CHARACTERIZATION OF AN N-OCTADECANE PCS IN A 0.5 M³ STORAGE TANK TEST FACILITY

Heat storage capacity characterization and scale-up of PCS

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Introduction

- Phase Change Slurry (PCS) = dispersion of PCM and carrier fluid (typically water)
  - pumpable independently of the PCMs phase (liquid/solid)
  - separation of storage- from power-unit
  - usage of existing storage tanks (e.g. building climate control)
- PCS composition found to be stable at a scale of 5 L is upscaled to 600 L
  - stability of 40.000 full crystallization and melting cycles at scale of 5 L
  - paraffin wax PCM, melting point ~28 °C
  - reported at IIR conference in 2016 by Niedermayer *et. al.*
- characterization in a 500 L storage tank test facility
  - energy characterization and comparison to reference water measurements
  - pump characteristics

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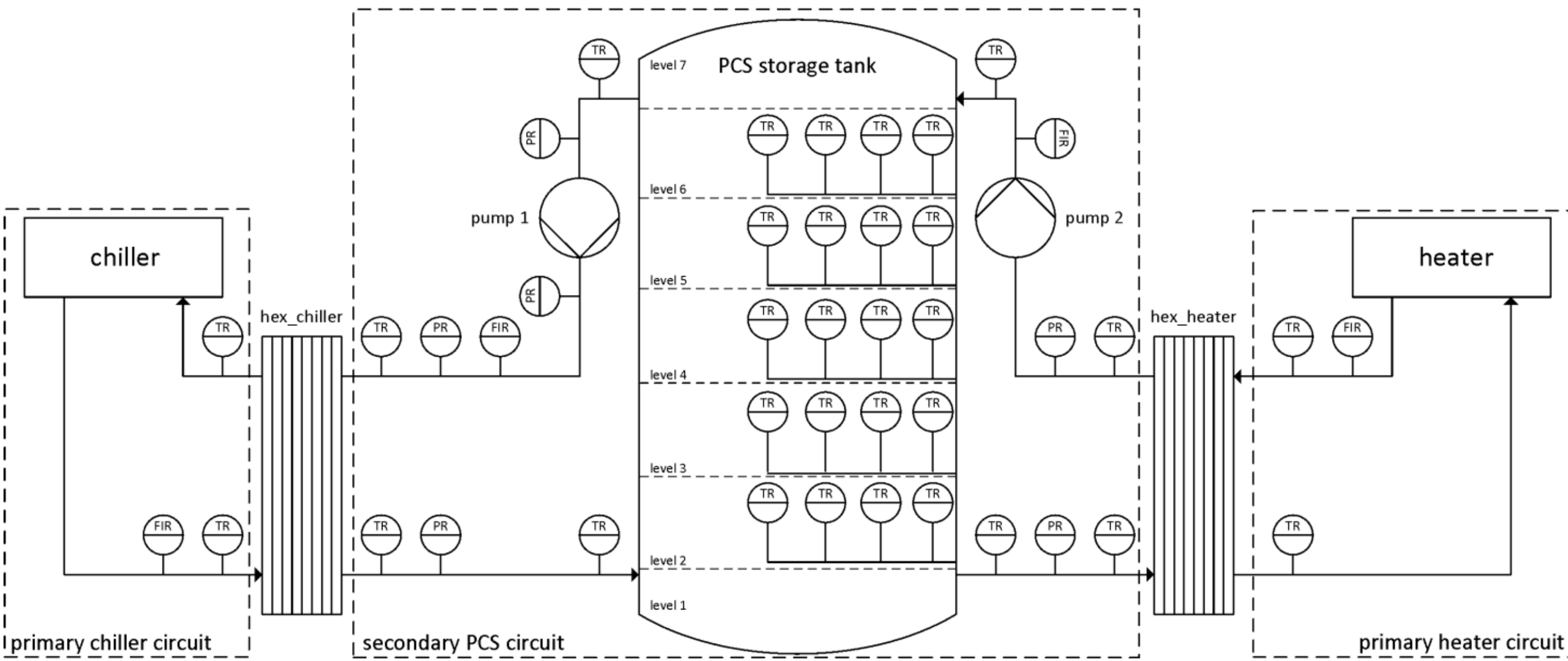
500 L storage tank test facility - overview

- main component: 500 L storage tank
- three circuits: PCS circuit + chiller/heater circuit for heat/cold supply
- flexible/variable construction
  - different hydraulic circuits possible (e.g. for pump characteristics)



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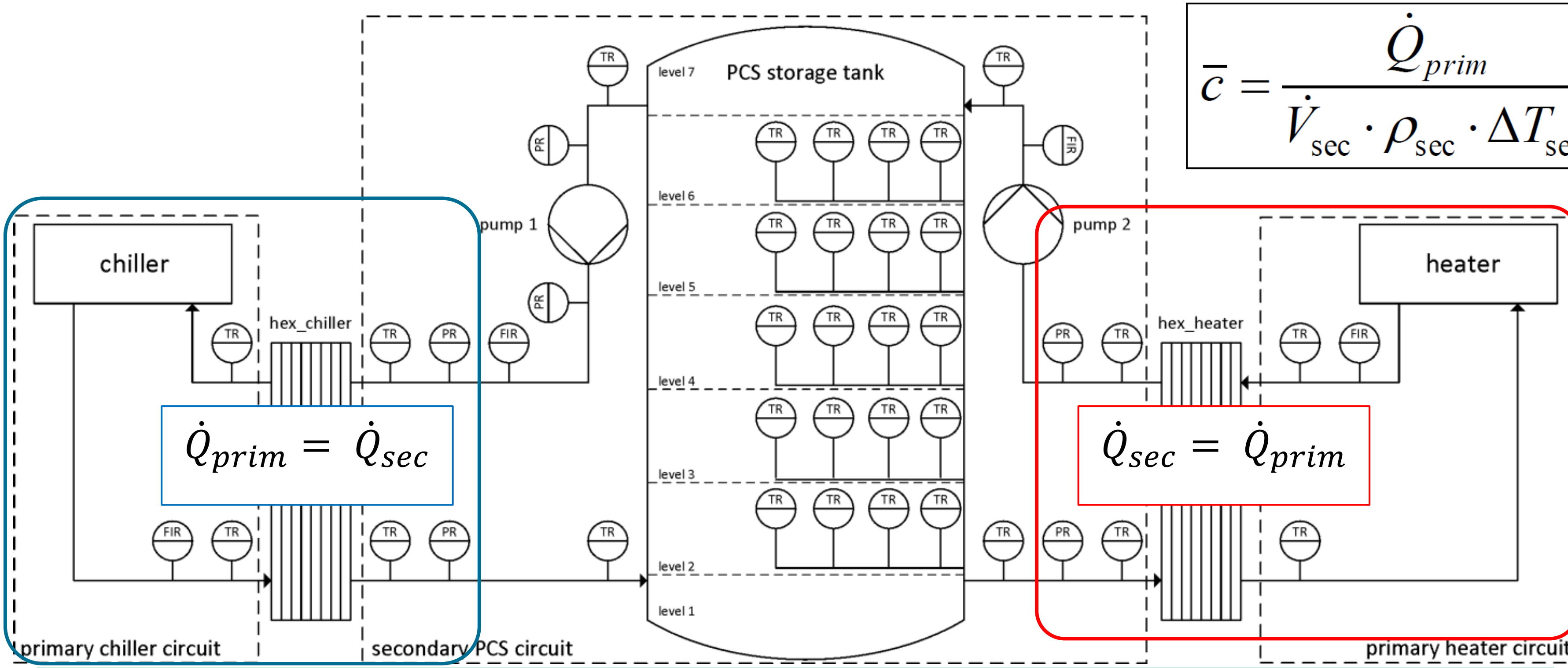
500 L storage tank test facility – heat/cold supply

- heat/cold supply with plate heat exchangers
- energy evaluation in primary circuit → ideal heat exchangers
  - reference experiments with water for confirmation



$$\dot{Q}_{prim} = \dot{Q}_{sec}$$

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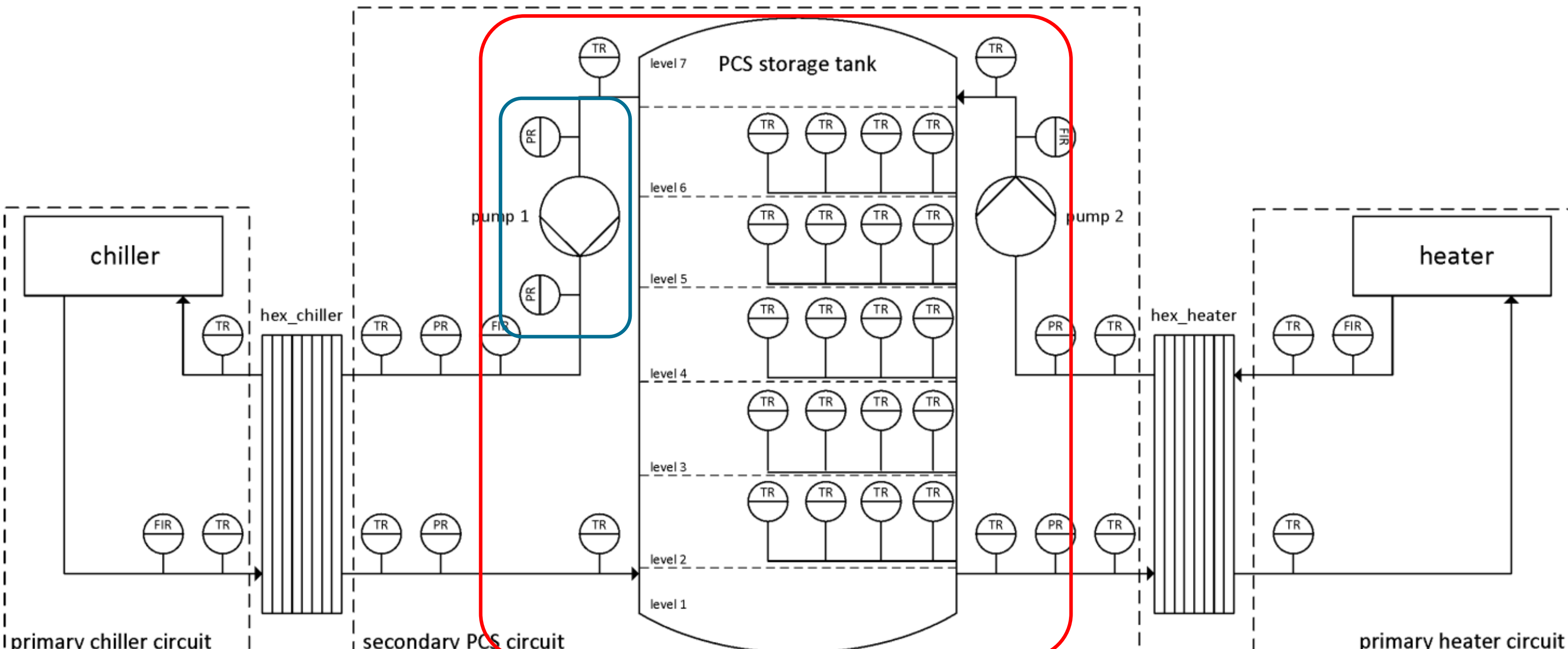
$$\bar{c} = \frac{\dot{Q}_{prim}}{\dot{V}_{sec} \cdot \rho_{sec} \cdot \Delta T_{sec}}$$

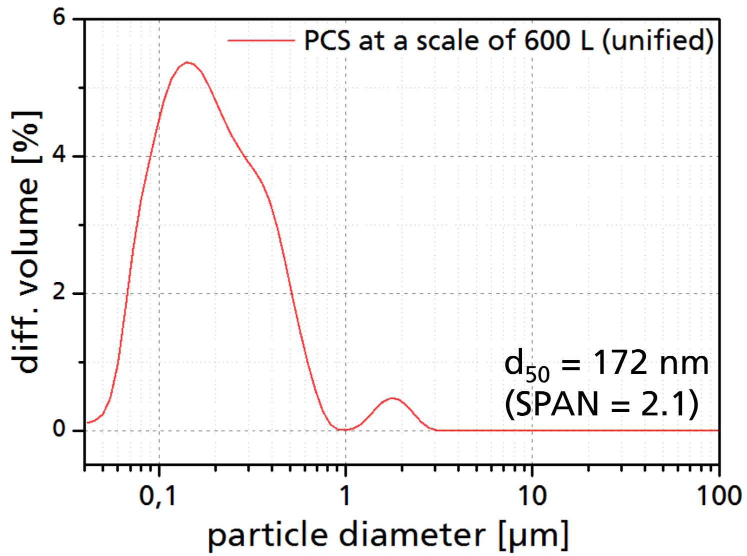
500 L storage tank test facility – storage tank/pump

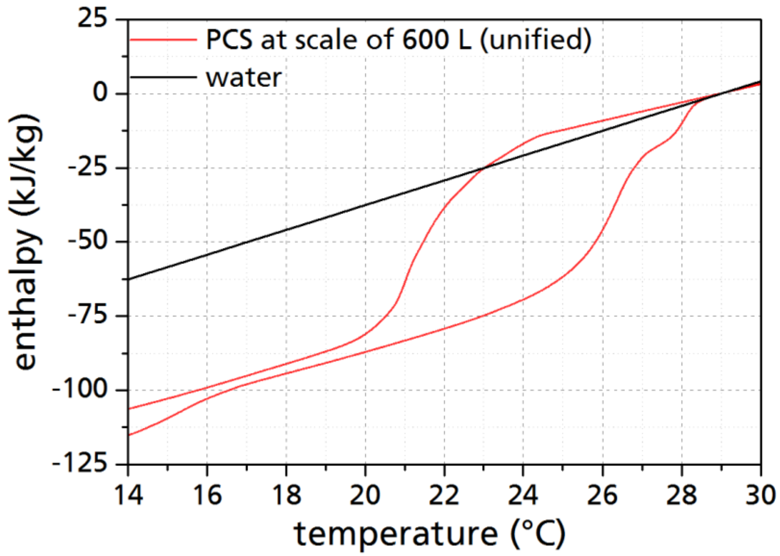
- temperature sensors on 5 levels inside storage tank
  - additional sensors on feed and return of the storage tank
  - charge/discharge with two rotary pumps
- pump 1 is equipped with pressure sensors on head and suction side
  - characteristic pump curve measurement



Production of 600 L PCS

- paraffin wax as PCM – melting point: ~28 °C
  - n-octadecane (Sasol Germany, Parafol 18-97)
- additive to reduce supercooling
- dispersing process with subsequent high pressure homogenization
- production of 6 individual 100 L batches due to vessel size limit
  - unification of the batches to result 600 L PCS





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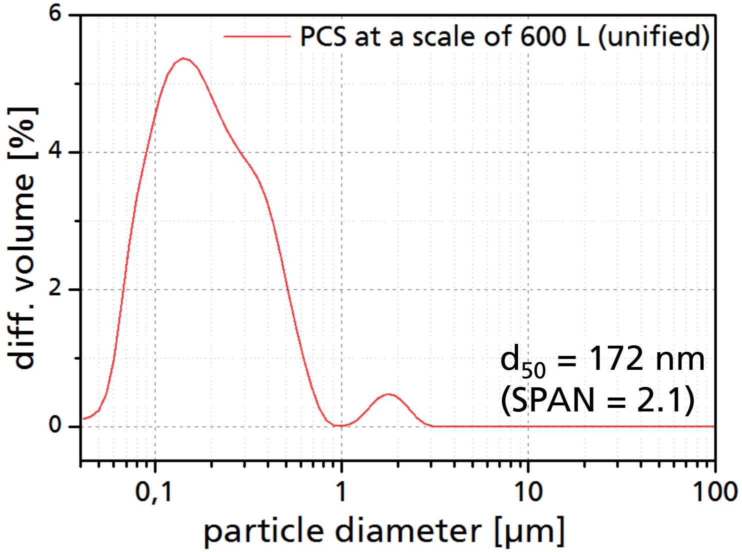

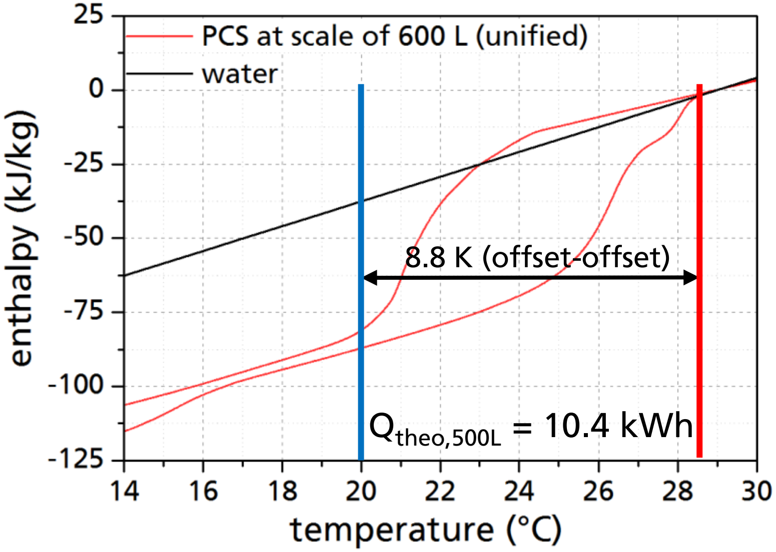

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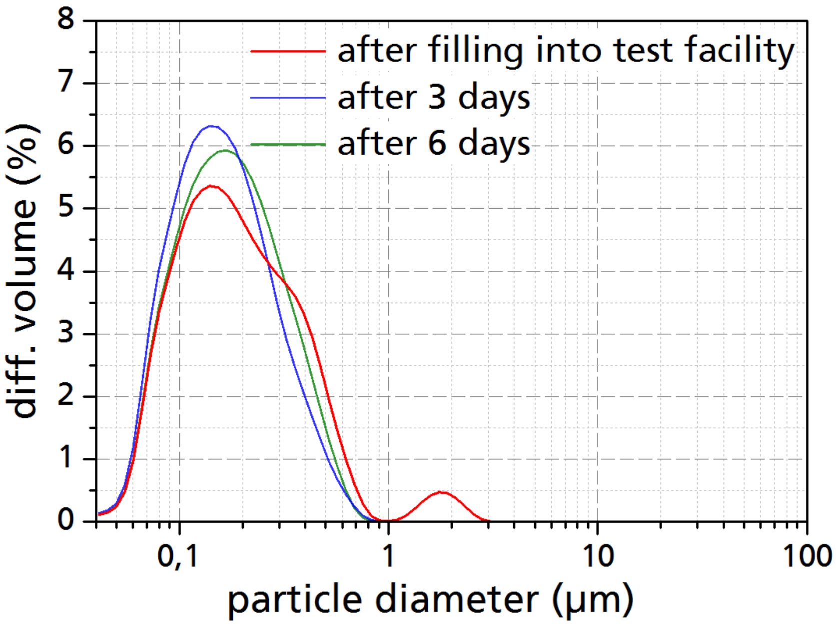
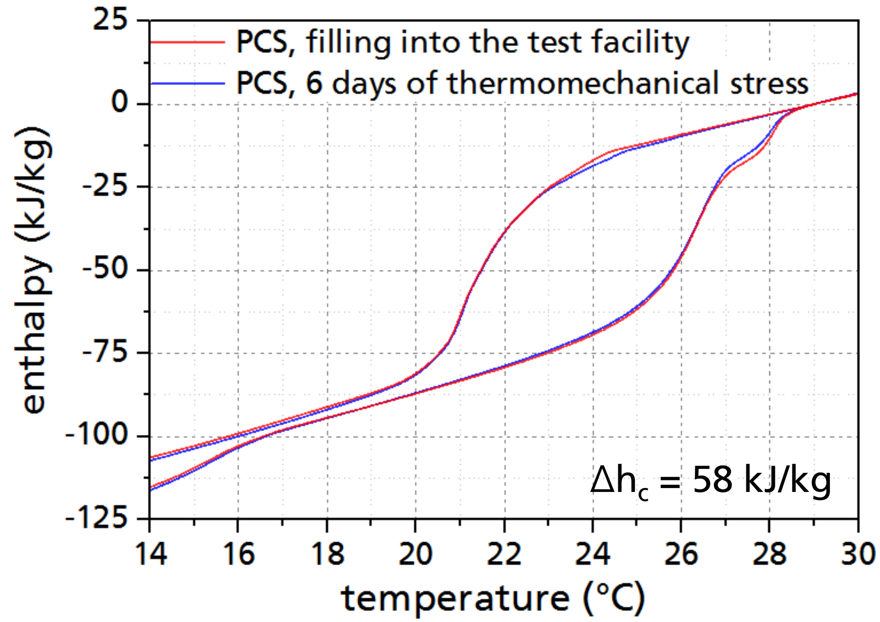
Sample analysis during PCS operation





- change in particle size distribution
  - change to monomodal distribution after 3 days of thermomechanical stress
  - after 6 days: d_{50} = 164 nm (SPAN = 1.7)
- no change in DSC characterization
  - after 6 days of operation Δh_c = 58 kJ/kg

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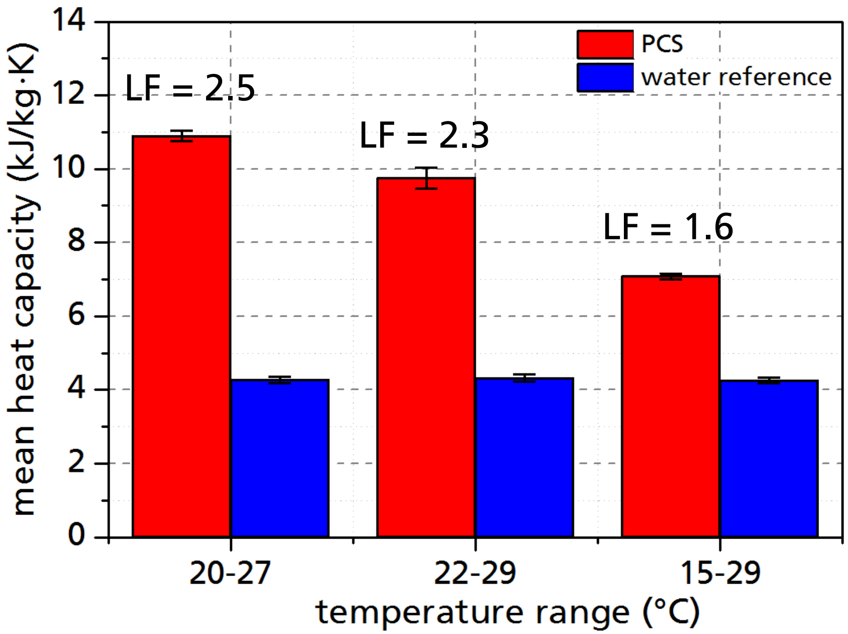
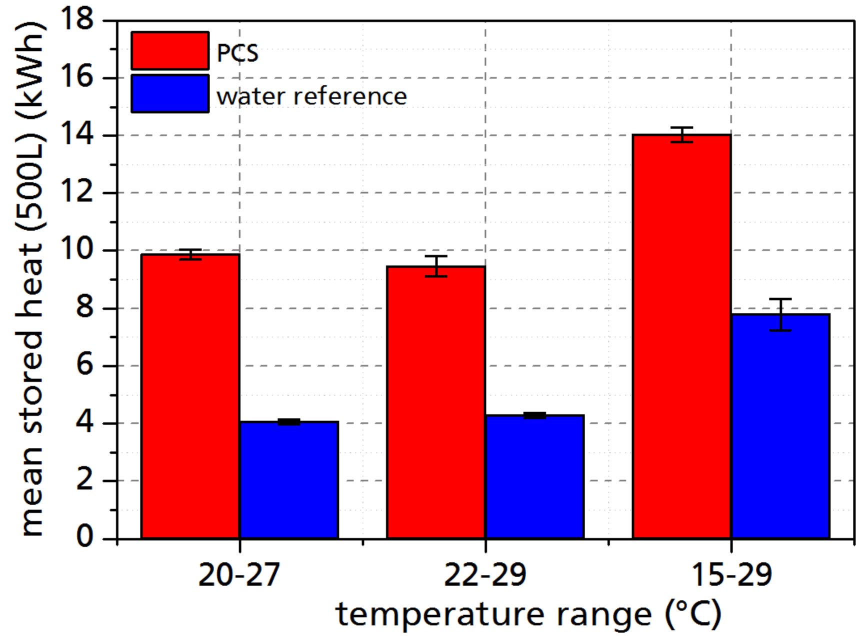
Heat storage capacity and stored heat





- mean values out of three full charge and discharge cycles
- volumetric flow rate of 250 L/h
- load factor (LF) in comparison to water of 2.5 in a temperature interval between 20 °C – 27 °C
  - wider temperature interval: proportion of sensible heat increases, LF decreases
- due to reduced stability only three temperature intervals were characterized

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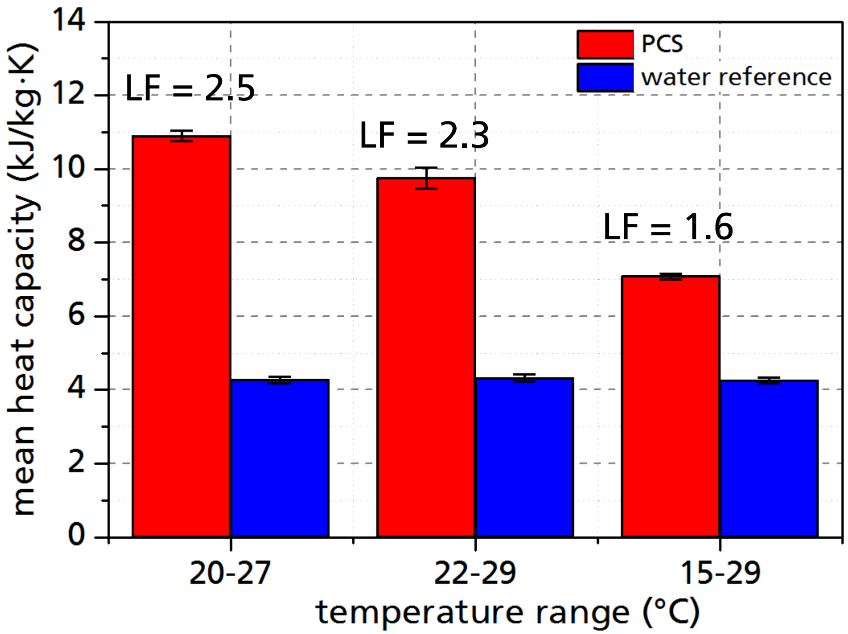

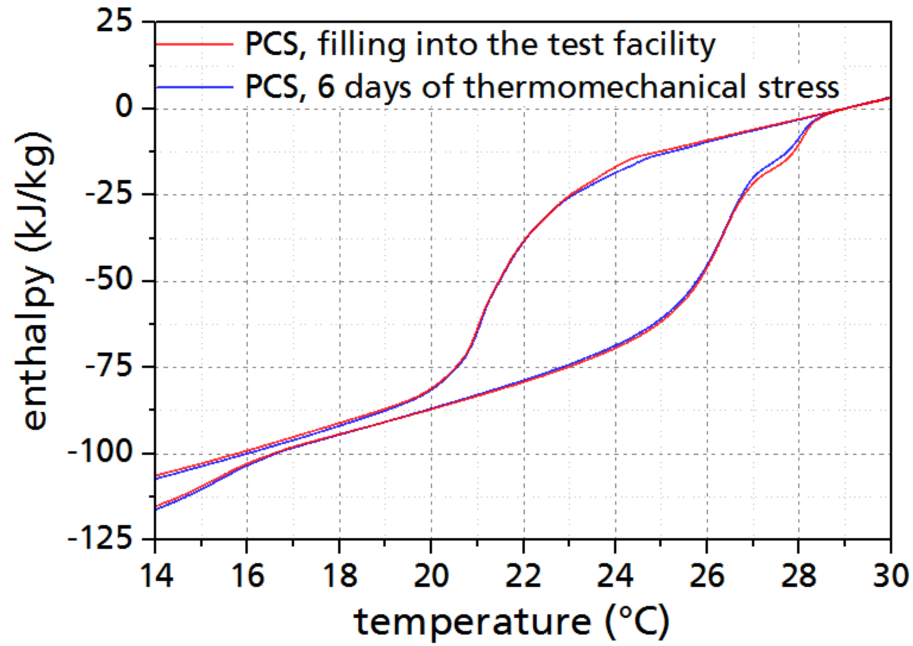

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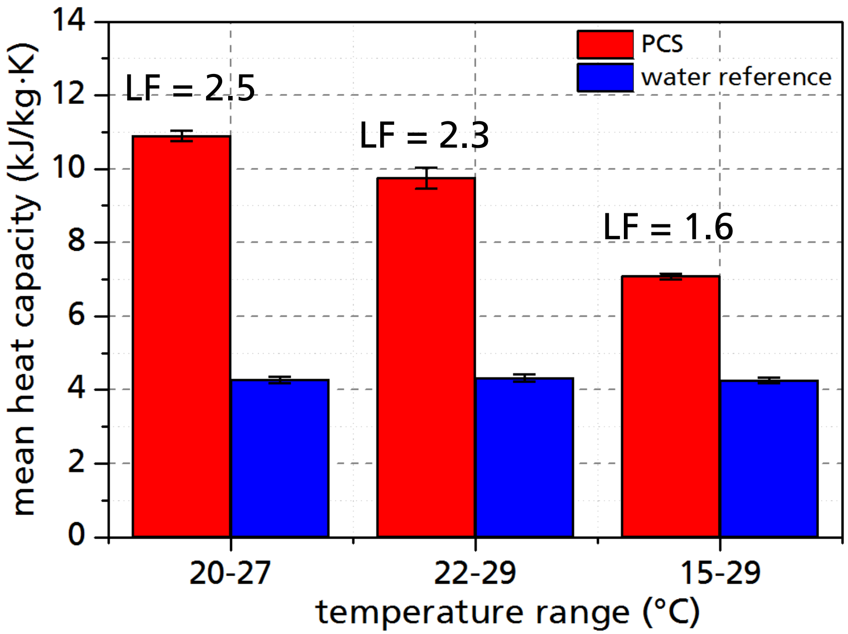

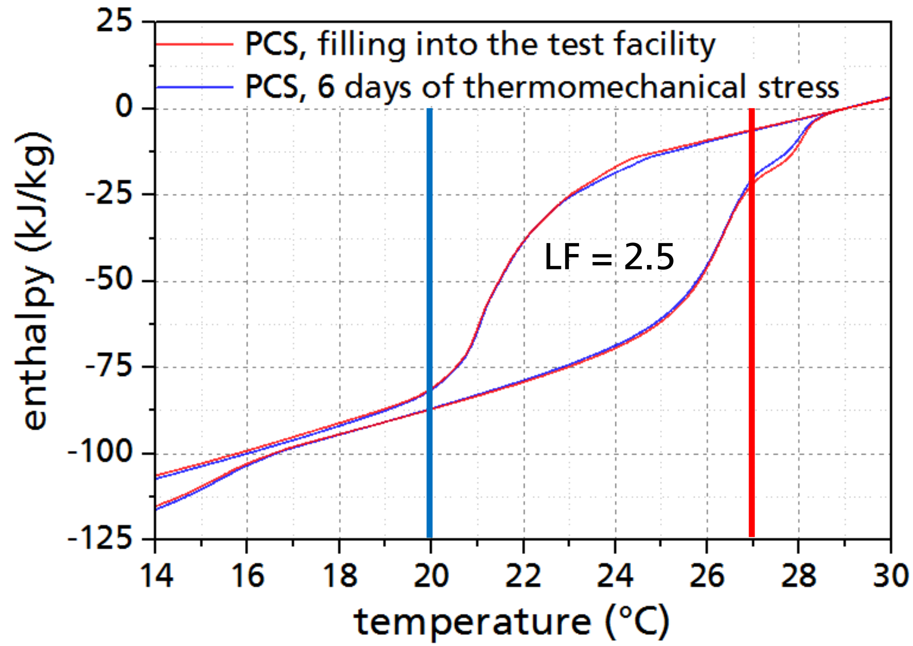

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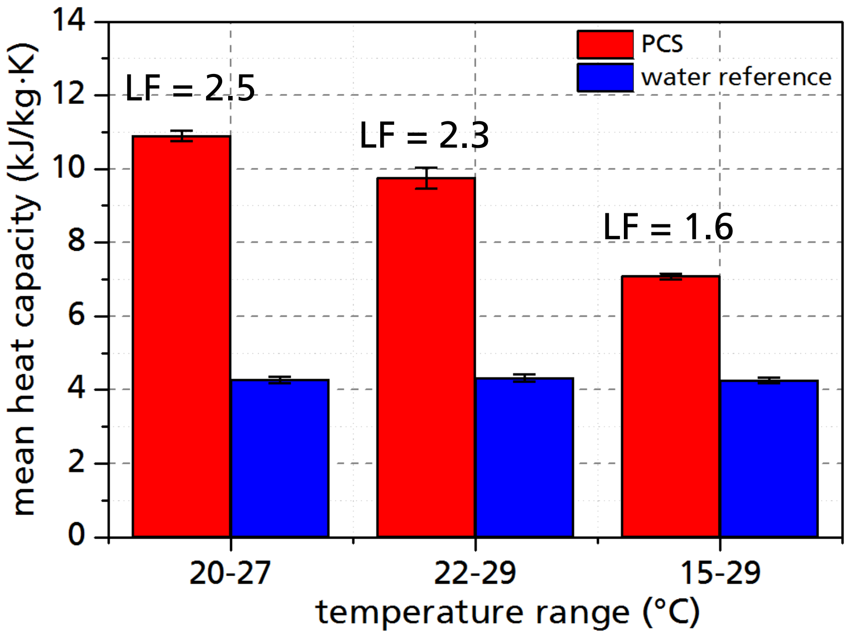

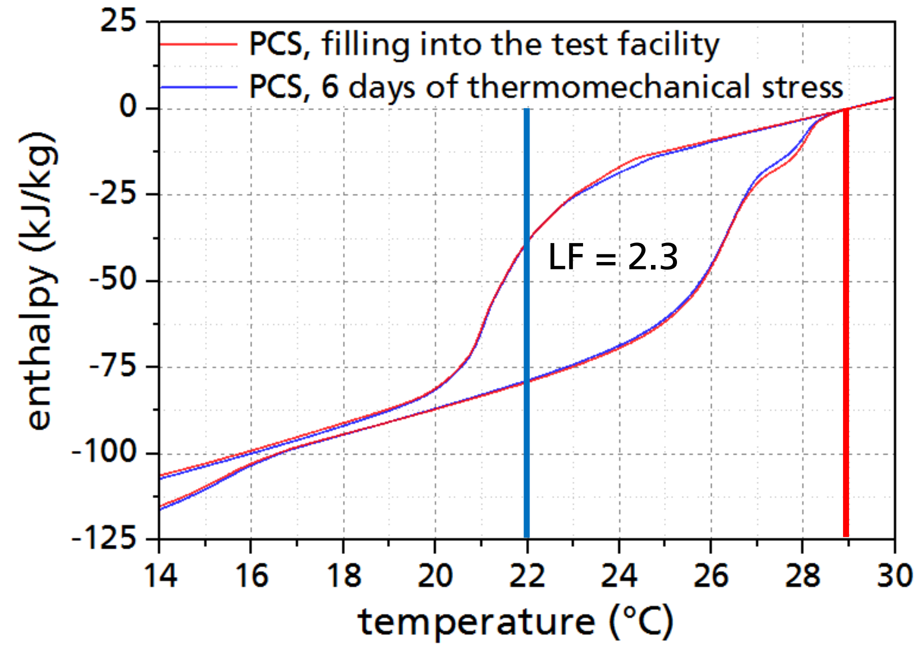

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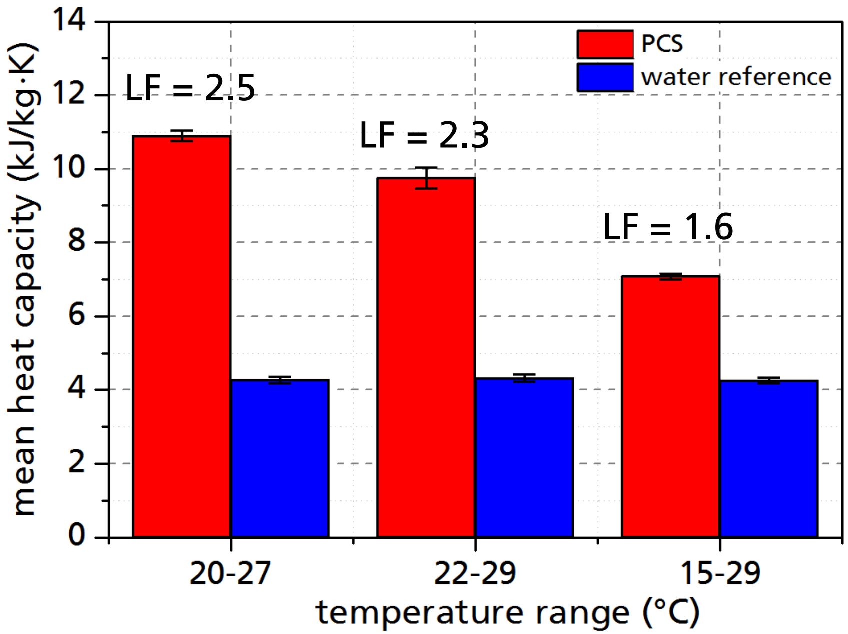

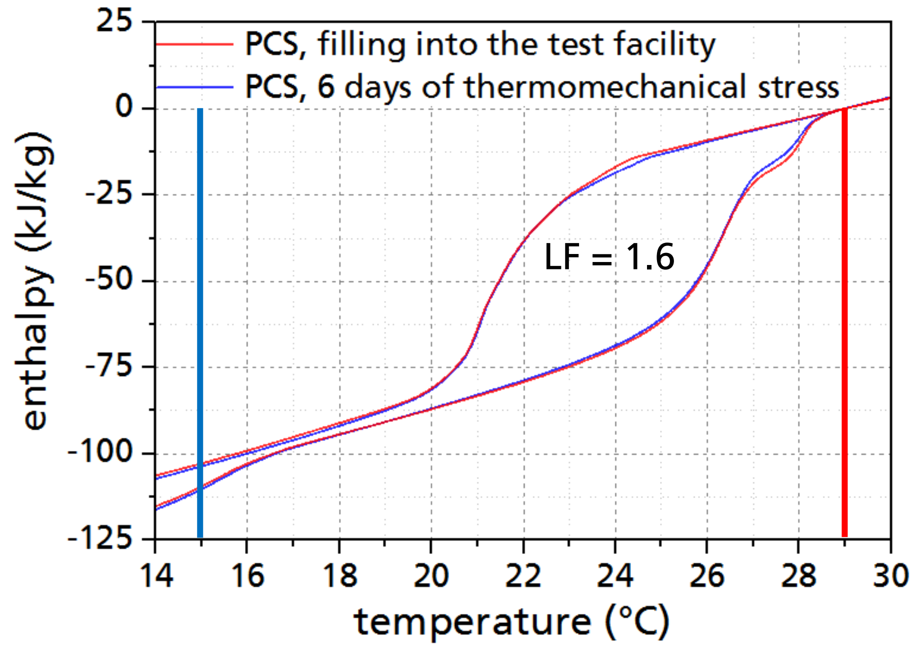

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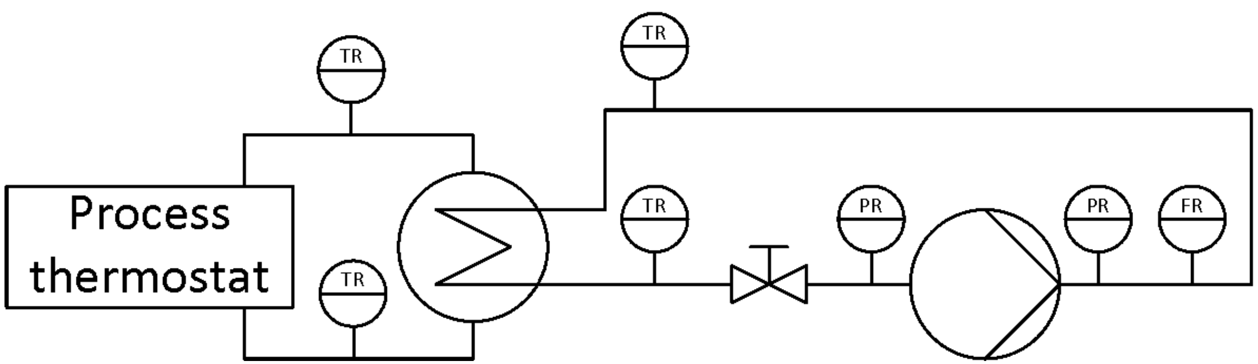
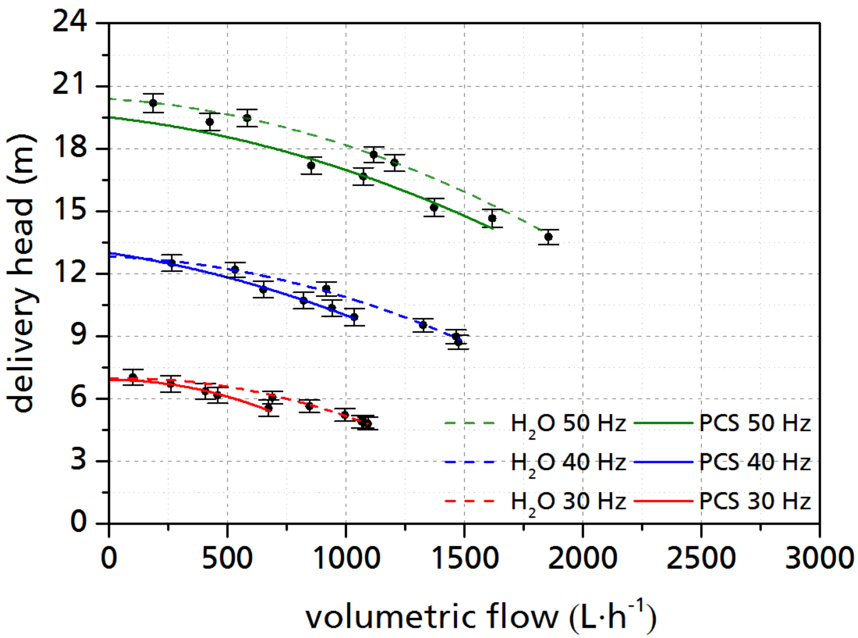
Pump characteristics – test circuit

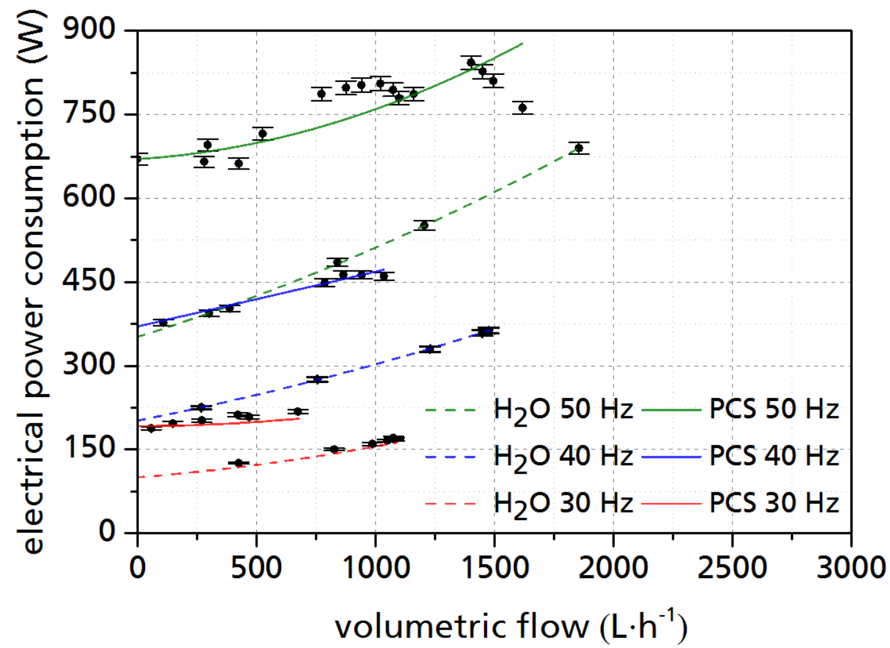
- reconfiguration of test facility to record pump characteristic curves
- pressure sensors at head and suction side of the rotary pump to calculate pump head H
- measurement of electrical power consumption during operation
- operation of the pump via frequency converter
  - measurement at fixed frequencies
  - variation of volumetric flow through throttle valve



$$H = \frac{\Delta p}{\rho \cdot g}$$

Pump characteristics – PCS/water comparison





- energy demand and head of pump at various volumetric flow rates for PCS and water operation was determined
  - measurements at constant temperature of 20 °C
- energy demand increase of 76% during PCS operation due to viscosity of PCS (η_{100} = 26 mPa·s)

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Conclusion & Outlook

- PCS is a promising alternative to sensible heat transfer/storage fluids
  - load factor of 2.5 in comparison to water (20 °C – 27 °C)
  - potential for increase in load factor: decrease hysteresis (lower sensible heat proportion)
- current scale-up PCS showed reduced stability in comparison to the PCS at a scale of 5 L
  - more research in scale-up process/influence of scale up
- influence of PCS operation on the energy demand of the pump of ~76% must be considered in future application concepts
- characterization of natural convection influence inside storage tank
  - stratification
- repetition of production and characterization of a PCS at a scale of 600 L at the end of 2018

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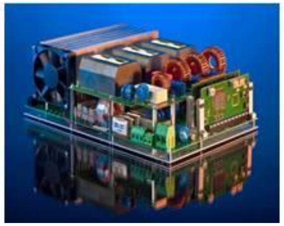
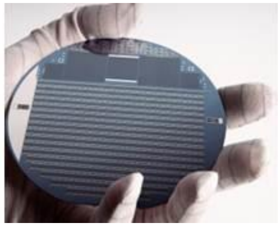
Thank you for your attention!

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