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Alumino-phosphate coatings: From lab-scale adsorption experiments to the design of adsorption chiller heat-exchangers

Thomas Nonnen, Ralph Herrmann, Andreas Kuhnt, André Große

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Who we are

2002 Founded as SorTech AG as spin-off from Fraunhofer ISE

2017 Rebranding into Fahrenheit GmbH

- Development and production of adsorption chillers
- Development of adsorption applications

35 Employees in Munich (sales, head office) and Halle/Saale (R&D and production)

>20 Patents granted

>600 Systems installed (Germany, Europe, overseas)

10 to 750 kW system cooling power

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Technical implementation of an adsorption chiller

MT (medium temperature)
RECOOLING CIRCUIT
- Dry recooler
- Cooling tower
- Swimming pool

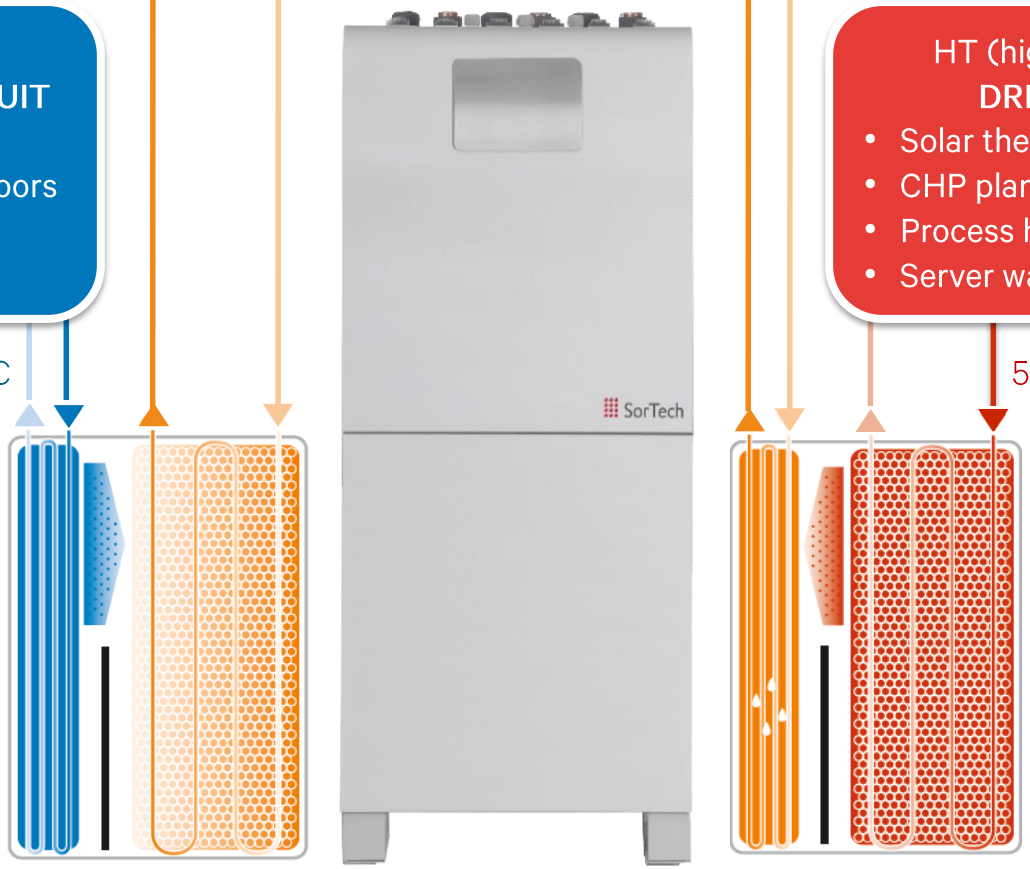
22 to 40 °C

LT (low temperature)
CHILLED WATER CIRCUIT
- Air conditioning
- Chilled ceilings/walls/floors
- Process cooling
- Server cooling

HT (high temperature)
DRIVE CIRCUIT
- Solar thermal
- CHP plant
- Process heat
- Server waste heat

8 to 21 °C

50 to 95 °C



Left module

Right module

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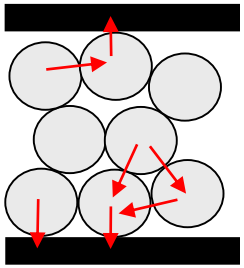
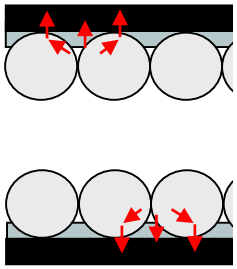
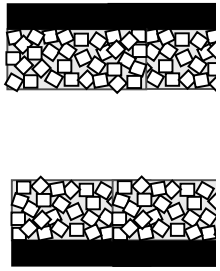
Rapid heat transfer is essential for adsorption cooling



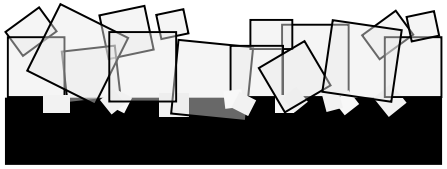
fixed bed



fixed monolayer



binder coating



partial support transformation (PST)

Increasing heat transfer
Increasing adsorption rate
Increasing cooling power

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Performance assessment on different scales

Scale	Experiments	Information on
Lab	Isothermal static adsorption, Isothermal dynamic adsorption	*p, T* operating window of the adsorbent, Influence of layer thickness and morphology
Heat exchanger	Non-isothermal dynamic adsorption	Interaction of adsorption and heat transfer
Module	Performance assessment	Interaction of condenser and adsorber
Chiller	Performance assessment	Interaction of modules with hydraulics

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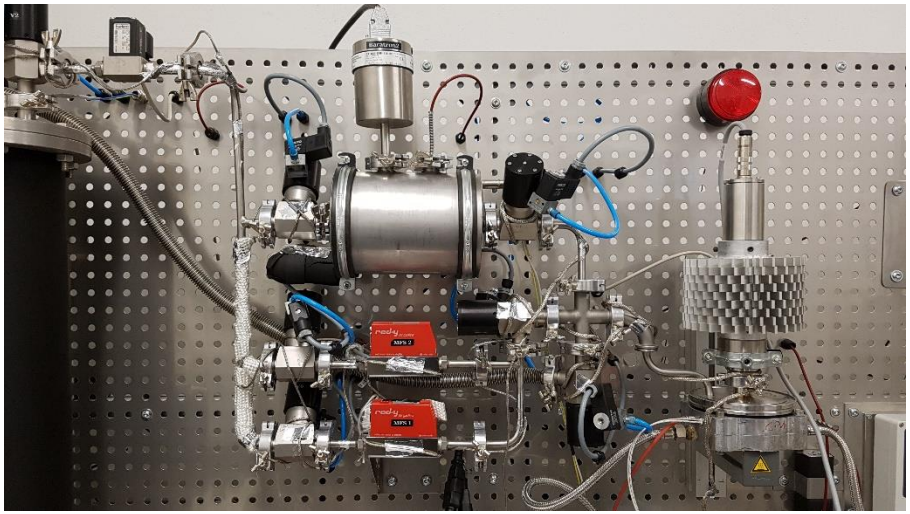
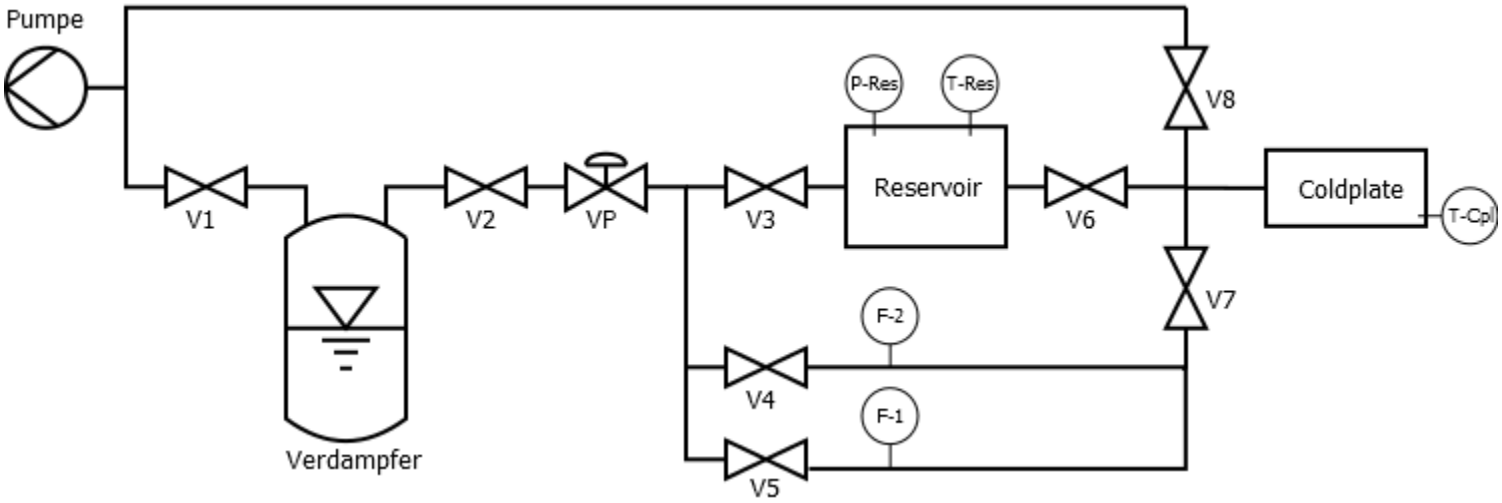
Lab-scale characterisation setup





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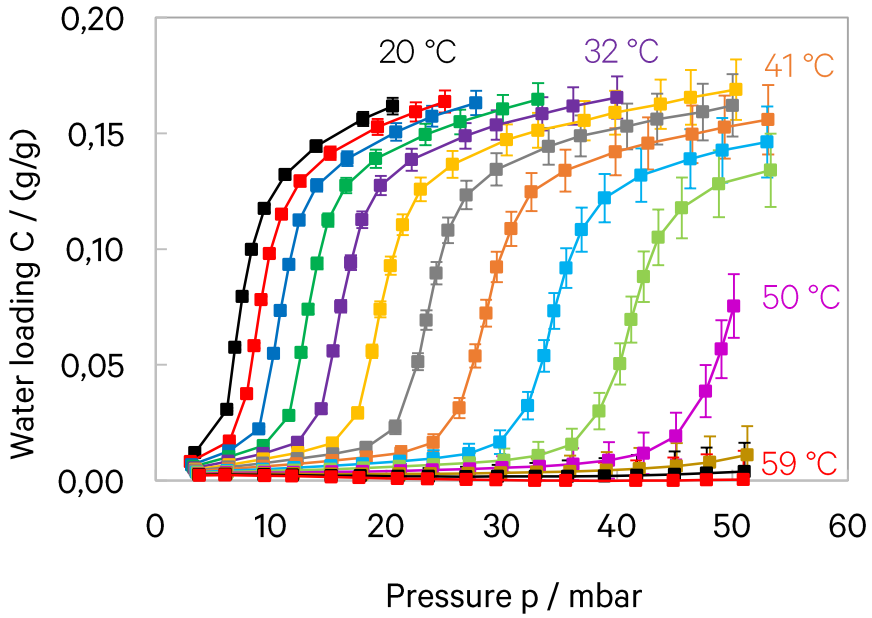
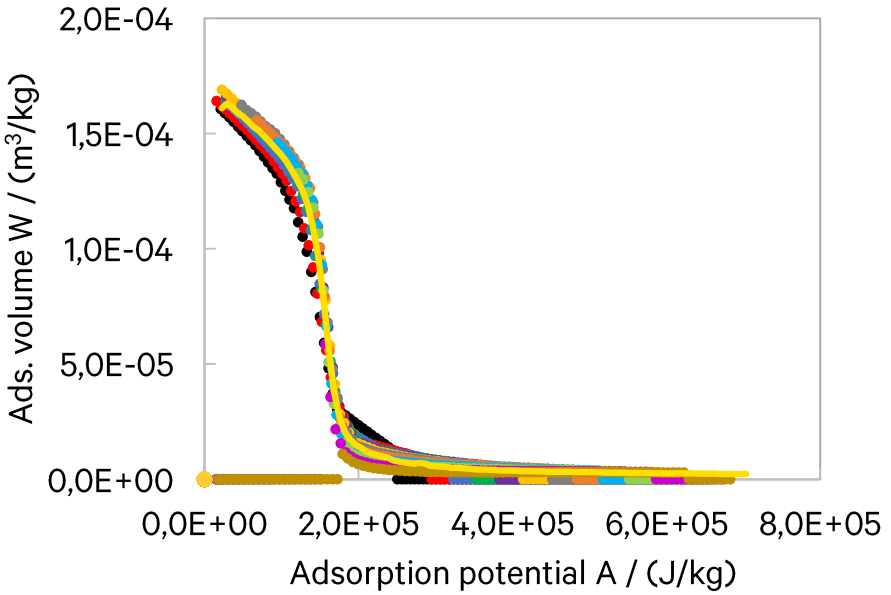
Calculation of the characteristic curve





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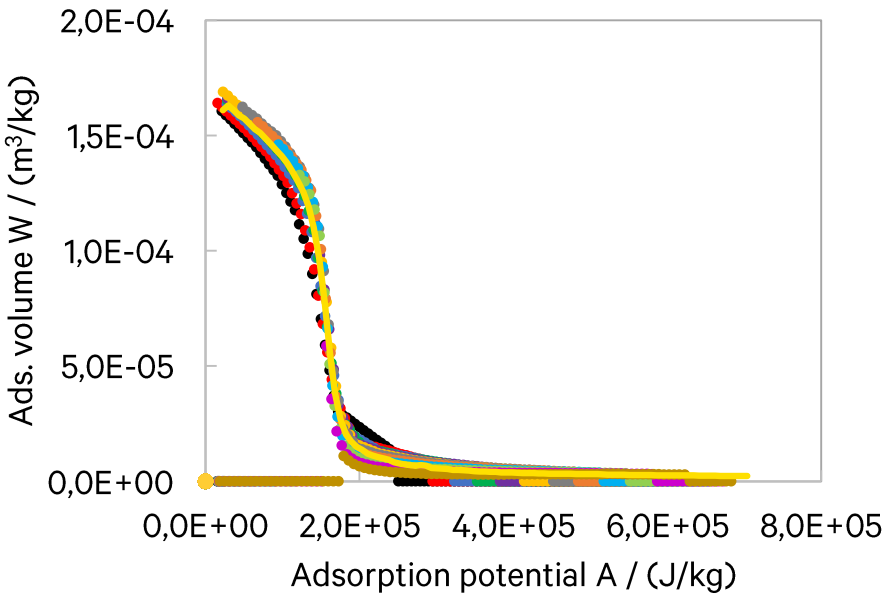
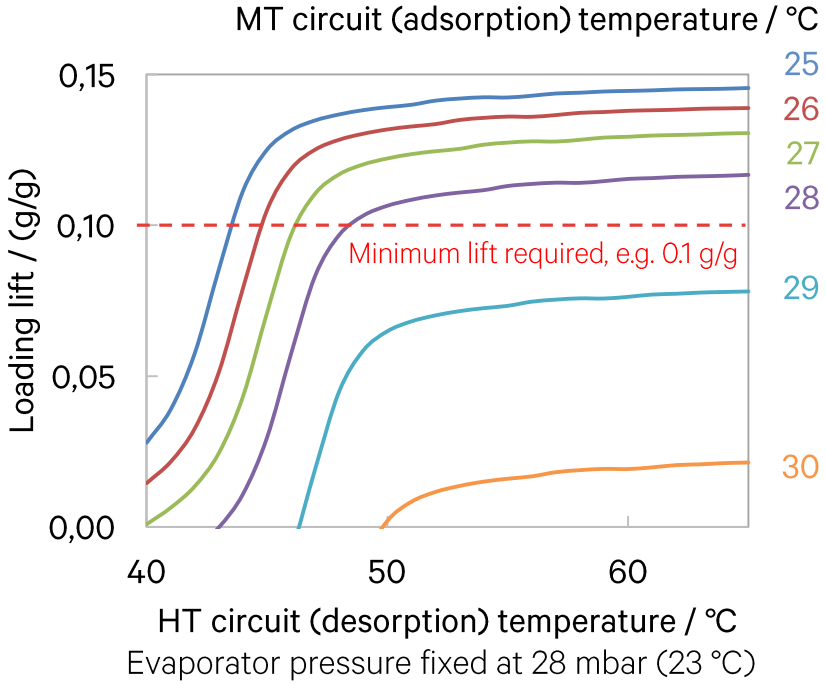
Assessment of the operation window from the characteristic curve





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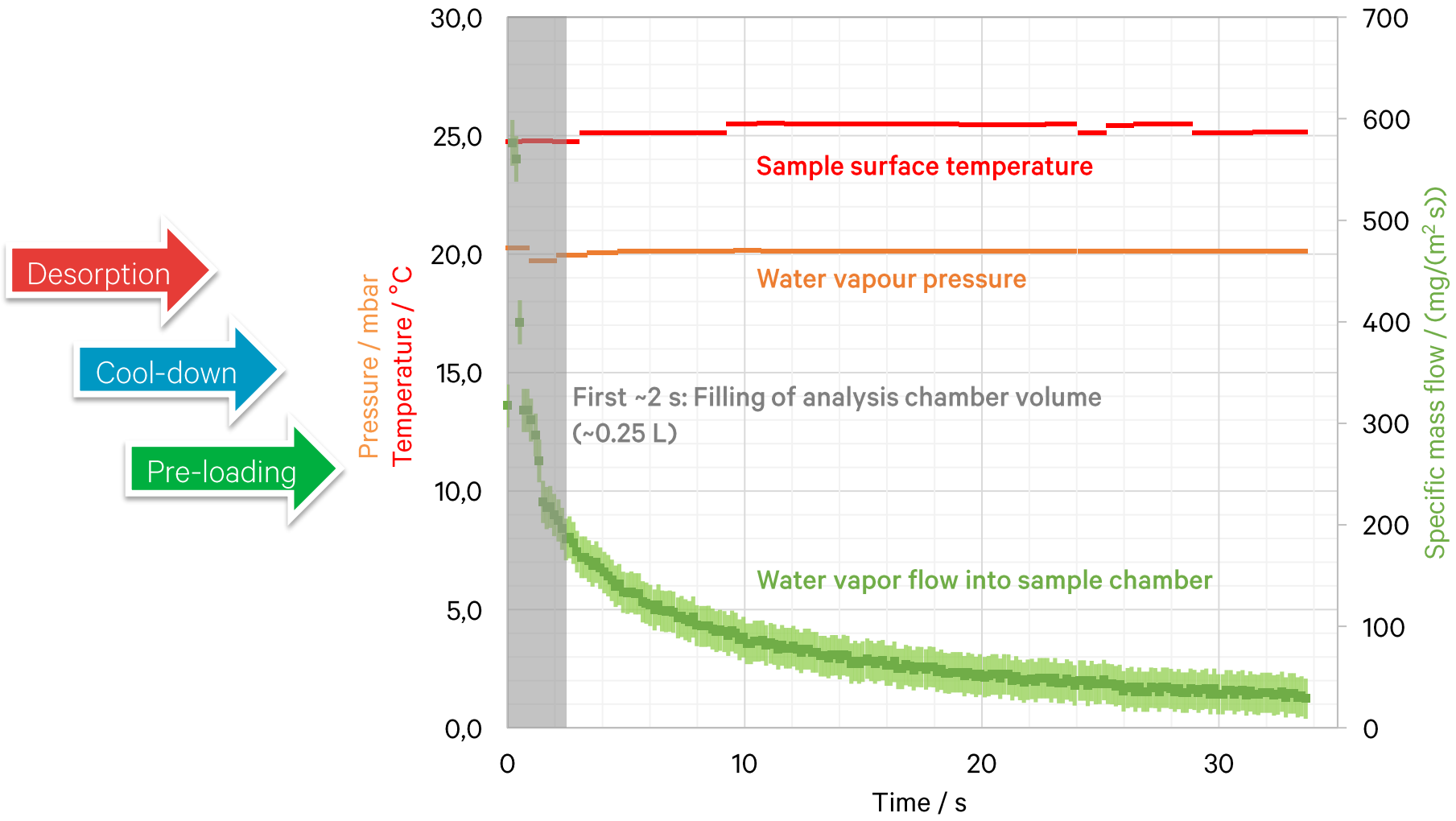
Isothermal pressure jump experiment



Identification of a suitable kinetic model

Elovich's equation

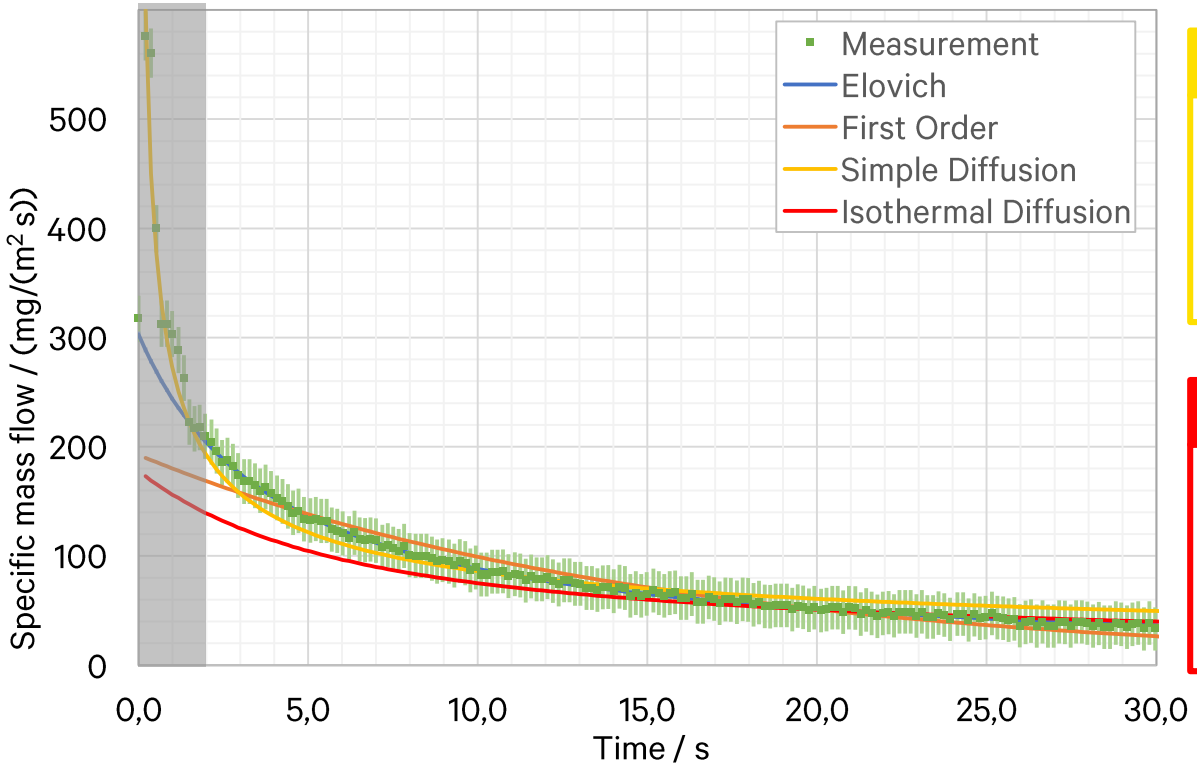
$$C(t) = \beta \ln\left(\exp\left(\frac{C_0}{\beta}\right) + \frac{r_0 t}{\beta}\right)$$

$$r(t) = r_0 \exp\left(-\frac{C(t)}{\beta}\right) \equiv \frac{\beta\, r_0}{\beta \exp\left(\frac{C_0}{\beta}\right) + r_0 t}$$

First order

$$C(t) = C_{eq}\left(1 - \exp\left(-\frac{t}{\tau}\right)\right)$$

$$r(t) = \frac{C_{eq}}{\tau} \exp\left(-\frac{t}{\tau}\right)$$



Simple diffusion

$$C(t) = C_0 + (C_{eq} - C_0)\sqrt{ut}$$

$$r(t) = \frac{(C_{eq} - C_0)}{2}\sqrt{\frac{u}{t}}$$

Isothermal diffusion

$$C(t) = C_{eq}\left(1 - \frac{6}{\pi^2}\sum \frac{1}{n^2} \exp\left(-\frac{n^2 \pi^2 D\, t}{r^2}\right)\right)$$

$$r(t) = \frac{\mathrm{d}C(t)}{\mathrm{d}t}$$

Qiu et al., Critical review in adsorption kinetic models, J. Zhejiang Univ. Sci. A 10 (2009) 716.

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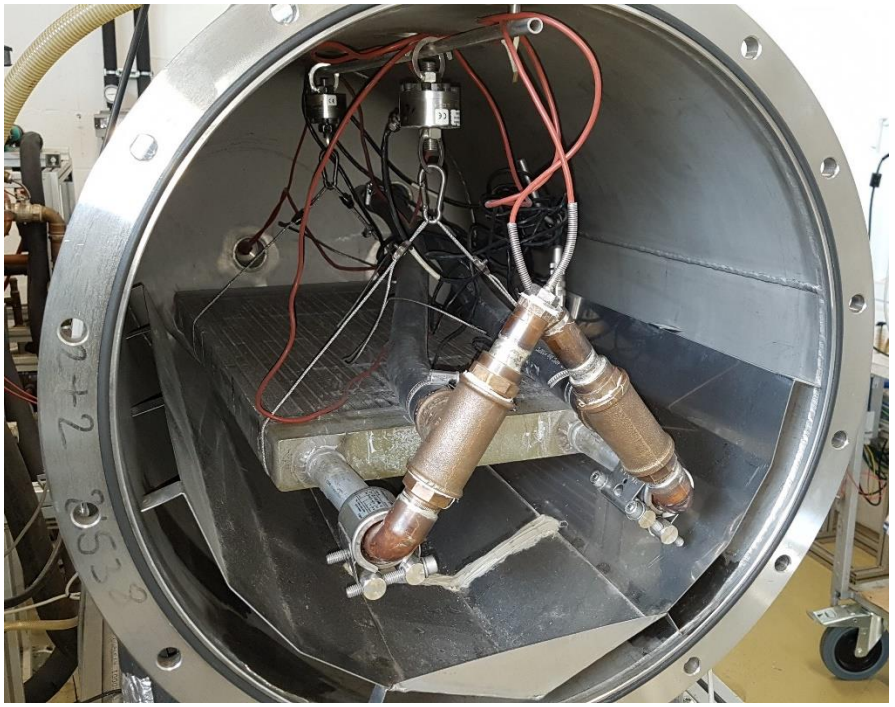
Heat exchanger scale setup



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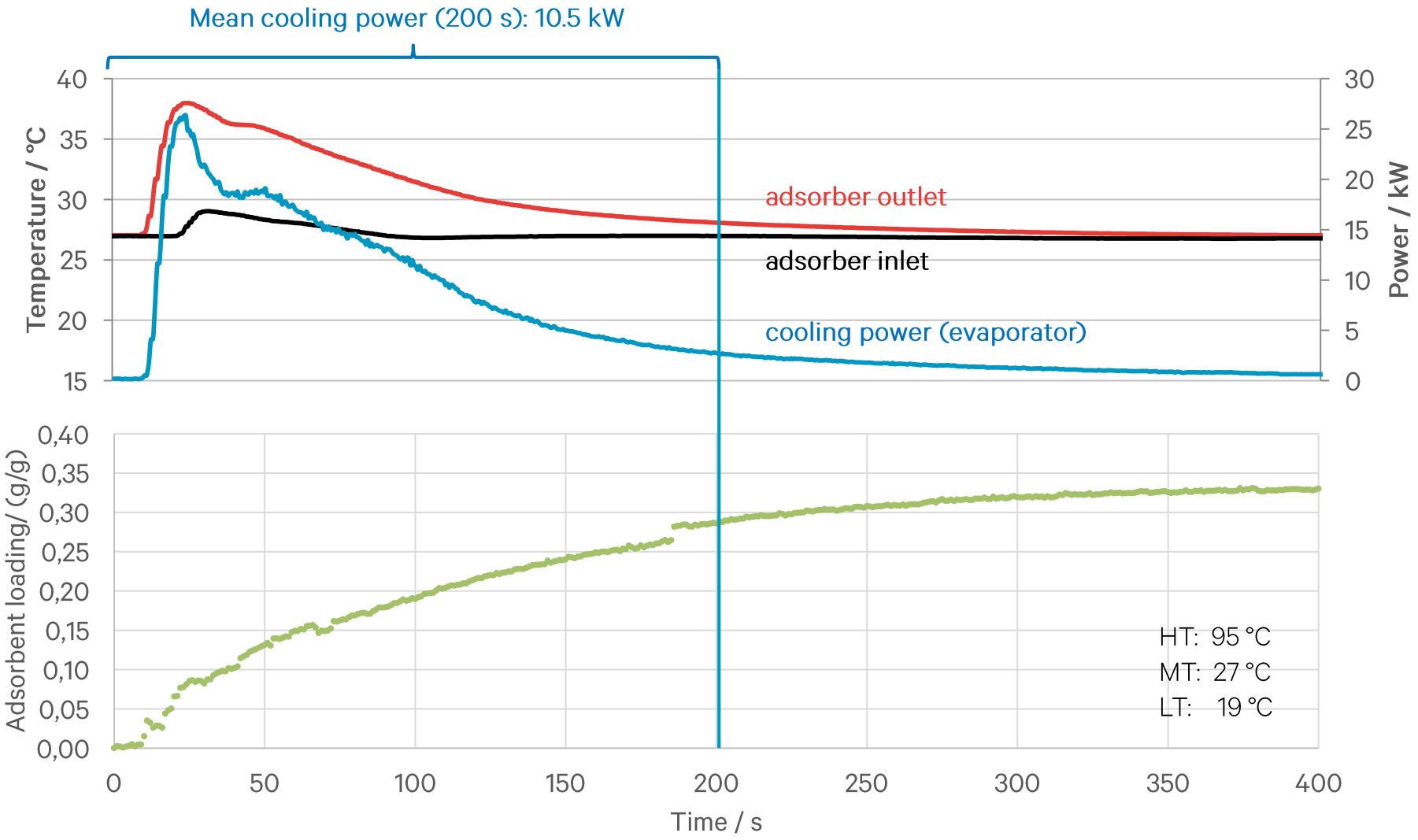
Non-isothermal adsorption experiment



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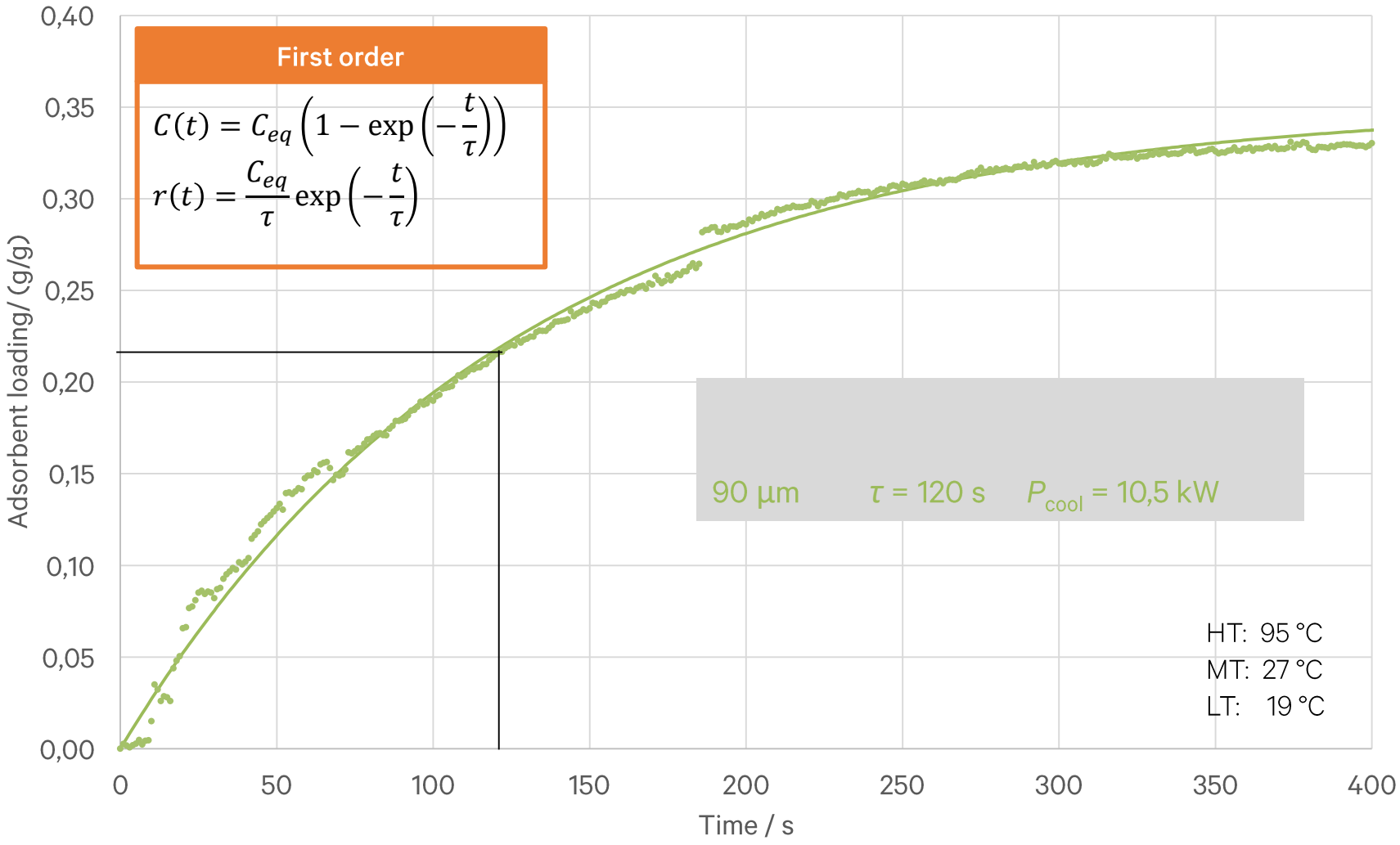
Non-isothermal adsorption experiment



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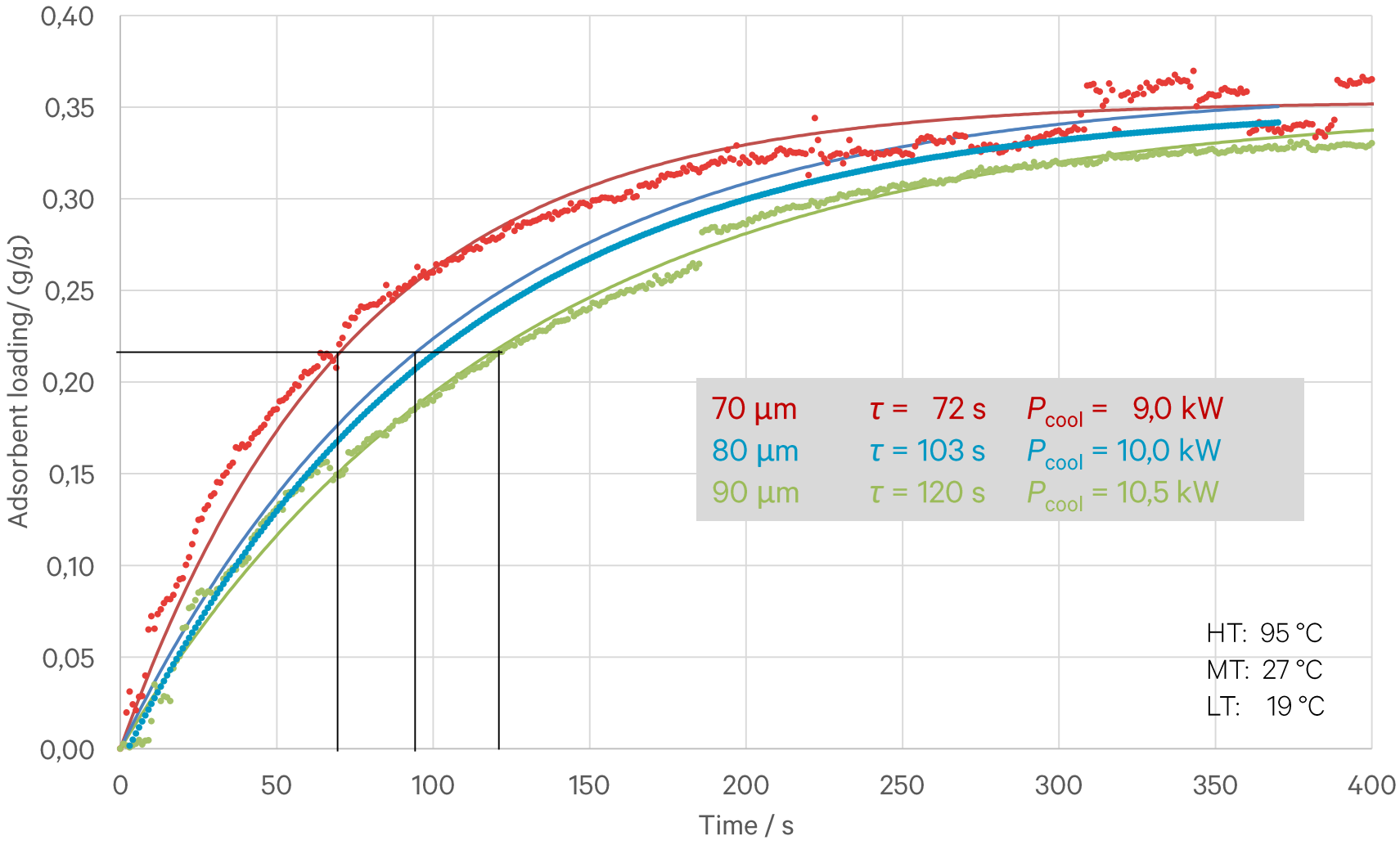
Influence of adsorbent-layer thickness on cooling power



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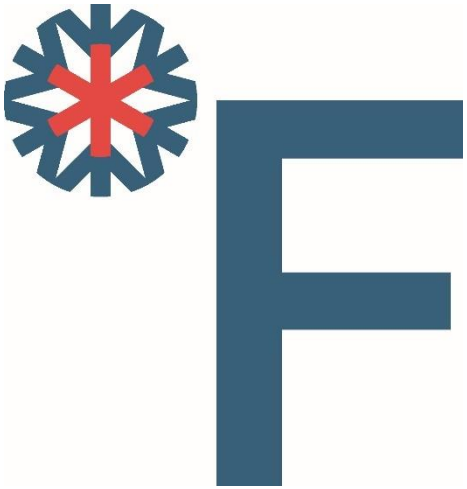
Summary and Outlook

- Rapid sorption process is essential for adsorption chillers (cooling power!)
- Static and dynamic sorption experiments on different scales throughout the development process

Outlook

- Mathematical adsorber performance prediction to reduce development time and cost

Contact



FAHRENHEIT GmbH

Sales & Head Office

Siegfriedstraße 19

80803 Munich, Germany

T: +49 89 340 762 21

M: +49 172 61 491 79

R&D & Production

Zscherbener Landstr. 17

06126 Halle (Saale), Germany

T: +49 345 27 98 09 - 0

www.fahrenheit.cool