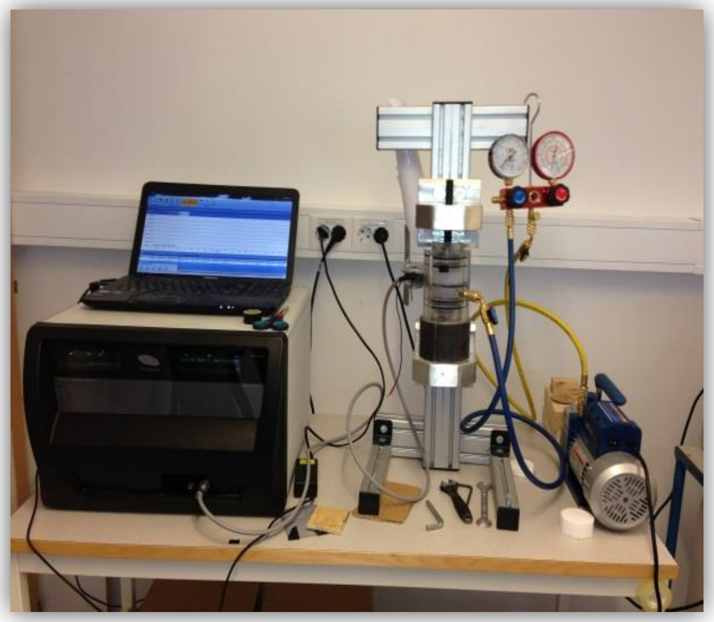
The Steady-state "Hot Plate apparatus"

Self-designed device

A new self-designed device, connected to a TPS instruments used for determining thermal conductivity of low density nano porous silica

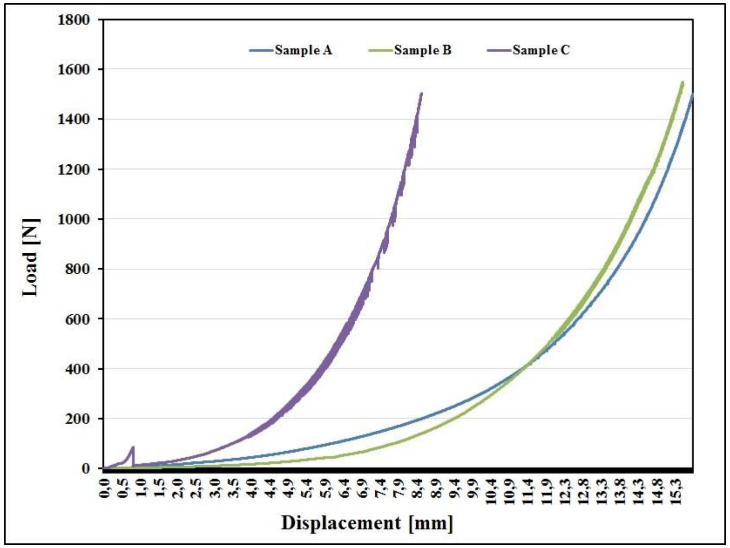
- *by varying the gas pressure down to 0.1 mbar*
- *by external compression up to 4 bar*





Load vs displacement

The deformation of the specimen height as a function of an increasing load was monitored, resulting in a curve showing the load-displacement of a defined quantity of the samples (volume and mass).



The load–displacement curves acquired as the result of more than 250000 measurements, which were then converted to stress–strain curves

Granular materials of similar size can show a great variation in fundamental mechanical properties in terms of their plasticity and elasticity, fracture strength and brittleness – ***How about the lambda value and the effect of compaction?***

Measured thermal conductivity values

At atmospheric pressure and without application of external compression

Samples	Measuring procedure	Temperature, (° C)	Thermal conductivity, (mW $m^{-1} \cdot K^{-1}$)	Thermal diffusivity, ($mm^2 \cdot s^{-1}$)	Duration	Precision	Accuracy
A (P-100)	Hot plate apparatus	25[C]	19.5	-	12 Hours	-	-
	THB method [a]	25	23.5	0.1183	45-60 second	1%	5 %
	TPS method [b]	25	29.1	0.216	160 Second	1%[d]	5 %
B	Hot plate apparatus	25[C]	36	-			
	THB method	25	36.4	0.2509			
	TPS method	25	38.7	0.328			
C	Hot plate apparatus	25[C]	34.2	-	12 Hours	-	-
	THB method	25	38.5	0.2071	45-60 second	1%	5 %
	TPS method	25	38.8	0.249	160 Second	1%[d]	5 %

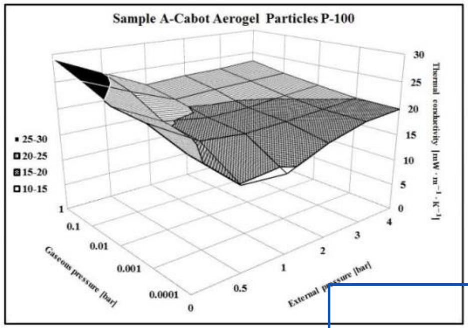
Sample A had a thermal conductivity of 19.7 mW $m^{-1}K^{-1}$, according to manufacturer and one previous work

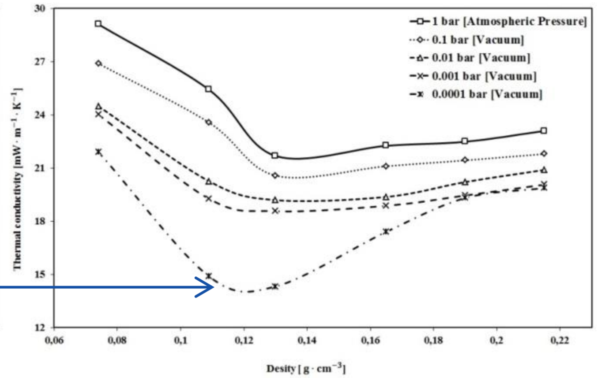
The greatest difference with the hot plate method being much closer to the data from the manufacturer, with a difference of only **1 %** while the THB and TPS methods differ by more than **16 %** and **32%.**

***Sample A*:**

Actual density: 0.074 g·cm^{-3}
Particle size: 0.01 - 4.0 mm
Pore size: Of about 20 nm

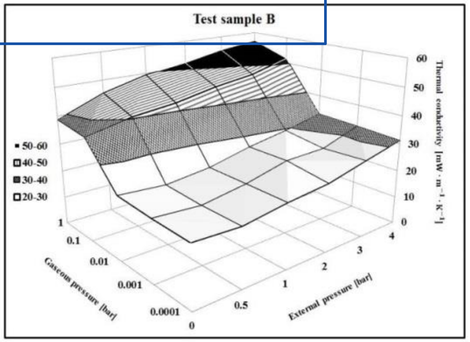
The sum of the contributions from solid and gas conduction, convection and radiative heat transfer is at a minimum

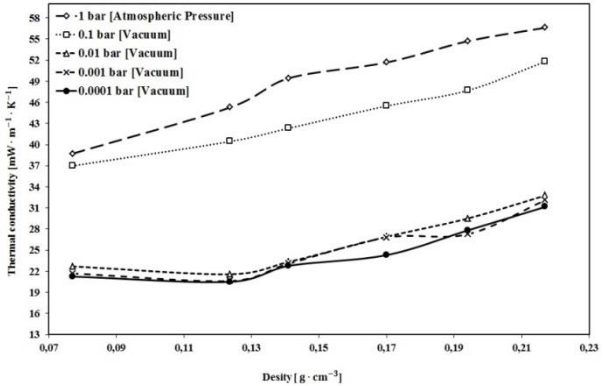




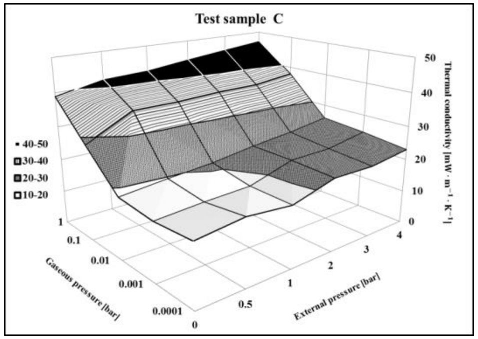
***Sample B and C*:**

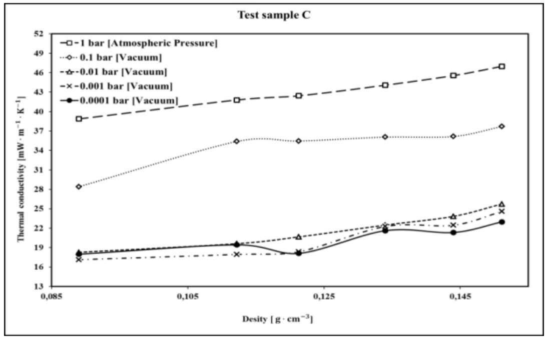
Actual density: 0.08 and 0.09 g·cm^{-3}, respectively
Particle size: 1.0 – 100 µm
Pore size of 10 – 25 nm





The thermal properties are significantly related to the particle packing and compaction.





Conclusions

- The thermal properties are significantly related to the particle packing and compaction.

- In general, the stationary hot plate method
  - Simpler to conduct
  - Gives more accurate results
  - Nevertheless, the method is restricted to large and standard dimensions of the testing sample as well as long measuring time

- The transient methods offer other possibilities.
  - Significantly less measurement time
  - Possibility to use a much smaller test sample giving an advantage when producing new high cost materials
  - Physically smaller sensor of transient method gives opportunity to be connected to other devices
  - Provide information about the thermal diffusion coefficient of the material

- The TPS technique is less suitable for conducting the thermal conductivity measurements on low-density nanoporous silica powders. However, deviations in the results are minimal for densities above a limit at which the pure conduction becomes dominant compared to heat transfer by radiation.

Publications

Comparison of Different Methods for Evaluating the Thermal Conductivity of Granular Core Materials for VIPs

Peyman Karami, Ph. D. Candidate [1]
Kjartan Gudmundsson, Ph. D., Associate Professor [1]

Energy and Buildings 75 (2014) 210–215

Energy and Buildings

Review

Textural and thermal conductivity properties of a low density mesoporous silica material

Ebenezer Twumasi Afriyie, Peyman Karami, Peter Norberg, Kjartan Gudmundsson

Energy and Buildings 85 (2014) 199–211

Energy and Buildings

A study of the thermal conductivity of granular silica materials for VIPs at different levels of gaseous pressure and external loads

Peyman Karami, Ebenezer Twumasi Afriyie, Peter Norberg, Kjartan Gudmundsson

[I] P. Karami, K. Gudmundsson, Comparison of different methods for evaluating the thermal conductivity of granular core materials for VIPs, Accepted for oral presentation and publication in proceeding of the 10th Nordic Symposium on Building Physics (NSB), Lund, Sweden, 15-19 June 2014.

[II] E. Twumasi Afriyie, P. Karami, P. Norberg, K. Gudmundsson, Textural and thermal conductivity properties of a low density mesoporous silica material, Energy and Buildings 75 (2014) 210–215.

[III] P. Karami, E.T. Afriyie, P. Norberg, K. Gudmundsson, A study of the thermal conductivity of granular silica materials for VIPs at different levels of gaseous pressure and external loads, Energy and Buildings 85 (2014) 199–211.

Thanks for your kind attention!