Storage Development for Direct Steam Generation Power Plants

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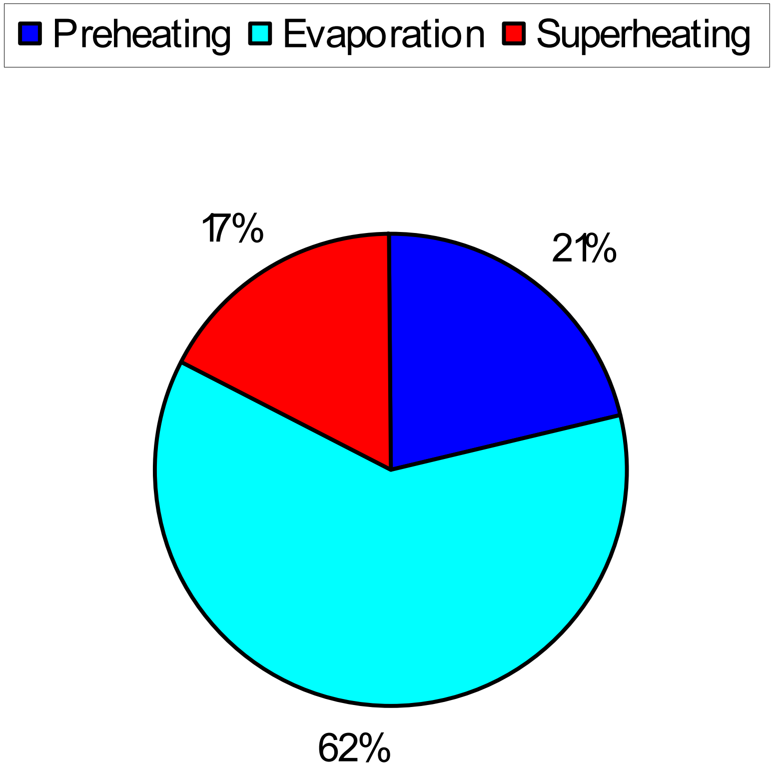
DLR Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Phase Change Thermal Energy Storage

Motivation

TES development for through plants with direct steam generation:

Major part of energy needed is for evaporation

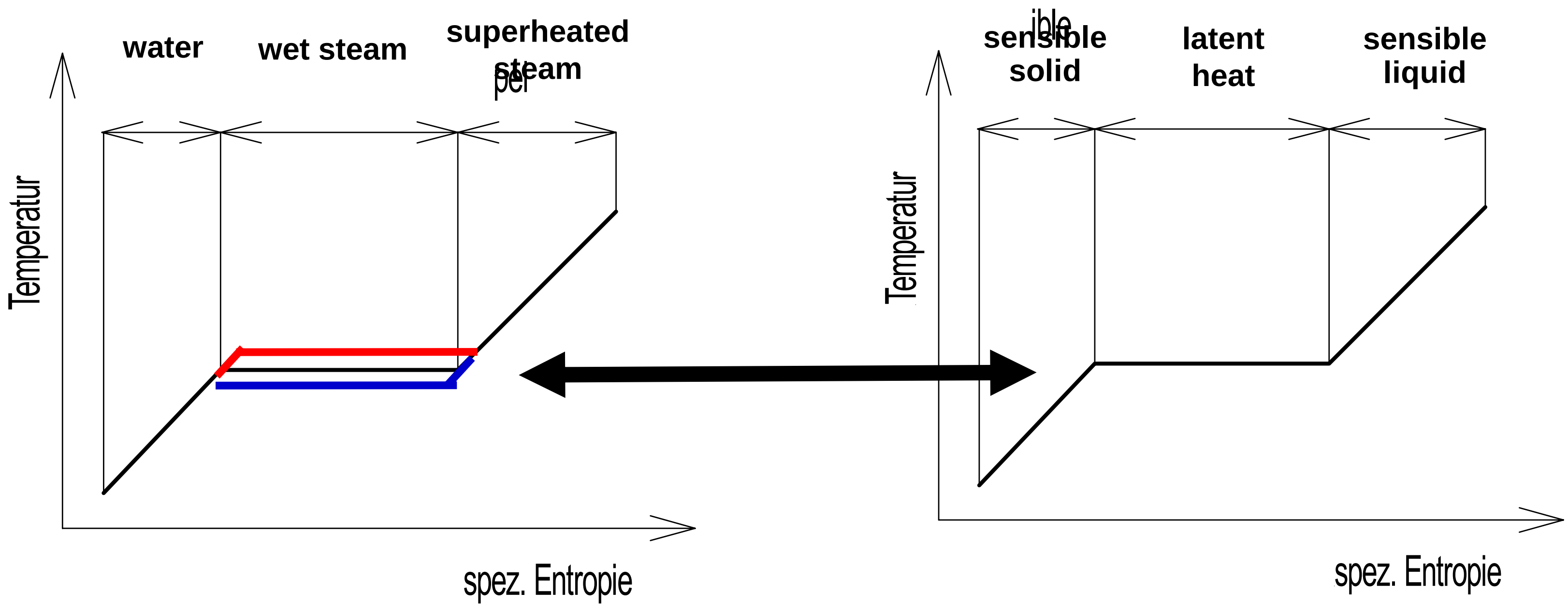


Correlation of storage medium and working fluid

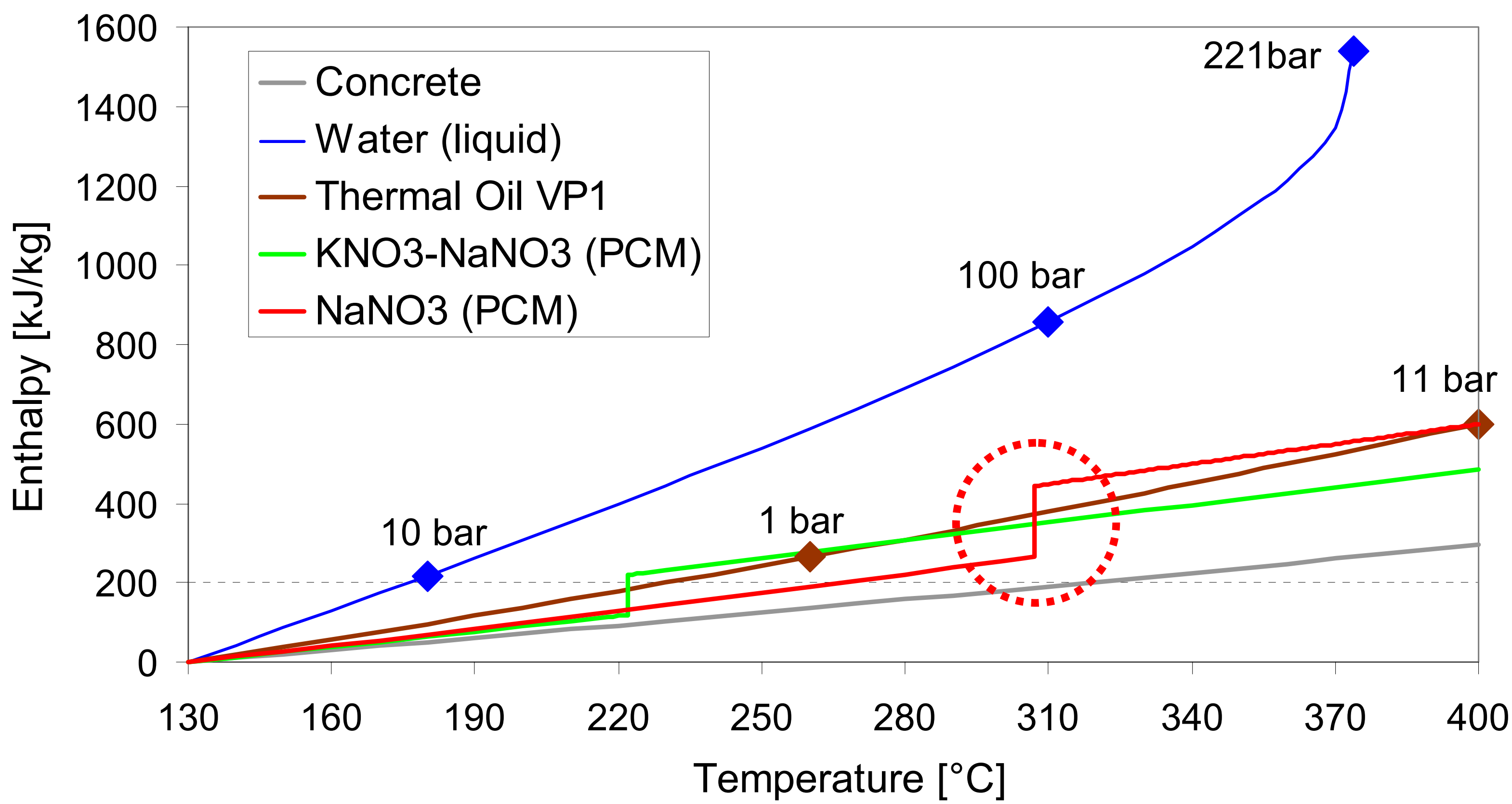
Why using Phase Change Material (PCM) ?

Working fluid water/steam
=> Evaporation phase (T=const)

Phase change storage medium
=> Melting phase (T=const)



Phase Change Thermal Energy Storage
Motivation



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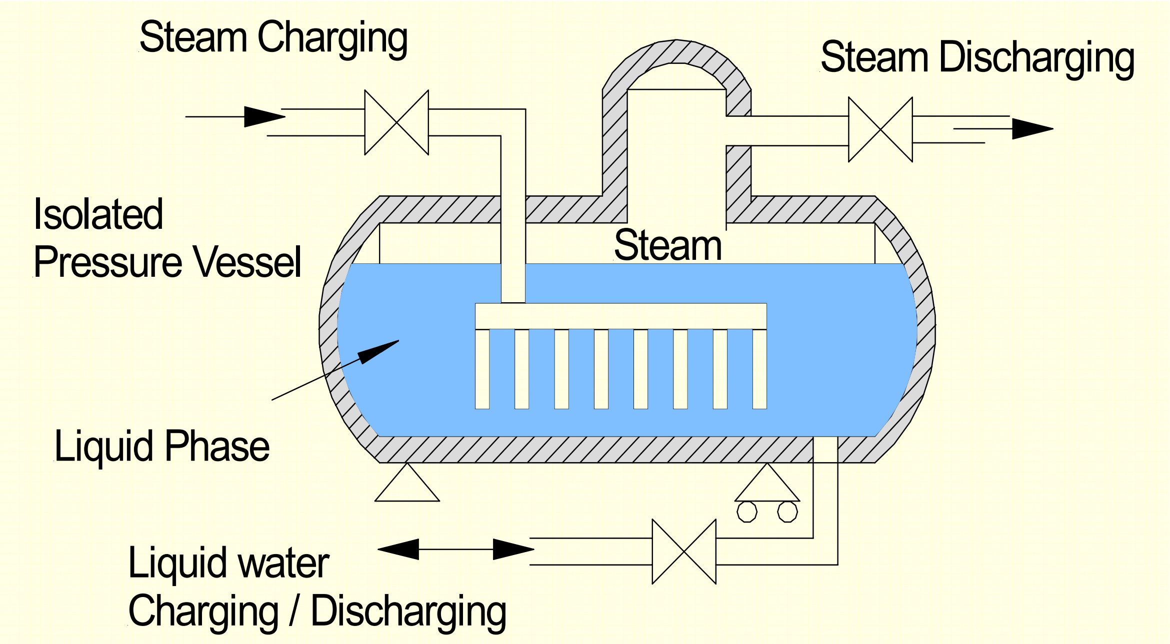
Steam Accumulators

Storage of sensible heat in pressurized liquid water



Charging process:
raising temperature in liquid water volume by condensing steam

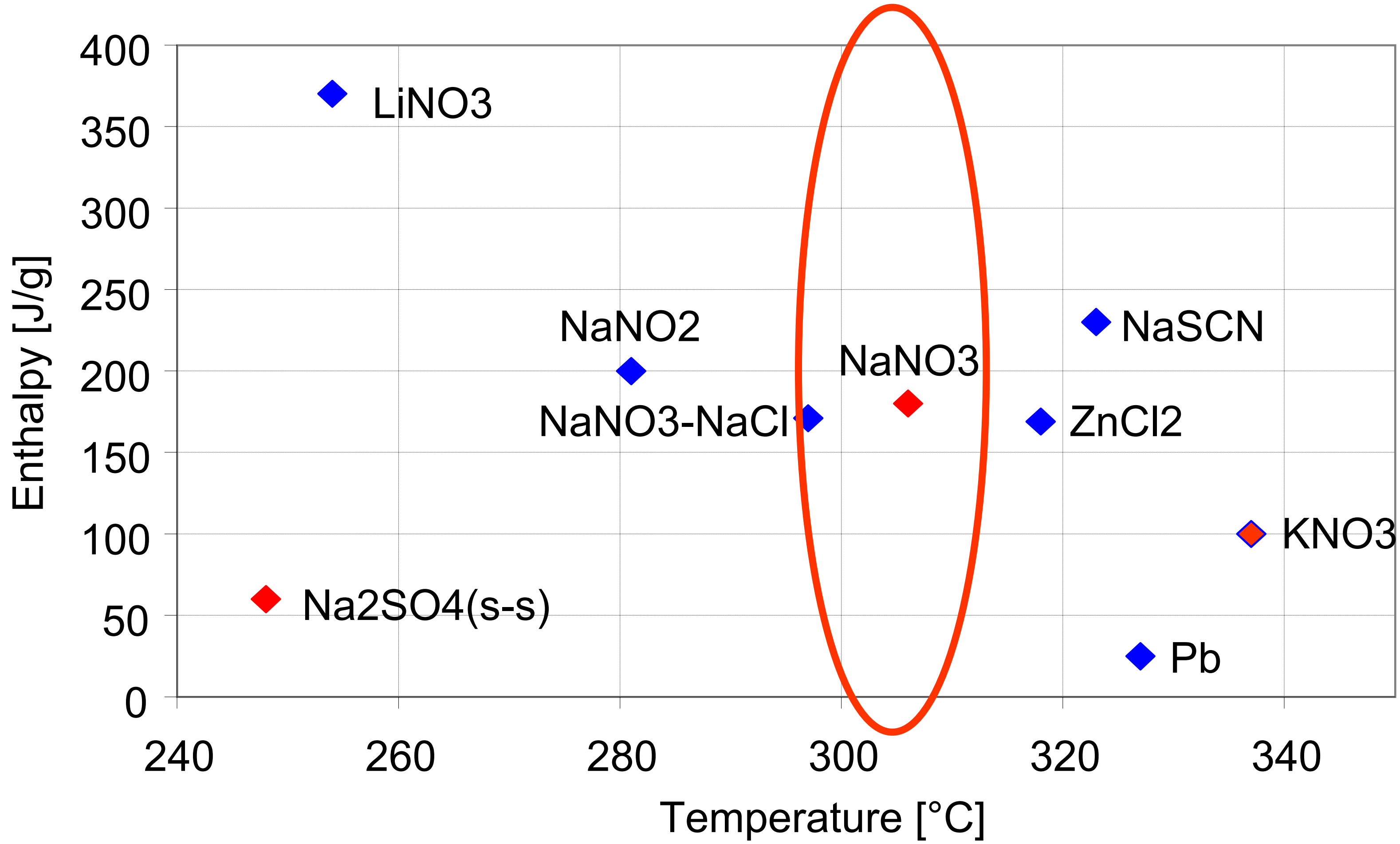
Discharging process:
generation of steam by lowering pressure in saturated liquid water volume

→ Buffer storage for peak power

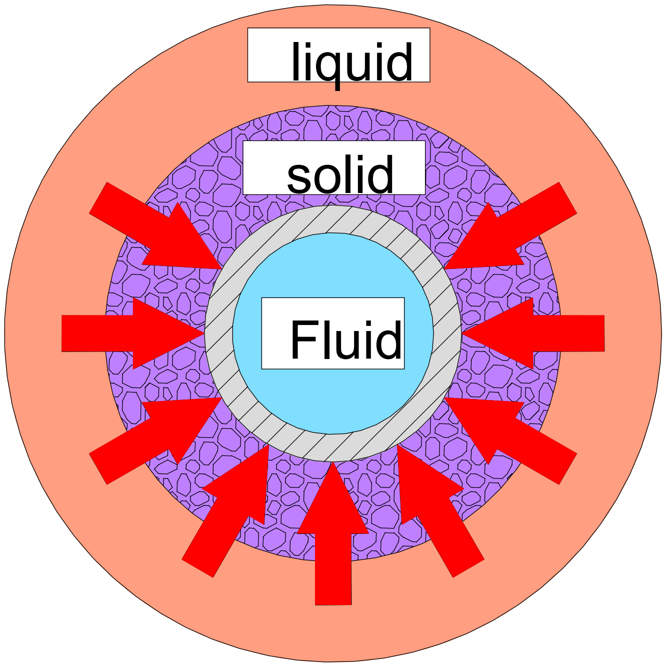
→ Inefficient and economically not attractive for high pressures and capacities

Selection of Phase Change Materials

Nitrate Salts



Challenge for PCM: Heat Transfer

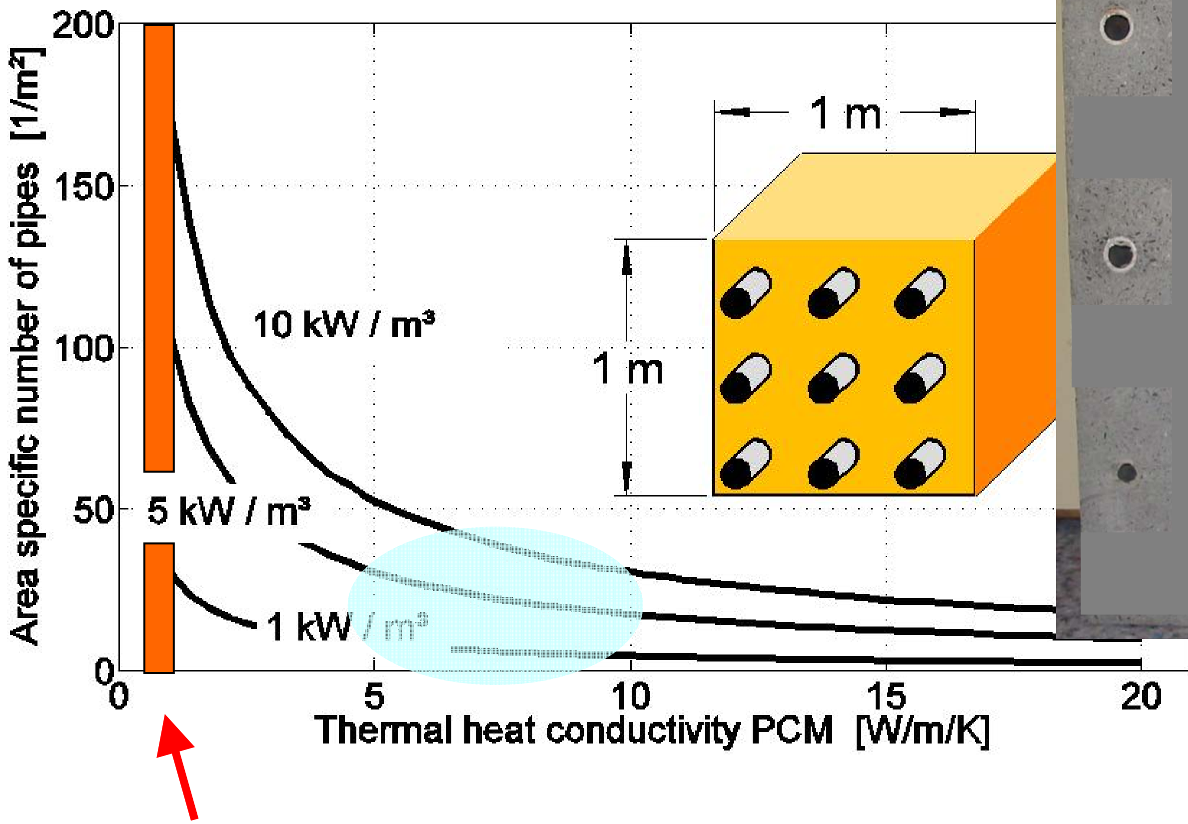


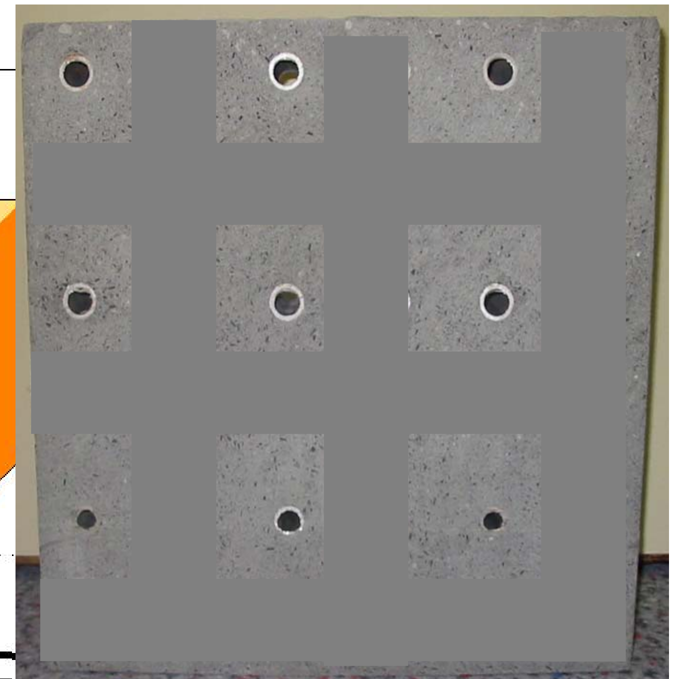
Heat transfer coefficient is dominated by the thermal conductivity of the solid PCM

→ Low thermal conductivity is bottle neck for PCM´s

Basic PCM storage design

Parallel Pipe Heat Exchanger embedded in PCM





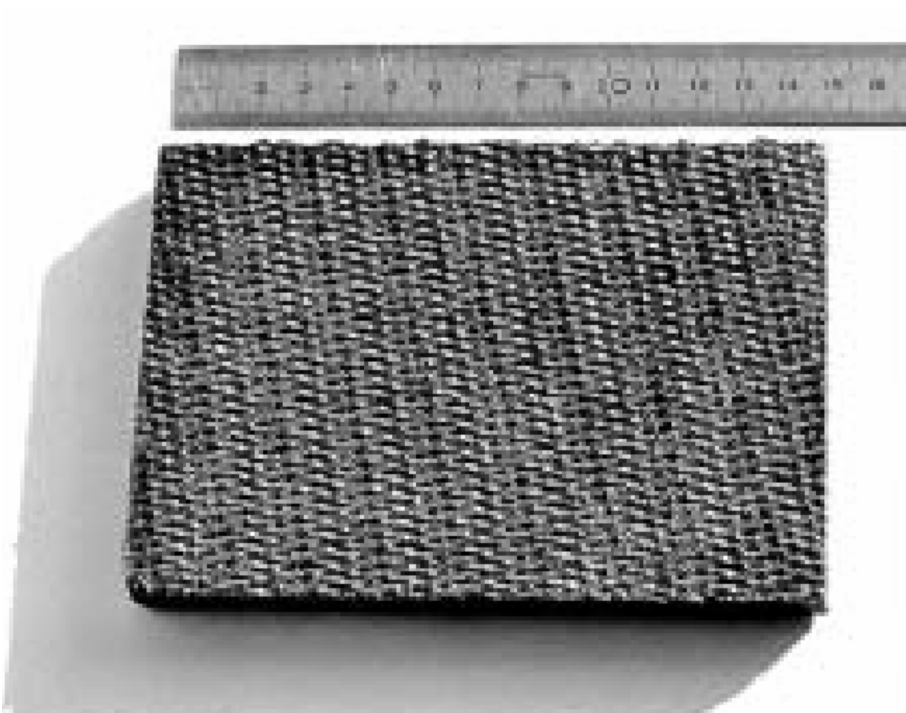
Characteristic value for Nitrates: 0,5 – 1,0 W/mK

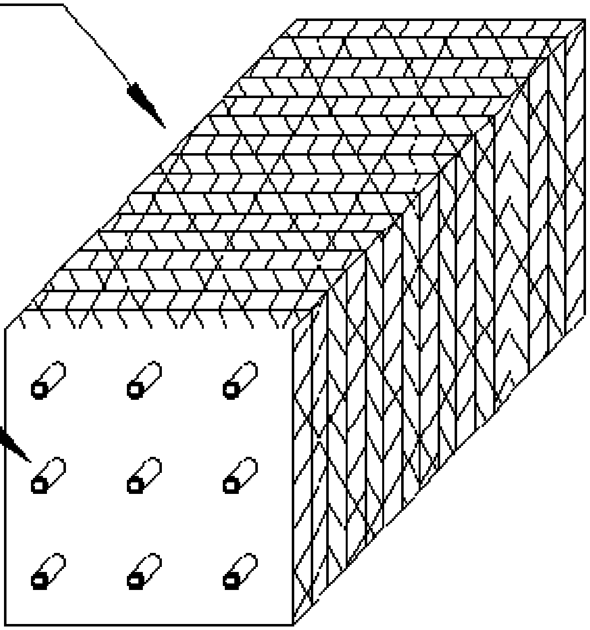
Heat transfer controlled by thermal conductivity

Enhancement of effective thermal conductivity

Composite materials with PCM

Expanded Graphite with infiltrated PCM

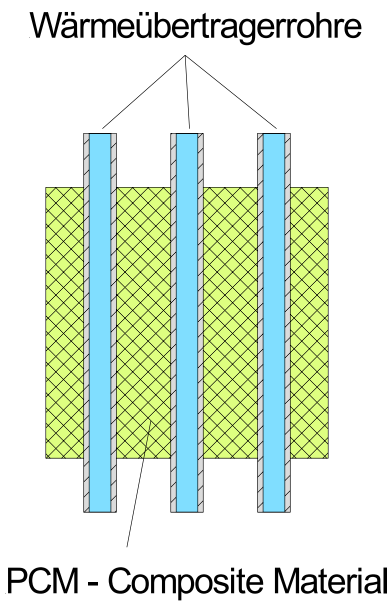




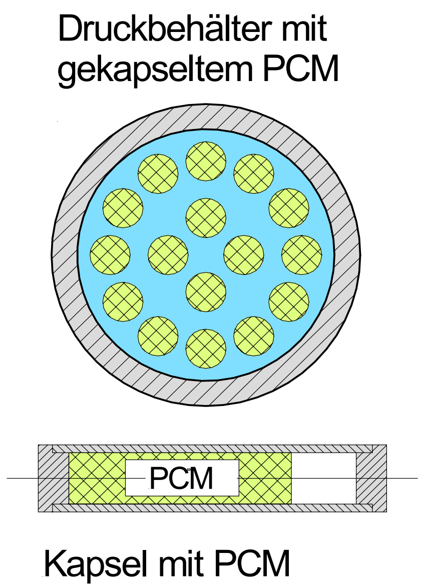
PCM thermal conductivity of 5-20 W/(mK) has been demonstrated

Design Options für PCM Storage
Principle Concepts

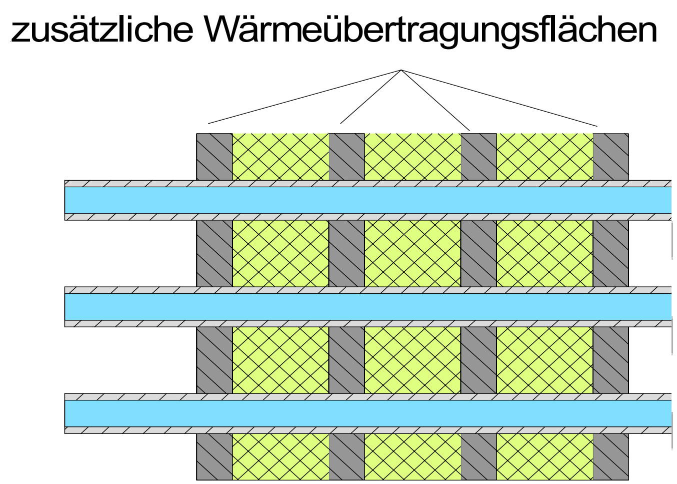
PCM/Graphite Composite



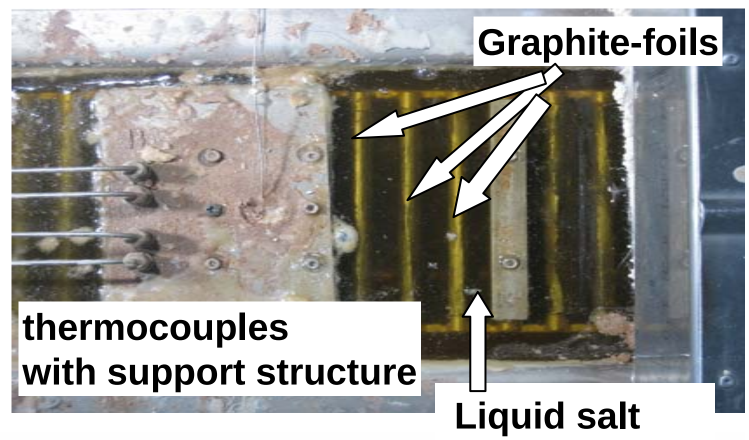
Macro Encapsulation



Extended Heat Exchanger Structure



Design Options für PCM Storage
Realized Lab-Test Components



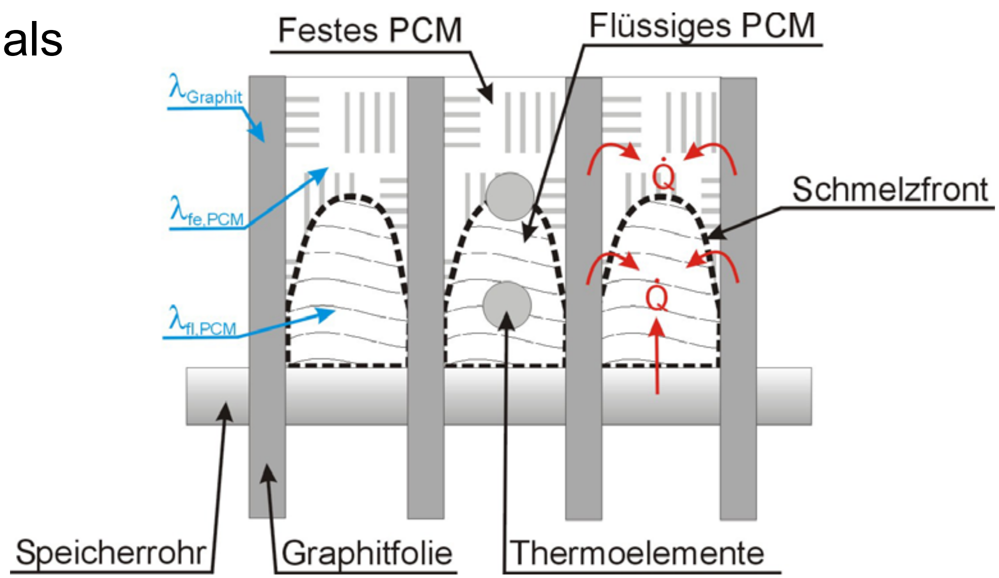
Selected concept: Sandwich-design

Advantages:

- No separation of composite materials
- Defined melting front
- Small reaction surface

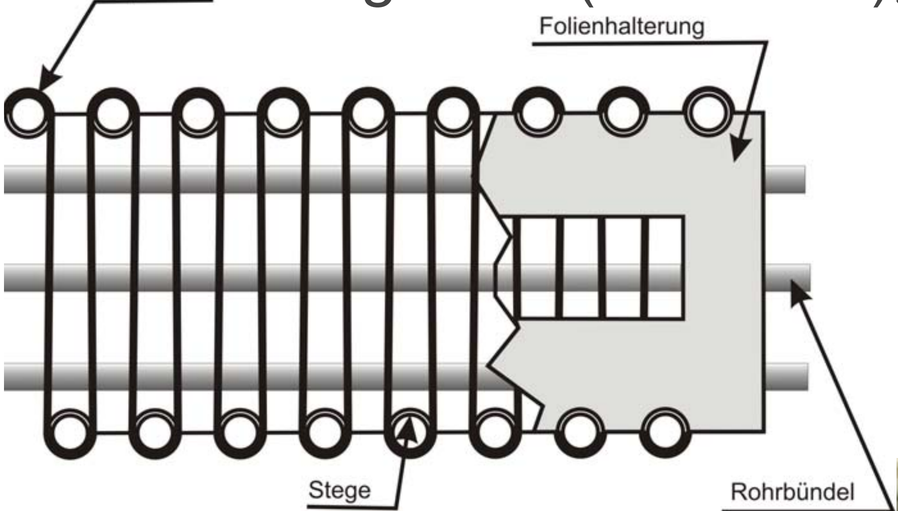
Further subjects for investigation:

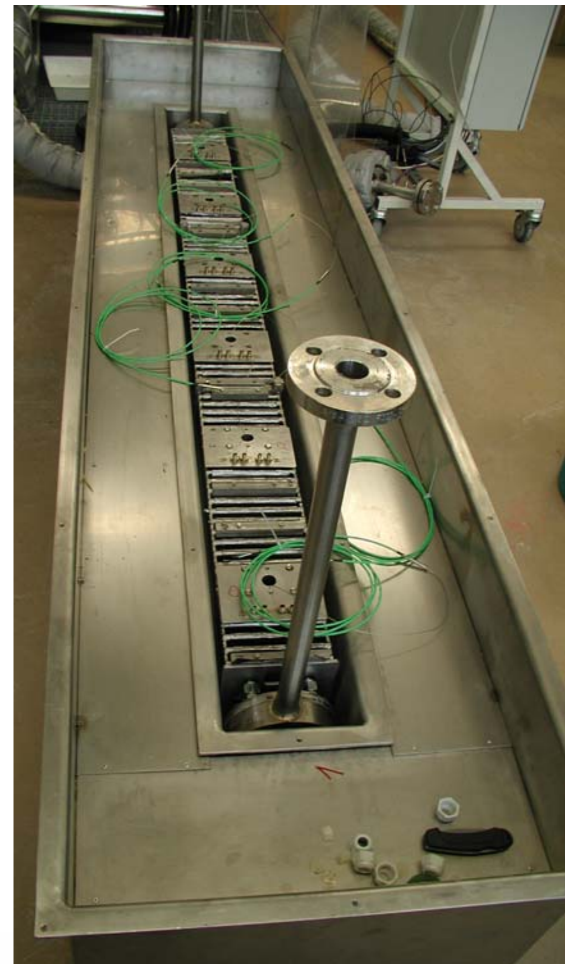
- Best fin geometry and material
- Long term stability
- Industrial fabrication process



Sandwich-design – First test module

120 kg PCM (K/NaNO3), Tm = 225°C



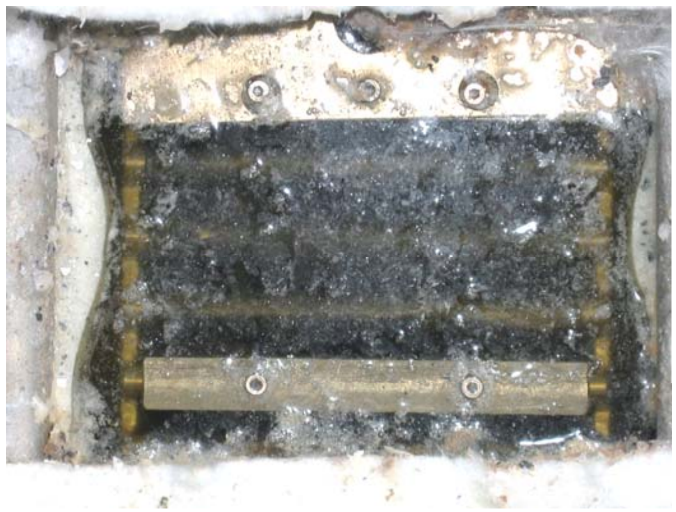


Sandwich-design – first test module

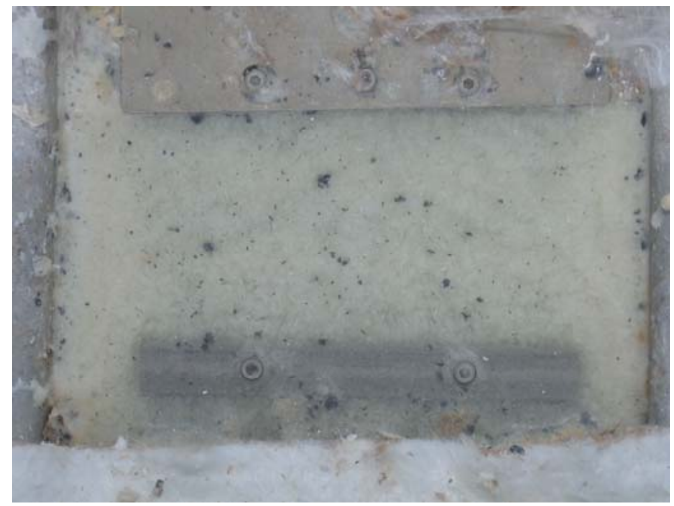
120 kg PCM (K/NaNO3), Tm = 225°C

View from the top

Molten PCM

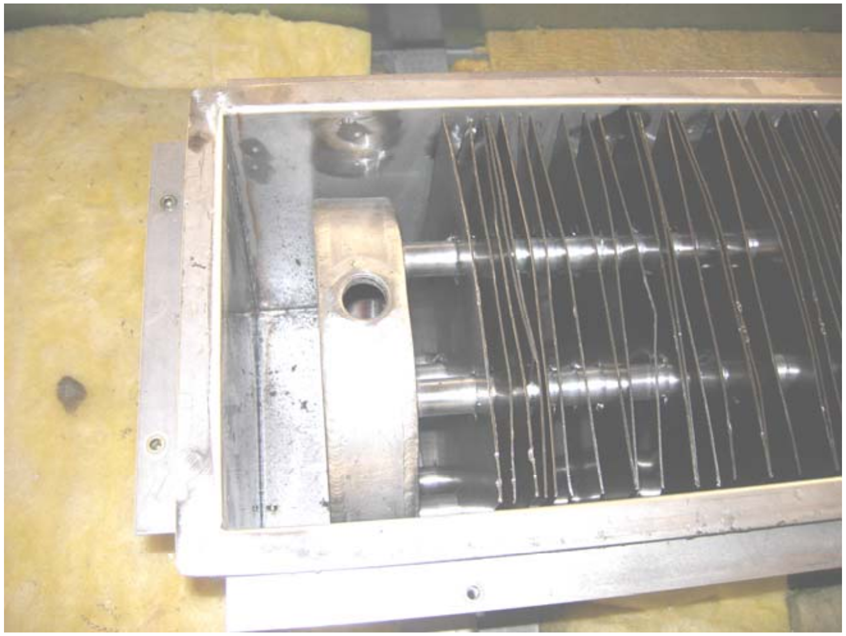


Solidified PCM



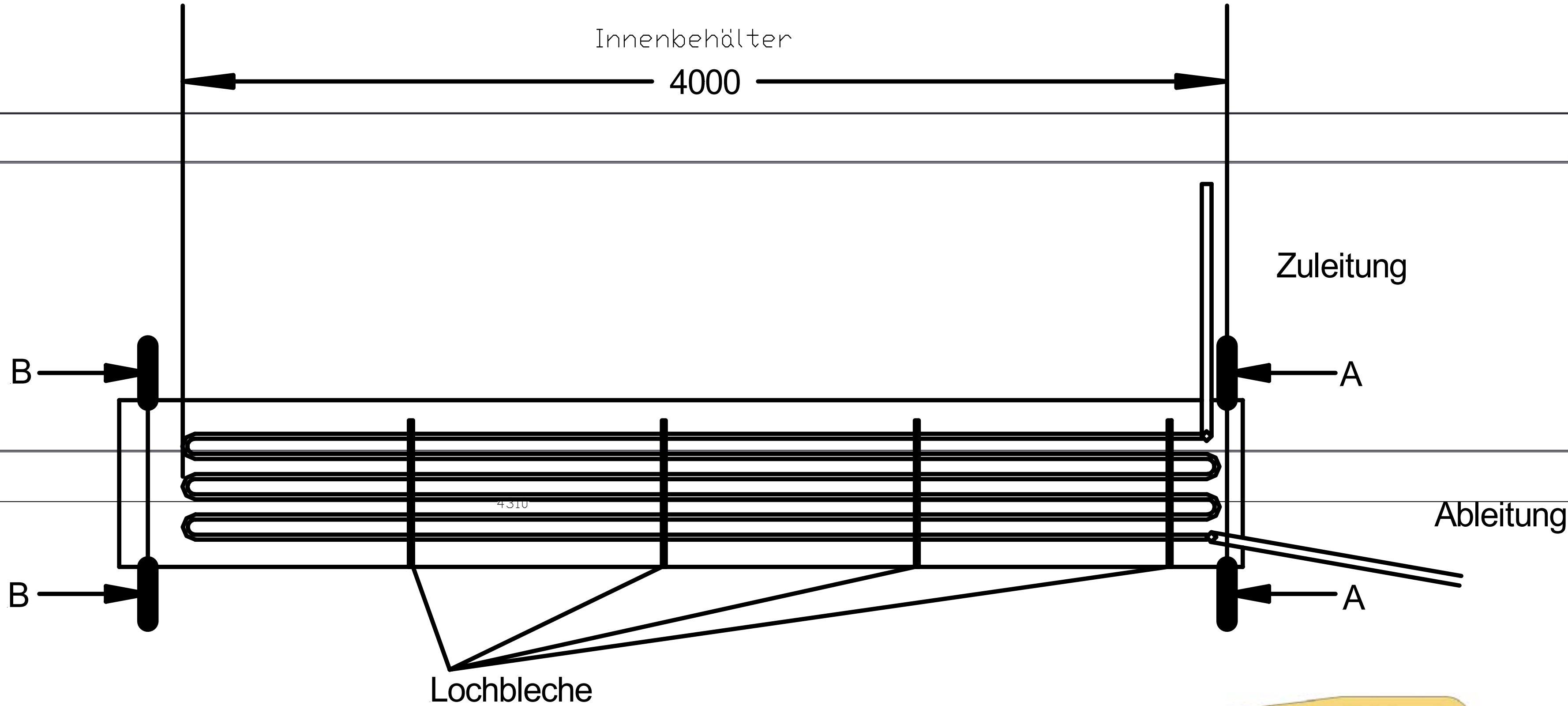
Sandwich-design – second test module

400 kg PCM (K/$NaNO_3$, $NaNO_2$), Tm = 145°C
for process heat applications



Sandwich-design – third test module

2000 kg PCM (K/NaNO3), Tm = 225°C
for direct steam generation on PSA

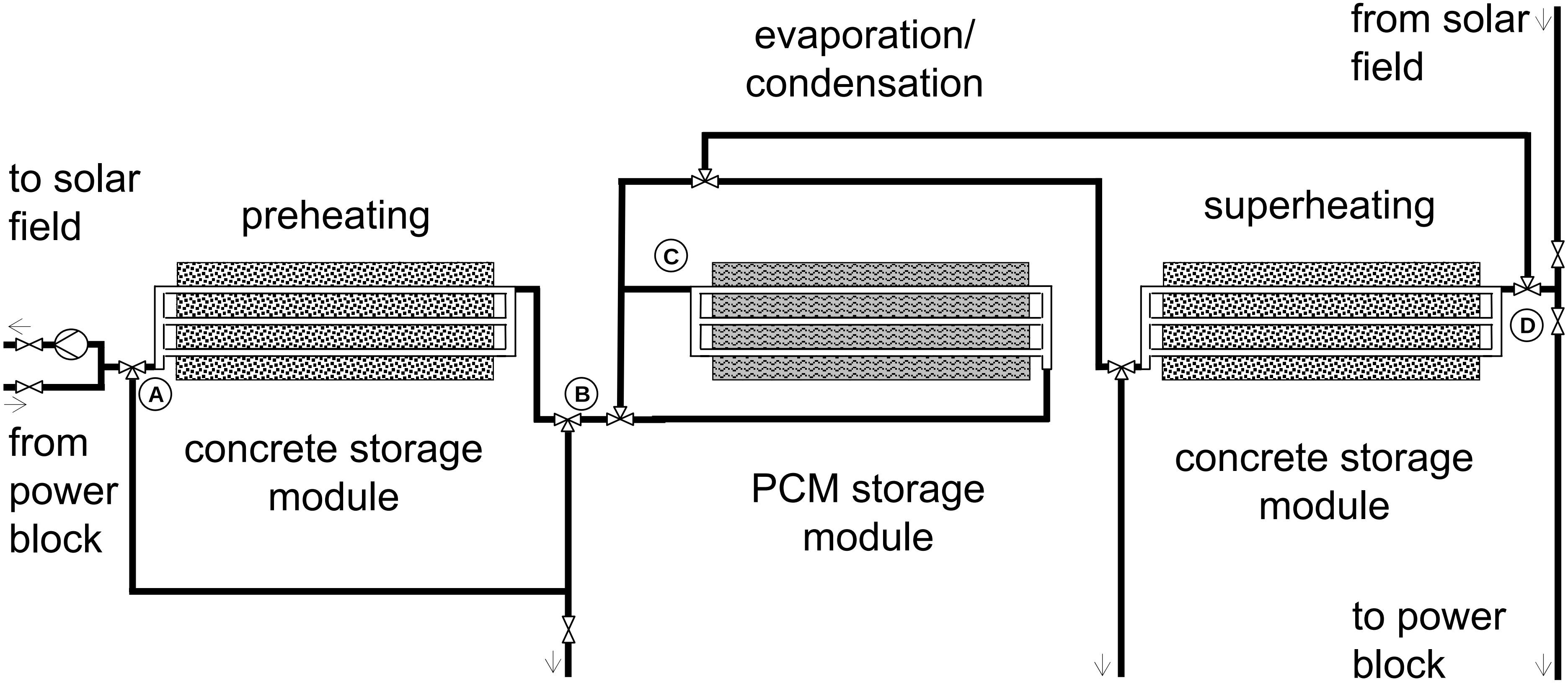


Storage system for Direct Steam Generation

- Project ITES – funded by German Ministry BMU
- Demonstration of complete storage system for direct steam generation power plants
- Preheating and superheating module – sensible storage material
- Evaporation module - PCM
- 1 MW test loop connected to conventional power plant of Endesa in Carboneras, Spain
- Testing period 2008/2009

Sandwich-design – Forth test module ITES

Approx. 20 000 kg PCM ($NaNO_3$), Tm = 306°C



A feed water inlet / outlet

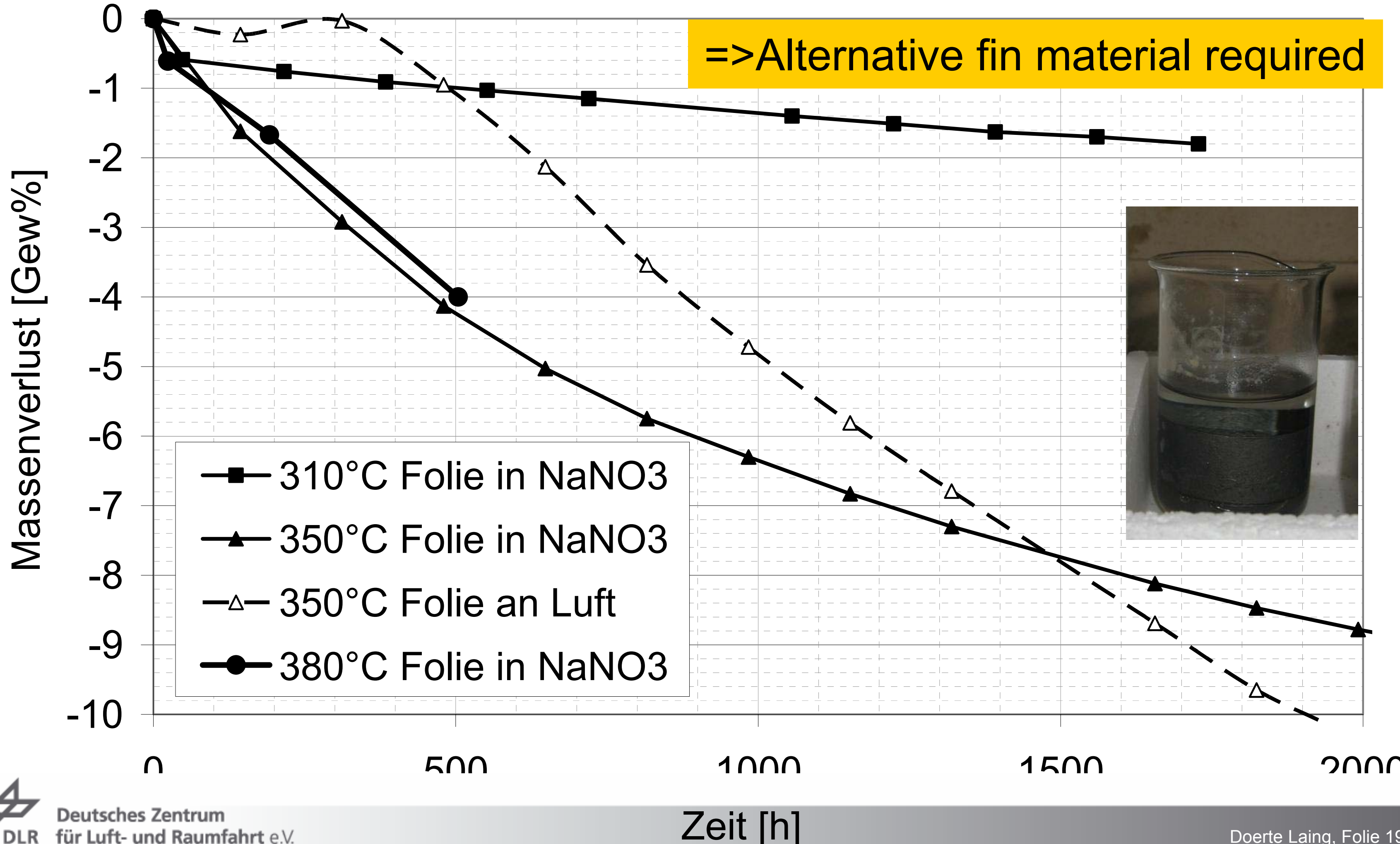
B liquid water

C saturated steam

D live steam inlet / outlet

Sandwich-design

Loss of mass of graphite foil in liquid NaNO3



Conclusions

- High potential for PCM storage in connection with water/steam systems
- Successfully implementation of PCM has to address 3 areas:
  - storage material
  - heat transfer
  - thermal engineering
- Current activities in PCM-technology focus on the development of composite materials and innovative storage designs to overcome the characteristic limitations of heat transfer in PCM
- Sandwich-design for PCM-storage is a promising design for process heat and large scale power generation
- Graphite not applicable at temperatures above 300°C
- Test of DISTOR test module will start this summer on PSA, Spain
- Construction and test of ITES test module in 2008/2009

Thank You
for your attention