Application of Vacuum Insulations in Buildings

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Bavarian Center for Applied Energy Research

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Southern facade

architect: Prof. Volz / Obernburg

picture: © Dieter Leistner

Northern Façade

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architect: Prof. Volz / Obernburg

picture: © Dieter Leistner

Experimental Building

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Experimental building was established end of 1998

installation and test of innovative façade elements

- vacuum insulations
- switchable insulations
- transparent wall insulations
- sun shading devices

First Installation of Vacuum Insulation Panels in a Building

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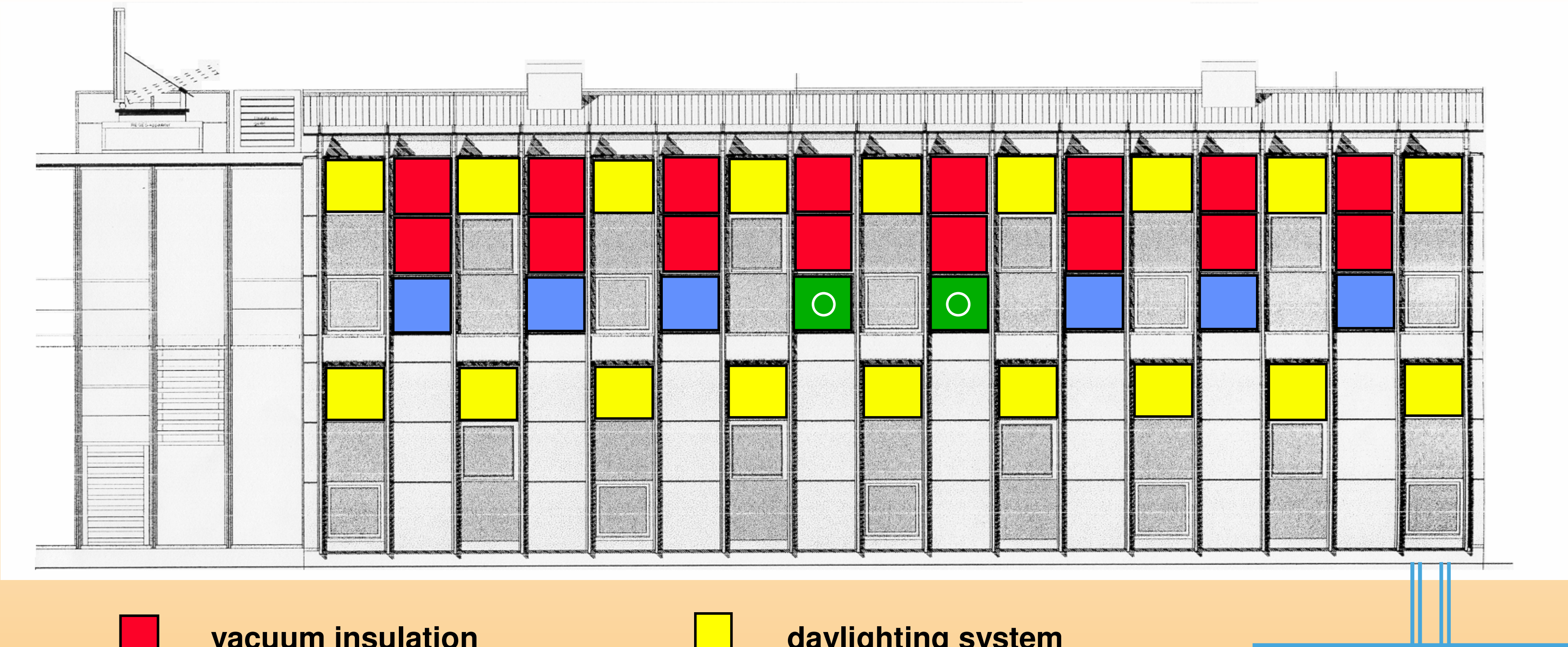

vacuum insulation

daylighting system

switchable insulation

transparent insulation

rainwater storage for liquid cooling

Bavarian Center for Applied Energy Research

Energy Consumption Germany 1995

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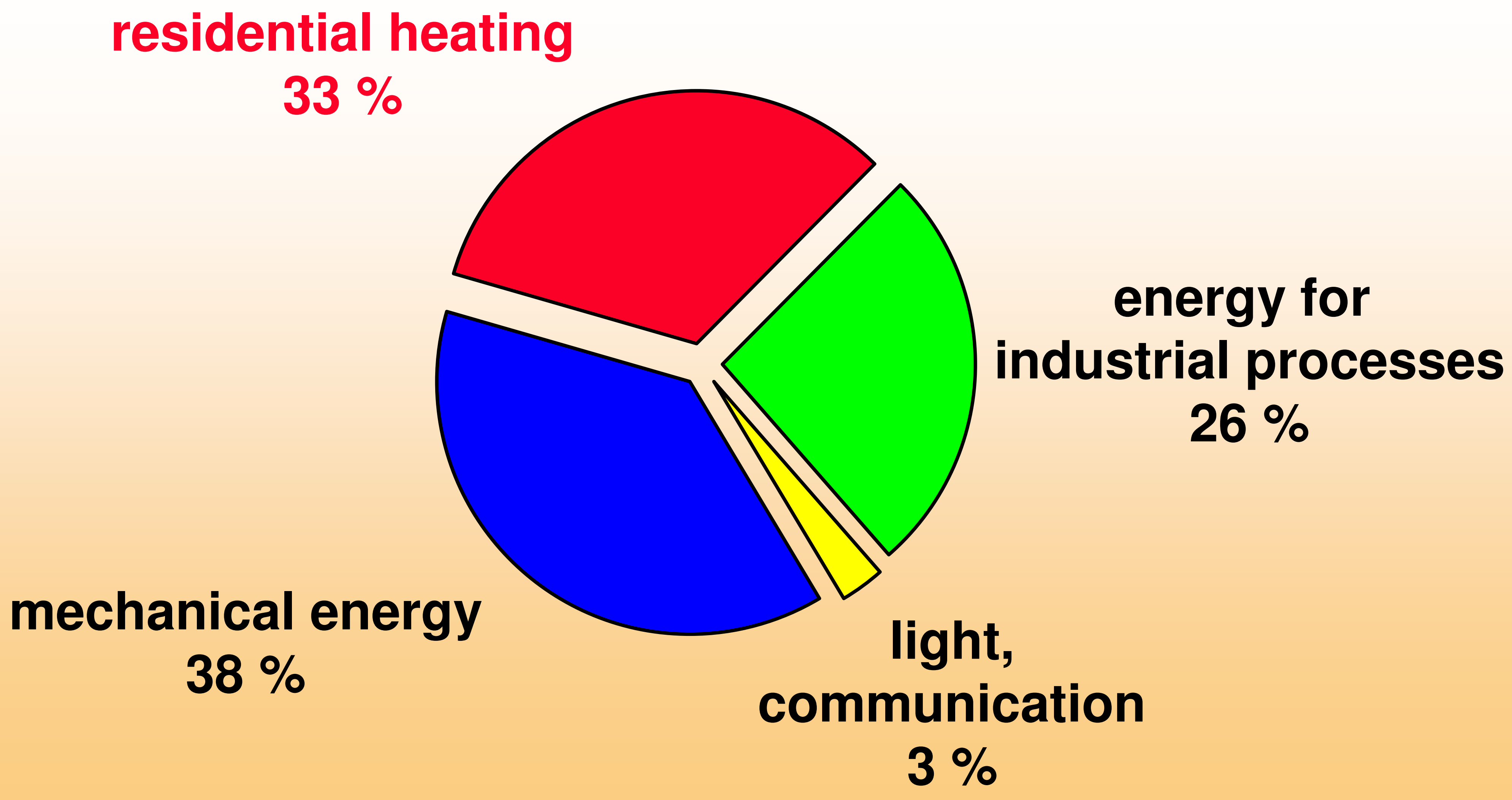

Thermal Insulation of Buildings

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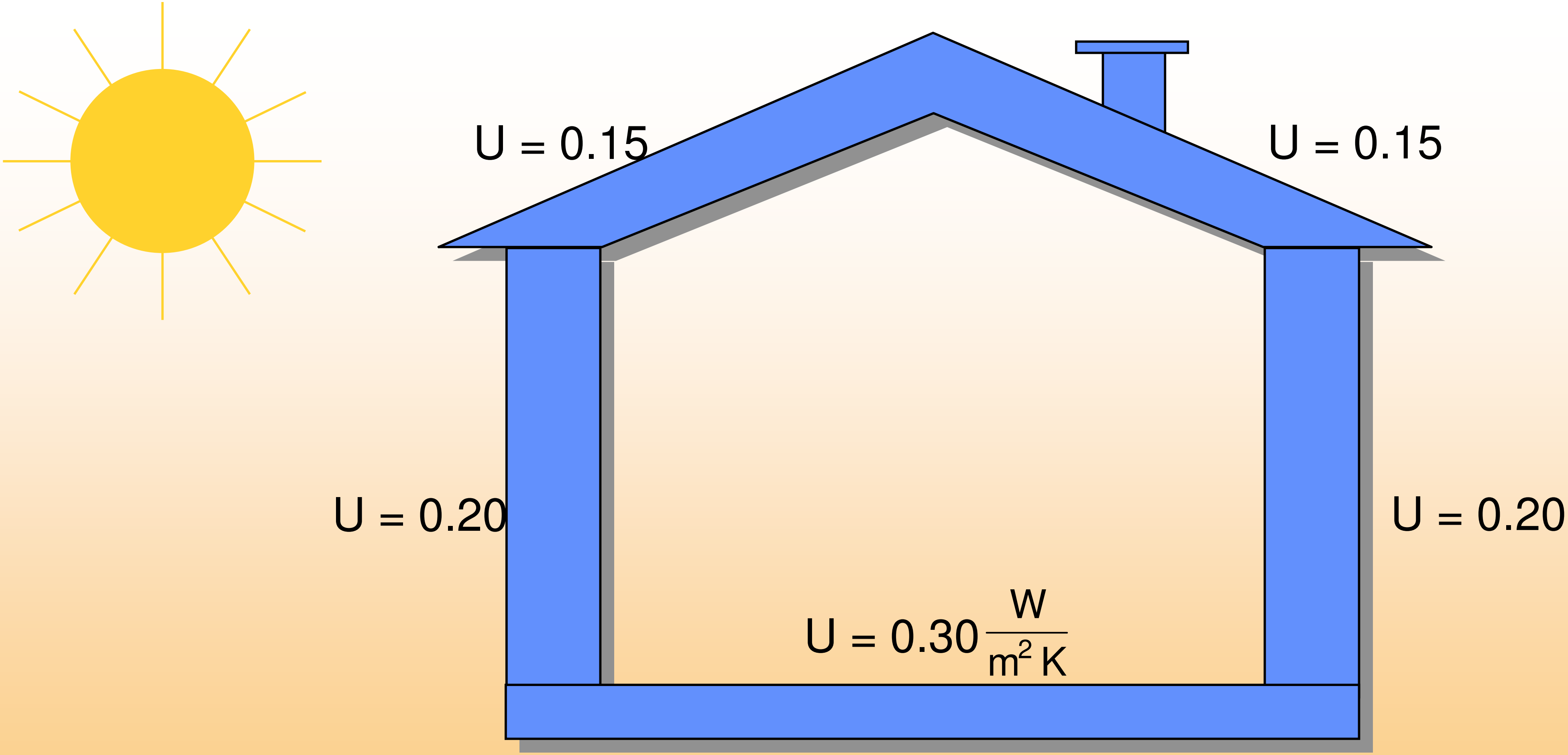

thickness of vacuum insulation (for $U = 0.20 \frac{W}{m^2 K}$): 20 - 30 mm

Saving Money with Vacuum Panels

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ultra low energy house:

	conventional	vacuum
insulation thickness	30 cm	4 cm
loss coefficient	0.13 W/m²K	0.13 W/m²K
R-value	7.7 m²K/W	7.7 m²K/W
total thickness (17.5 cm stone)	47.5 cm	21.5 cm
saved thickness	-	26 cm

Value of additional living area (@1500 EUR/m²):

per m wall 375 EUR

per m² insulation 125 EUR

Comparison of Materials for Vacuum Panels

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	thermal conductivity 10^{-3} W/mK	maximum gas pressure hPa	cover material
glass fibers	2 - 4	~ 0.1	stainless steel
organic foams	4 - 7	~ 1	Al-laminated foil
microporous powders	4 - 7	~ 20	Al-laminated foil plastic barrier foil

Requirements for Vacuum Insulation of Building Façades

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- long life expectancy (30 - 50 years)
- moderate costs
- easy application

choice: fumed silica + Al-laminated foil

Al-laminated foil:

increase of gas pressure < 1 mbar/year

Measurements and Samples

pyrogenic silica boards with opacifier

(WDS-SIC-NT 160 kg/m³ from Wacker / Kempten)

analysis of thermal conductivity

- radiative conductivity
- solid thermal conductivity
- influence of gas pressure
- further reduction of thermal conductivity possible?

Measurements of Core Material

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sample: fumed silica powder board with opacifier
160 kg/m³

apparatus: evacuable, guarded hot plate
2 samples with 200 mm diameter

external pressure load: 0.1 MPa

- variation of gas pressure at 10°C
- variation of temperature of evacuated sample

Dependence on Gas Pressure

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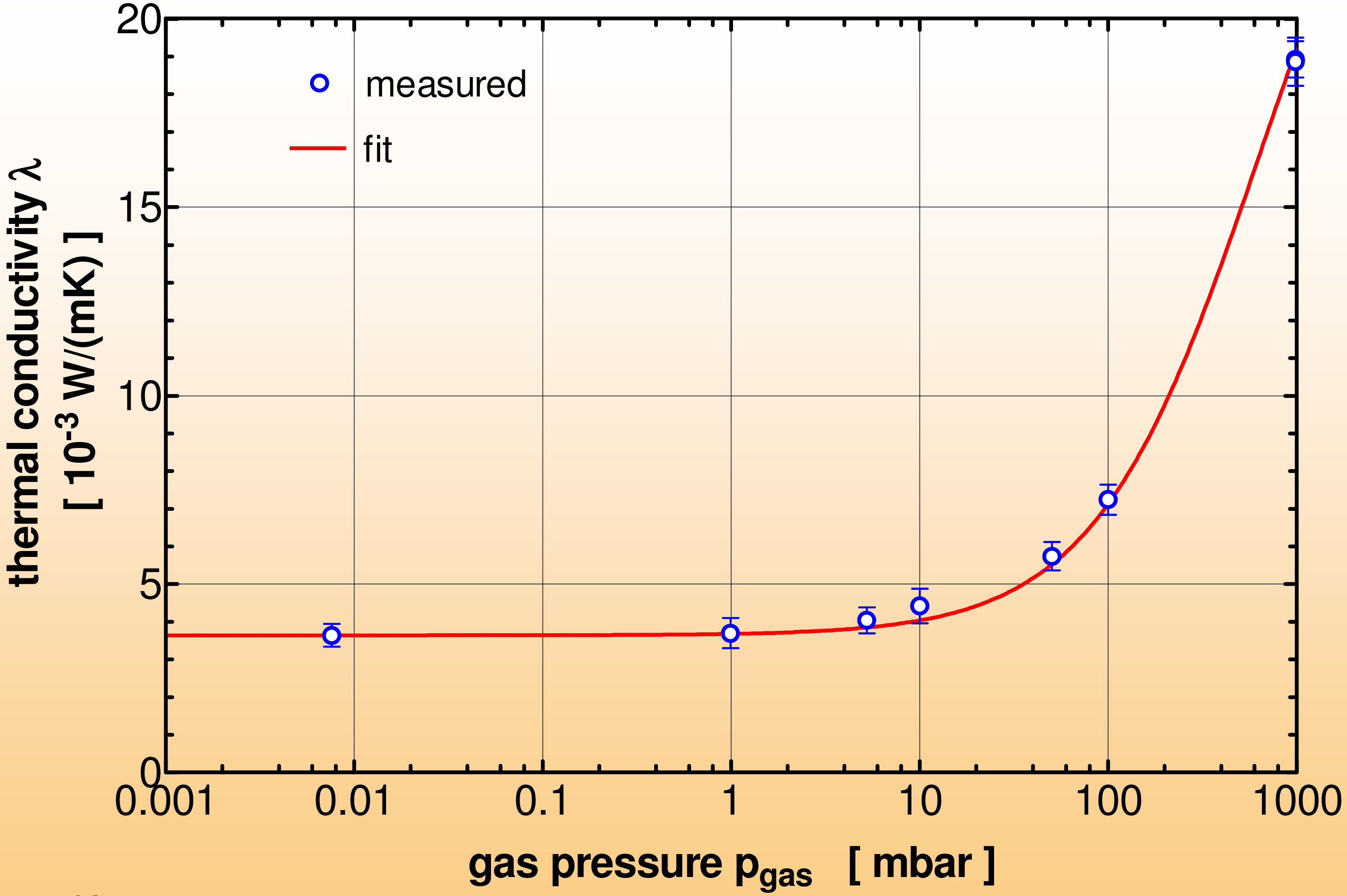

temperature: 283 K
external load: 1 bar

Analysis

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thermal conductivity, evacuated: $3.6 \cdot 10^{-3}$ W/mK

gas pressure dependence:

$$\lambda(p_{gas}) = \lambda_{evac} + \frac{\lambda^0_{gas}}{1 + \frac{p_{1/2}}{p_{gas}}}$$

$\Rightarrow p_{1/2} = (630 \pm 60)$ hPa

Dependence on Temperature

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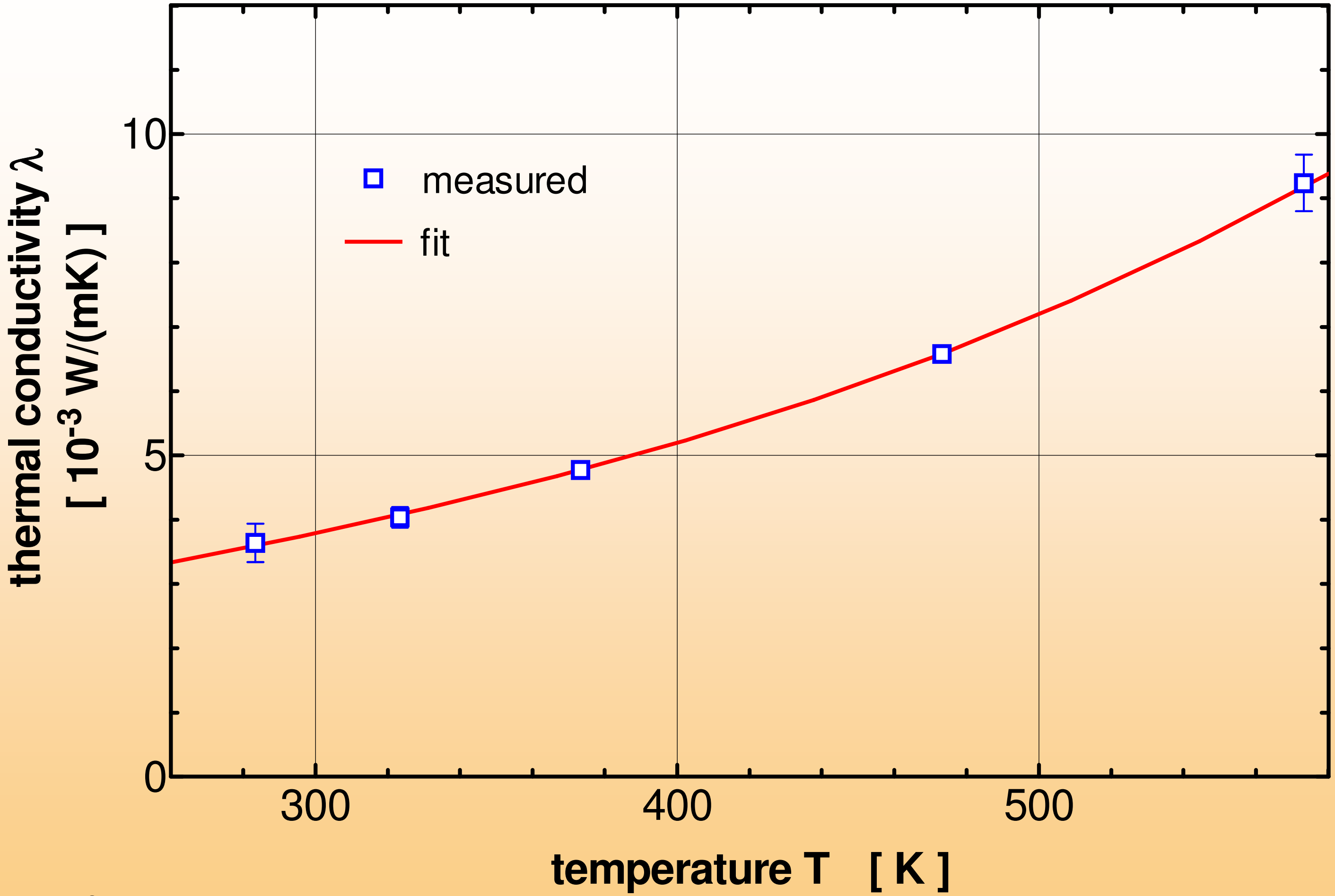

gas pressure: < 10^{-3} mbar
external load: 1 bar

Analysis: Temperature Dependence

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$$\lambda(T) = \lambda_s(T) + \frac{16 \cdot n^2 \cdot \sigma \cdot T^3}{3 \cdot E}$$

E: extinction coefficient = $e \cdot \rho$

fit to data: $E/n^2 = 10000\ m^{-1}$ $e/n^2 = 61\ m^2/kg$

at room temperature:

solid conductivity $\lambda_s = 3.0 \cdot 10^{-3}$ W/mK

radiative conductivity $\lambda_r = 0.7 \cdot 10^{-3}$ W/mK

Measurement of an Evacuated Panel

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sample: powder board 20 mm thick
evacuated and sealed in laminated Al-foil

apparatus: guarded hot plate, 340 x 340 mm^2
including 70 mm guard ring

result: $\lambda = 3.9 \cdot 10^{-3}$ W/mK
at room temperature

Skin

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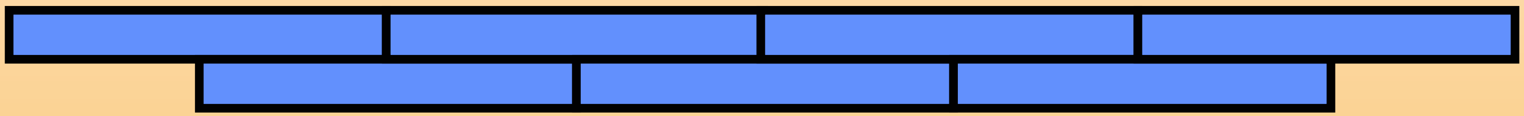
laminated Al-foil: thickness 7 µm

heat losses due to rim of 1 m² panel:

$$\Rightarrow \lambda_{rim} \leq 6 \cdot 10^{-3}\ \mathrm{W/mK}$$

losses proportional to ratio circumference/area

may be reduced by double layer



Advantage: gas pressure increase less than 1 mbar/year

Installation in New ZAE-Building

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- 43 m² vacuum insulation panels

- 8 segments
  0.9 m x 1.9 m
  2 layers, 20 mm each
- 1 segment
  0.9 m x 2.9 m
  2 layers, 20 mm each
- 4 segments
  0.9 m x 2.9 m
  1 layer, 20 mm

Manufacturing of Vacuum Panels

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- silica powder boards delivered by Wacker ($900 \times 500 \times 20\ mm^3$)
- drying of panels at 150°C
- wrapping in laminated Al-foil
- evacuating and sealing ($p_{gas} < 1$ mbar)
- test of gas pressure
- installation of panels in façade

Insulation of Southern Façade with Panels 0.5 m x 0.9 m

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double layer of vacuum panels in order to avoid thermal bridging

thickness: 2 x 20 mm

outside cover: card board
+ glass pane

inside cover: wooden board

Production of Vacuum Panel 0.9 x 2.9 m

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20 mm thick vacuum panel Al-foil on both sides

inside cover: glass pane

outside cover: card board + glass pane

Installation of a Vacuum Panel

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Northern façade

inside view of a glass covered vacuum panel after installation

the Al-foil covers the panel

sized 0.9 x 2.9 m² in total

Vacuum Panel behind Radiator

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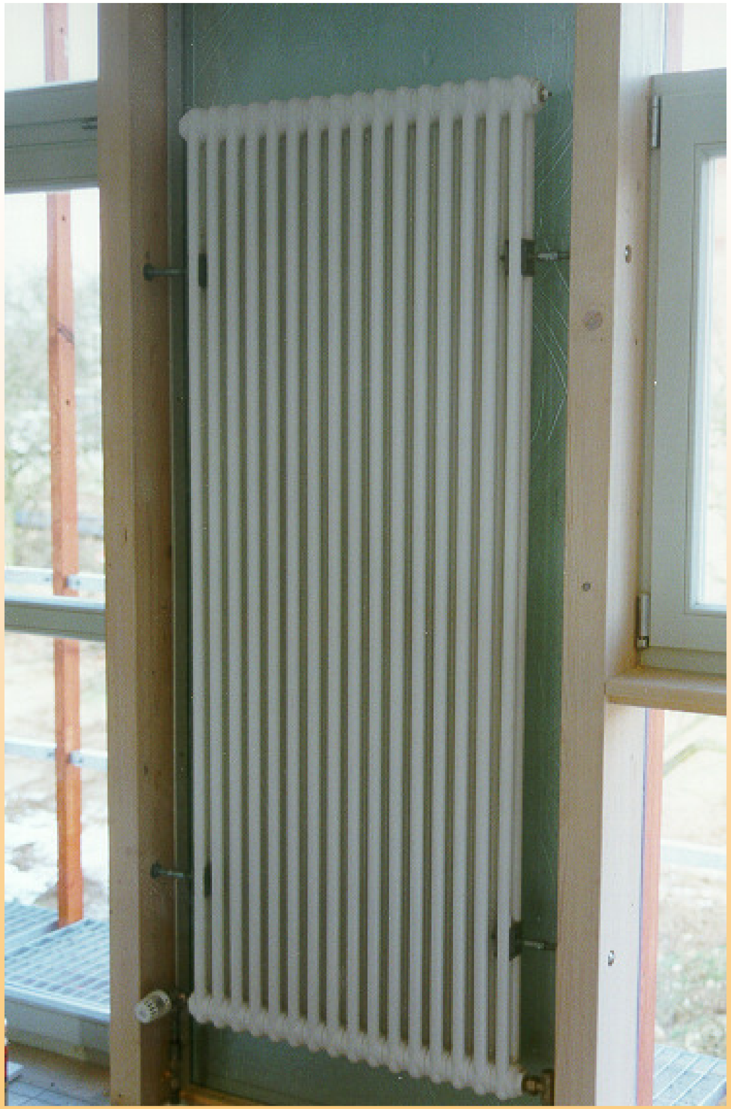

IR - Thermal Imaging

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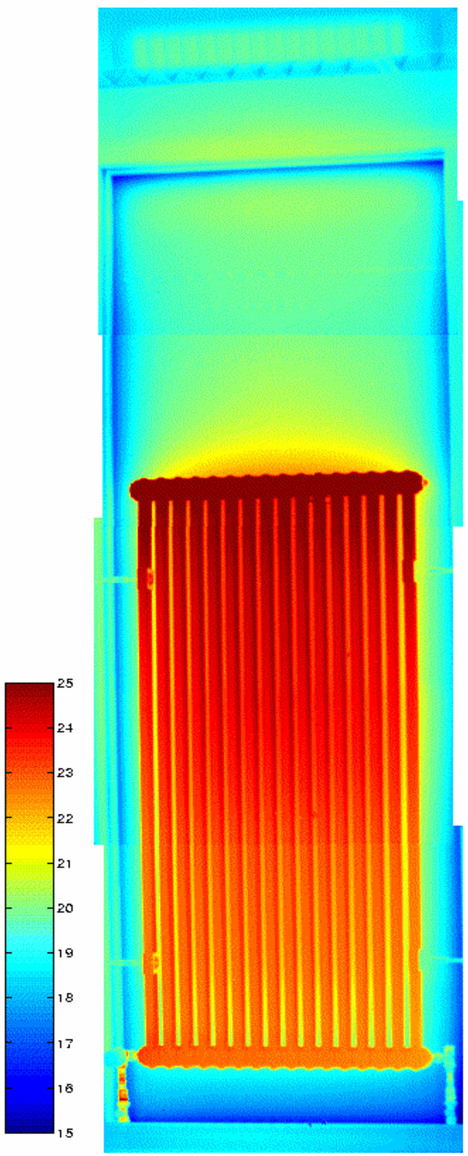
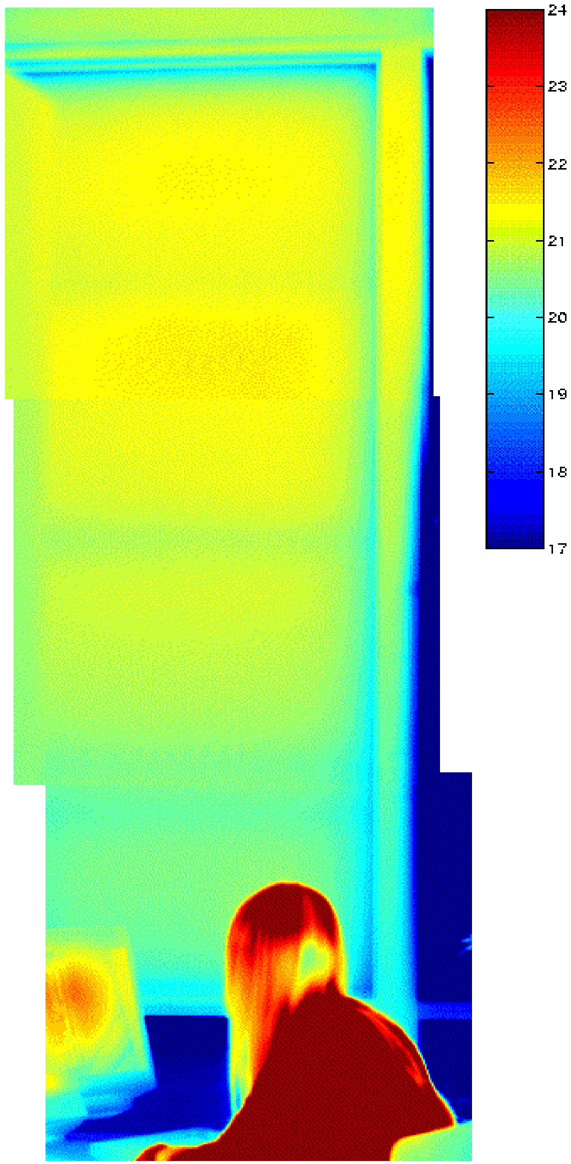
Raum 122 (rechts), Ti = 22,0 °C



Raum 128 (links), Ti = 23,3 °C



Application Fields in Buildings

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- wall insulation (inside or outside)
- floor insulation
- ceiling insulation
- roof insulation
- breast-wall with integrated radiator
- roll shutter cases
- doors
- façade construction in combination with glazing

Vacuum Panel under Plastering

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back side paste

application of primer
on front side

Vacuum Panel under Plastering

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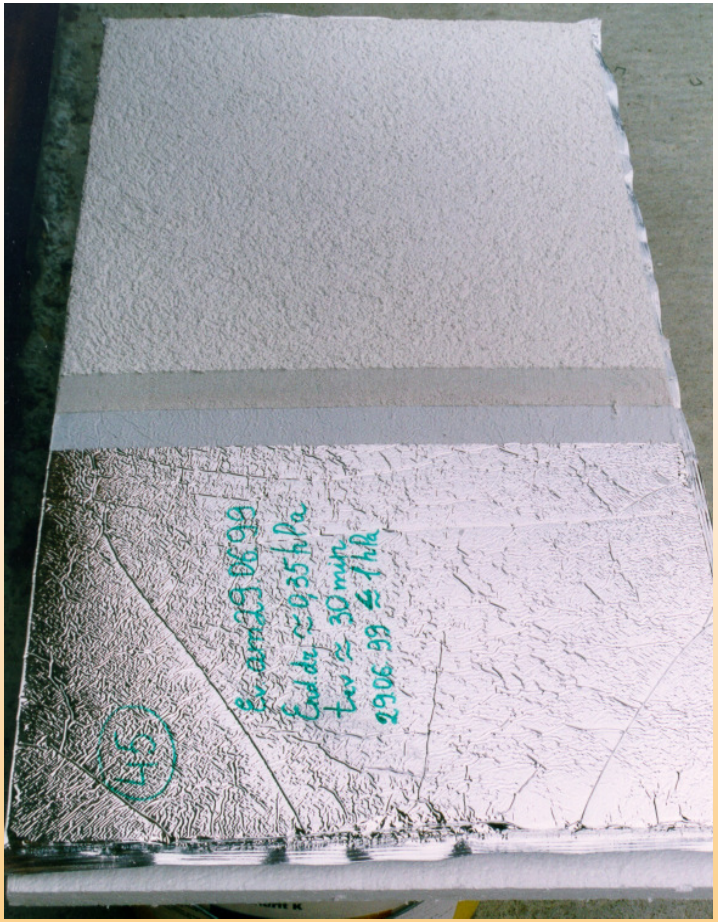
application of plaster



finished

Vacuum Insulated Radiator

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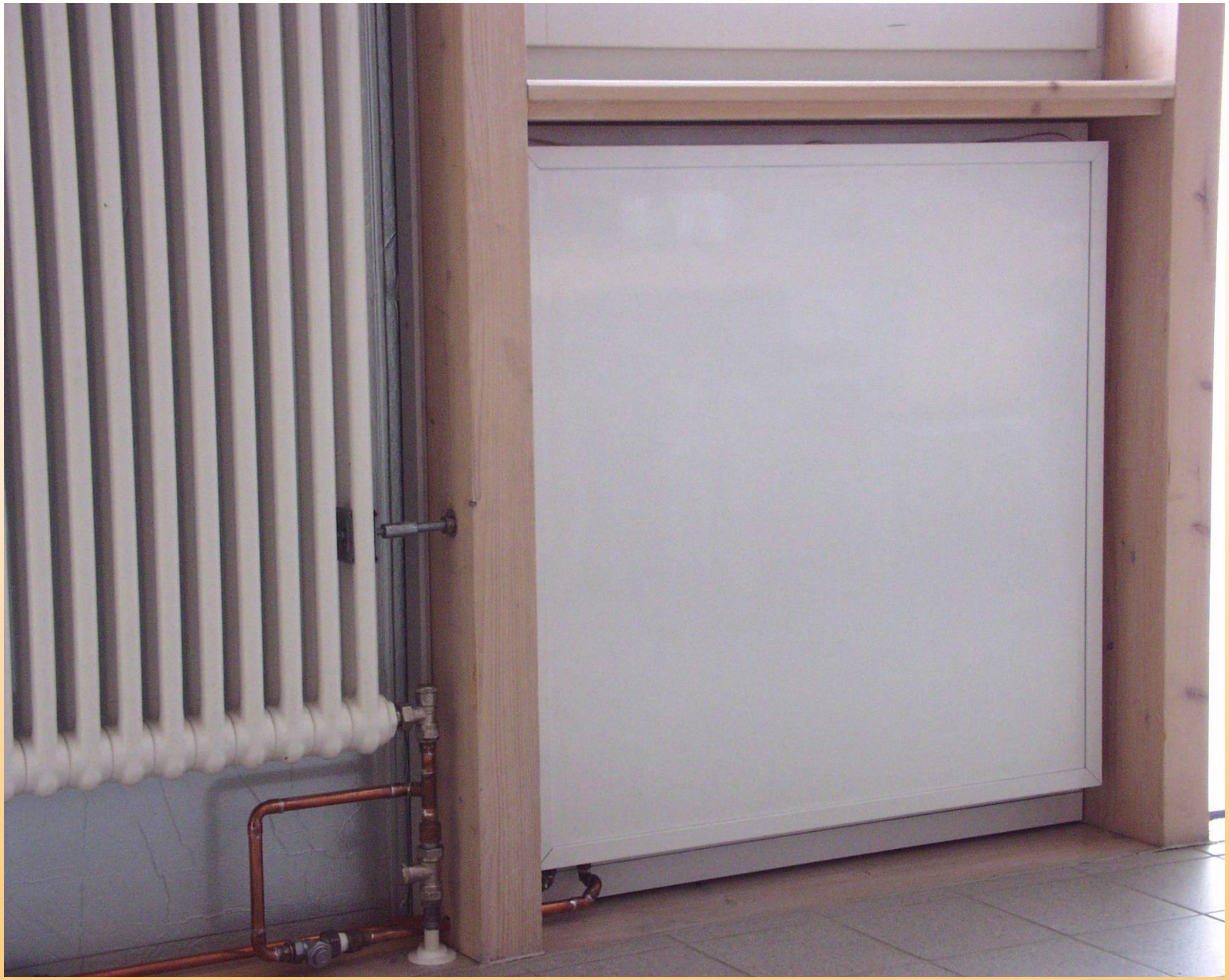
installation as integrated façade element



Skin

metalized high barrier foils:

- no thermal bridges ⇒ small sizes possible
- life time sufficient for cold storage (10 - 20 years)
- application possible in buildings?

  (higher temperatures, longer life time required)

Conclusions

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- evacuated fumed silica powder boards analysed: thermal conductivity around $4 \cdot 10^{-3}$ W/mK

- about 27 m^2 of a building façade have been successfully vacuum insulated end of 1998
  no sign of deterioration of gas pressure up to now

- further projects of applications of vacuum panels in buildings are in progress