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Non-destructive Method to Determine the Water Vapour Pressure in Vacuum Insulation Panels (VIP)

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The partial pressures have a different temperature dependence

Dry atmospheric gases	Water vapour
according to the ideal gas law: $p \cdot V = N \cdot k \cdot T$	proportional to the saturated vapour pressure $p_{saturated}(T)$
$\Downarrow$	$\Downarrow$
$p_{dry} = \text{const.} \cdot T$	$p_{WV} = \varphi \cdot p_{saturated}(T)$
Linear dependence	**exponential** dependence

Provided: Sorption isotherm ≠ f(T)
$\Rightarrow \varphi(T)$ = constant
(if water content has not changed)

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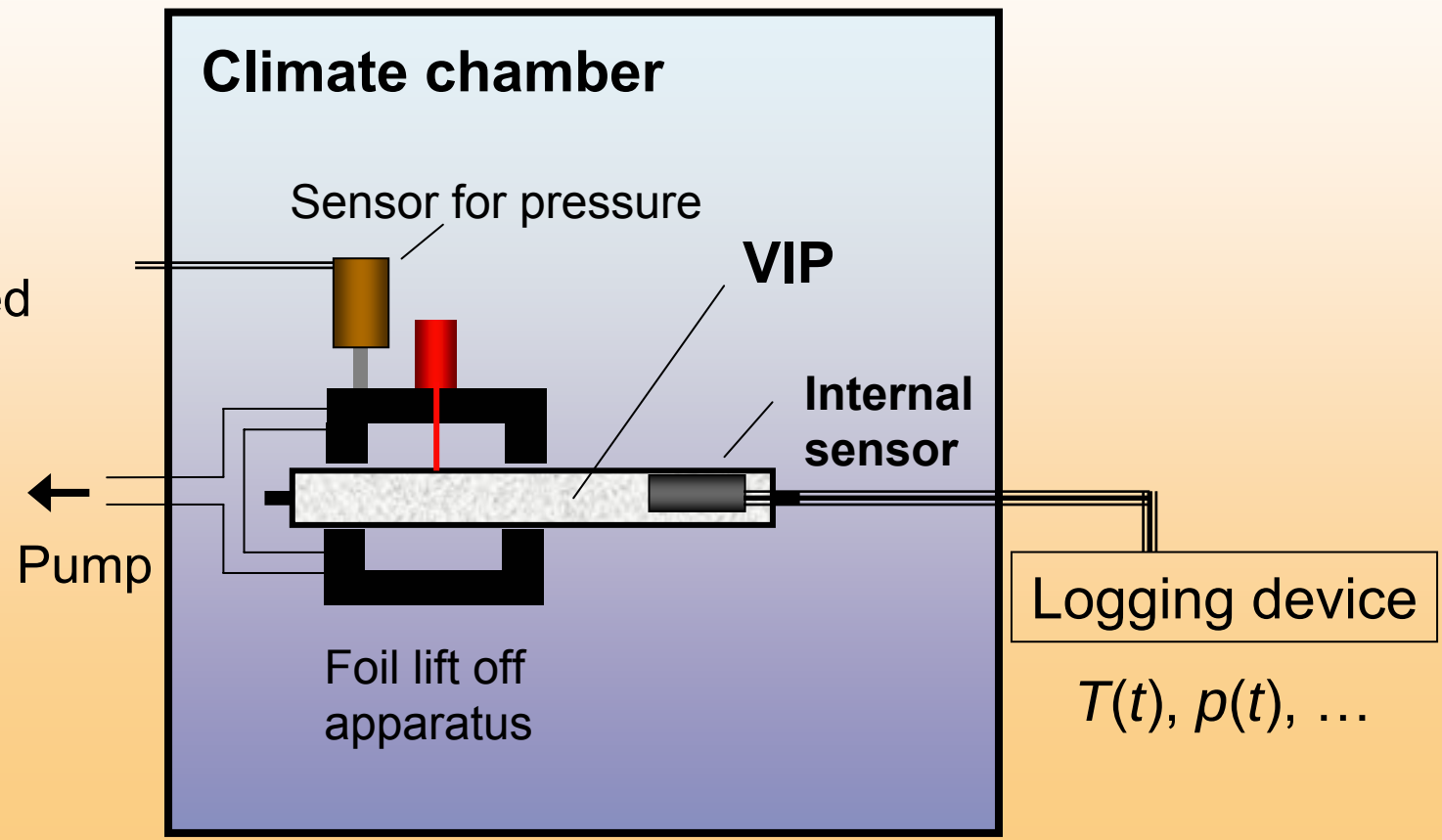
Pressure measurement:

Internal or flanged sensor
continuous data logging

Foil lift-off method

usable for industrial manufactured panels



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Non-destructive method to determine the WV partial pressure:

- measurement of internal pressure at least two different temperature (climate chamber)
- solving the equation:

$$p_{1,2}(\vartheta_{1,2}) = p_o \cdot \frac{273.15\,°C + \vartheta_{1,2}}{293.15\,°C} + \varphi \cdot 6.11\,mbar \cdot \exp\left(\frac{c_1 \cdot \vartheta_{1,2}}{c_2 + \vartheta_{1,2}}\right)$$

p_o : $p_{dry}\,(\vartheta = 20\,°C)$,

φ : relative humidity and

ϑ : temperature / °C.

Magnus equation with

c_1 = 17.08 and c_2 = 234.18 °C.

from $p_1(\vartheta_1)$ and $p_2(\vartheta_2)$ we derive p_o and φ.

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Alternative method to determine the water content (**destructive**):

- cut the enclosure
- measure the mass loss upon drying the kernel

mass loss $m_{water} = m_{wet} - m_{dry}$

water content $x_{water} = m_{water} / m_{dry}$

From the sorption isotherm $x_{water}(\varphi)$ we derive φ.

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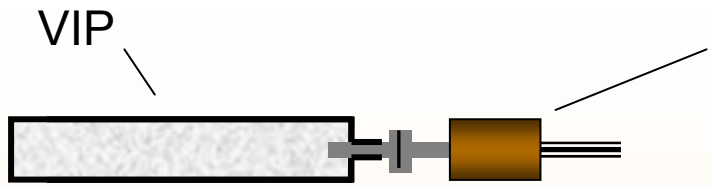
Setup:



- dried,
- **loaded with water** and
- evacuated.

total pressure at 20 °C:
≈ 40 mbar

Procedure:

Step	1	2	3	4	5	6
Time / h	12	12	12	12	8	8
Temperature / °C	20	35	45	20	0	20

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Measurement

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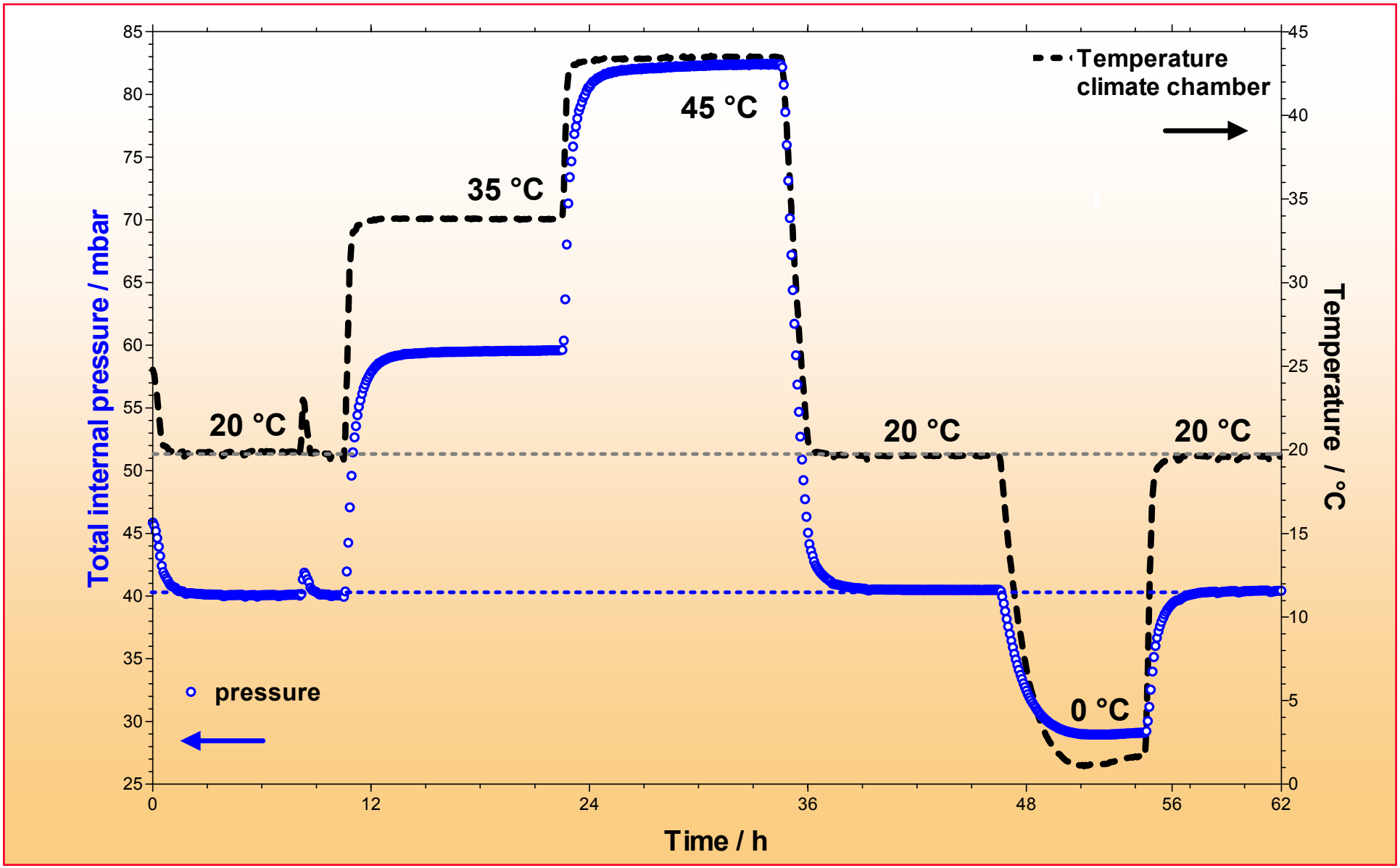

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determined with **non-destructive** method

φ (determined) / %	p_{WV} (23 °C) / mbar
61	≈ 17

calculated values with sorption isotherm (**destructive**)

m_{water} / g	x_{water} / m-%	φ (calculated) / %	p_{WV} (23 °C) / mbar
9.6	2.9	50	≈ 14

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Panel preparation II

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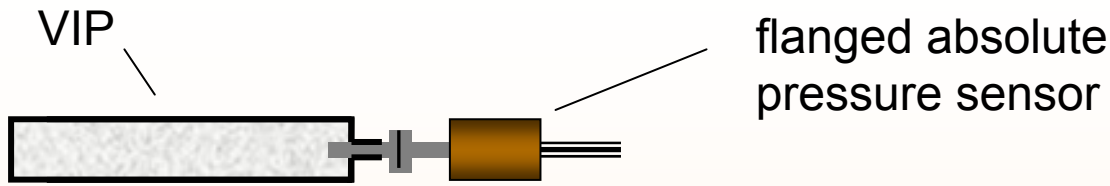

Panel	Setup		Total pressure at room temperature
1	dried, **loaded with water**, evacuated.	**wet**	≈ 20 mbar
2	dried, evacuated.	**dry**	≈ 6 mbar

Different points of temperature (10 °C .. 45 °C)
and step times (up to 15 h)

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Measurement II

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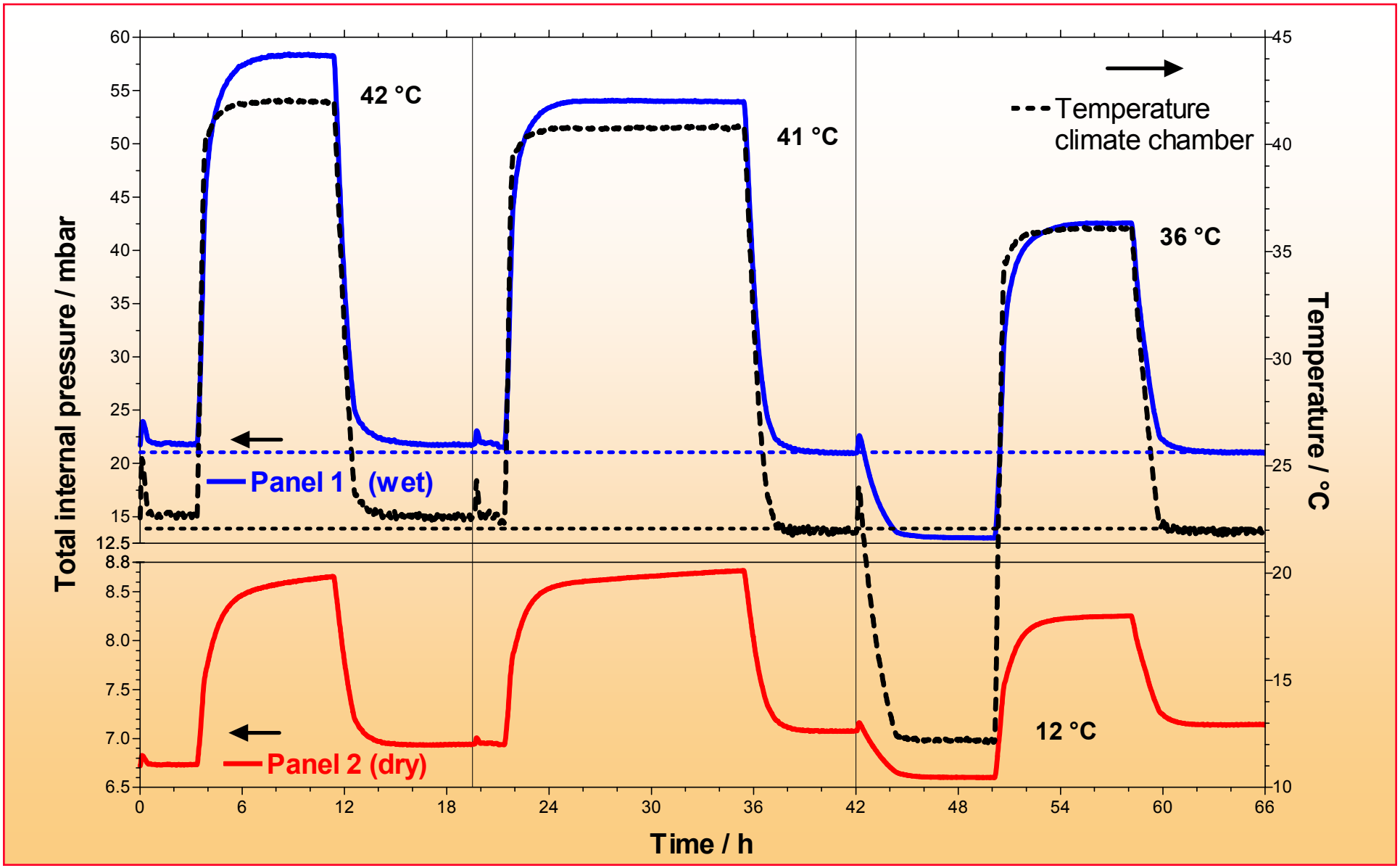

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Table II

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Panel:	T_1 / °C	T_2 / °C	p_1 / mbar	p_2 / mbar	φ / %	p_{WV} (23 °C) / mbar	p_0 / mbar
1 [wet]	22.8	42.0	21.9	58.1	66.5	18.7	3.4
	21.9	40.8	21.0	54.0	64.6	18.2	3.9
	12.2	22.6	13.0	21.7	65.4	18.4	3.8
	12.2	36.1	13.0	42.6	64.2	18.1	4.0
	22.0	36.1	21.0	42.6	63.9	18.0	4.1
				mean values:	64.9	18.3	3.8
2 [dry]	22. 6	41.9	6.9	8.7	2.4	0.7	6.2
	21.9	40.8	7.1	8.7	2.4	0.7	6.4
	12.2	21.9	6.6	7.1	2.1	0.6	6.5
	22.0	36.1	7.1	8.3	2.4	0.7	6.5
				mean values:	2.3	0.7	6.4

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determined with **non-destructive** method

	φ (determined) / %	p_{WV} (23 °C) / mbar
1	65	≈ 18
2	2.3	≈ 0.7

calculated values with sorption isotherm (**destructive**)

	m_{water} / g	x_{water} / m-%	φ (calculated) / %	p_{WV} (23 °C) / mbar
1	13.4	4.0	59	≈ 17
2	0.7	0.18	2.1	≈ 0.6

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Summary and Acknowledgment

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We have developed a new approach to determine the water vapour pressure within a VIP:

– non-destructive
– independent on sorption isotherm
– easy to perform once the foil lift-off device is commercially available.

These investigations were performed within the project
„Energieoptimiertes Bauen, Teilkonzept 1: Aufbau einer Koordinationsstelle für die nationalen Tätigkeiten zum ECBCS-Annex 39 „High Performance Thermal Insulations for Buildings“ (HiPTI) der Internationalen Energieagentur (IEA) und Qualitätskontrolle von Vakuumisolationspaneelen [0327321E]“
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