Experimental and theoretical assessment of an active PCM storage concept

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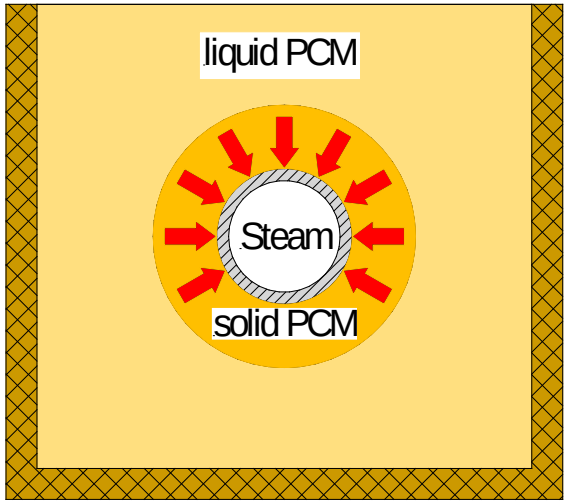
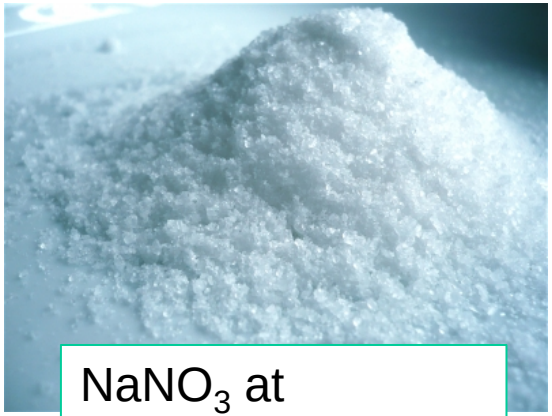
Development of Latent Heat Storage Storage concepts

Nitrate salts as phase change material (PCM)



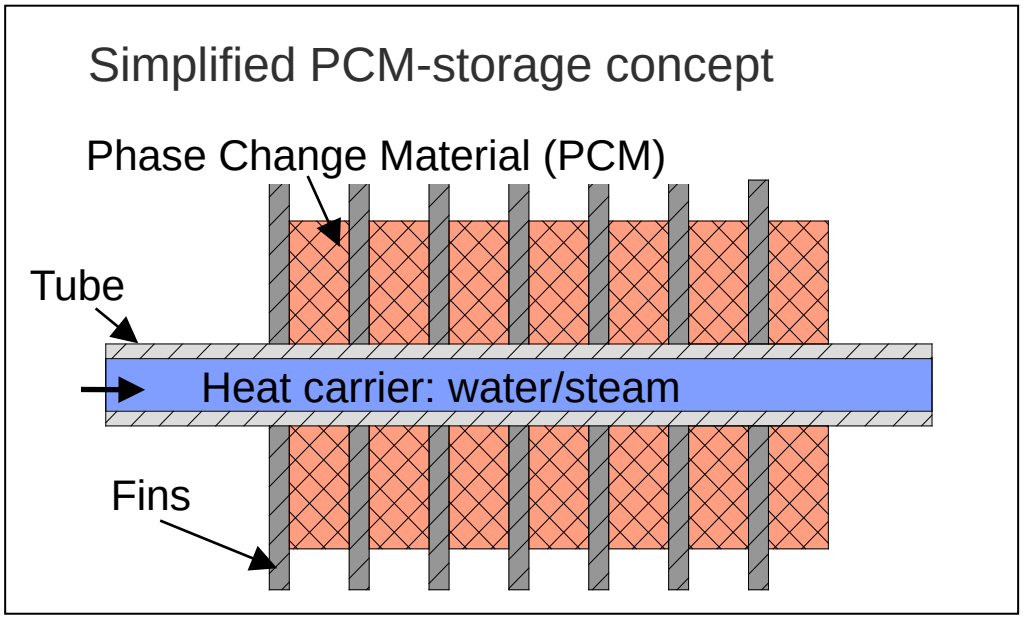
Heat transfer coefficient is dominated by the thermal conductivity of the solid PCM (<1.0 W/mK)

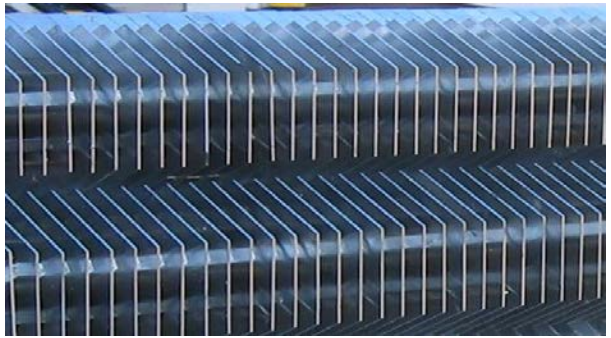
→ Low thermal conductivity is bottleneck for PCM



$NaNO_3$ at room temperature

Heat transfer concept for Latent heat energy storage
State of the art:
Embedded Finned tube heat exchanger





Radial finned tubes

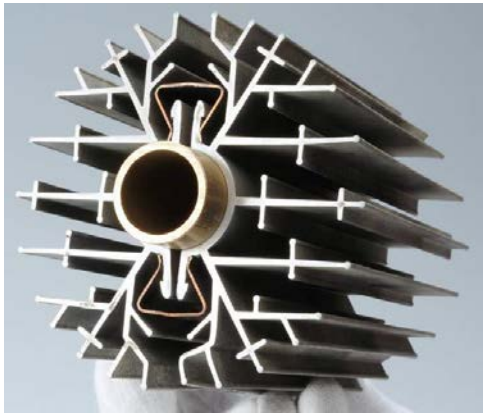
Heat transfer concept for Latent heat energy storage

State of the art: Finned tube heat exchanger embedded into PCM volume

Pilot-scale latent heat storage unit:
$NaNO_3$ as the PCM,
Embedded parallel tube heat exchanger
with radial aluminum Fins

T_{melt} 305°C
Latent heat 175 kJ/kg

1.4m x 1m x 6m
PCM Mass: 14 tons
Capacity: ca. 700 kWh



axial finned tubes

- Increase of capacity requires increased heat exchanger
- Power not constant for constant steam pressure
- Heat exchanger not accessible

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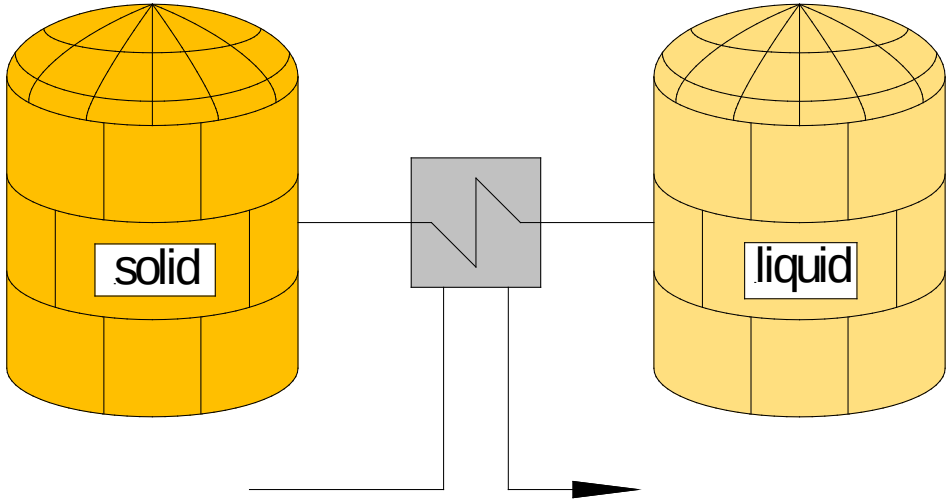
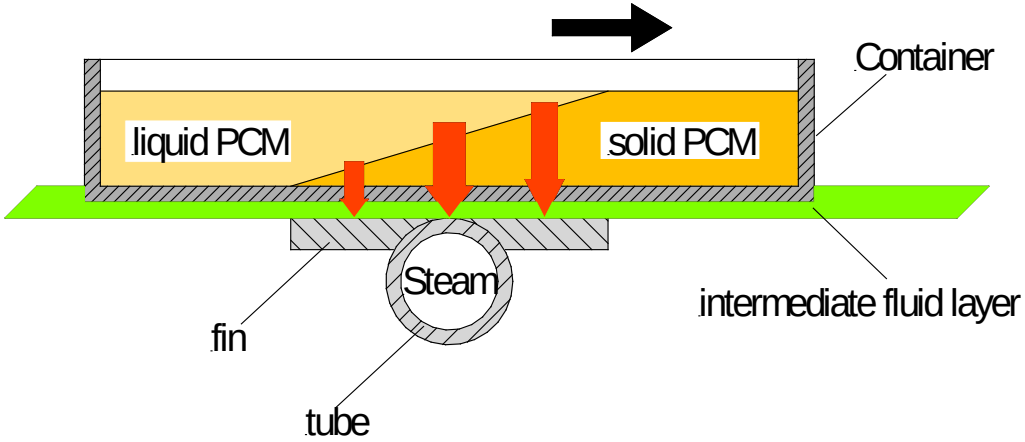
Active PCM concept



- Transport of storage material (solid + liquid phase)
- Mechanical separation of heat transfer surface and storage material
- Constant power possible
- Capacity and power independent

PCMflux Concept

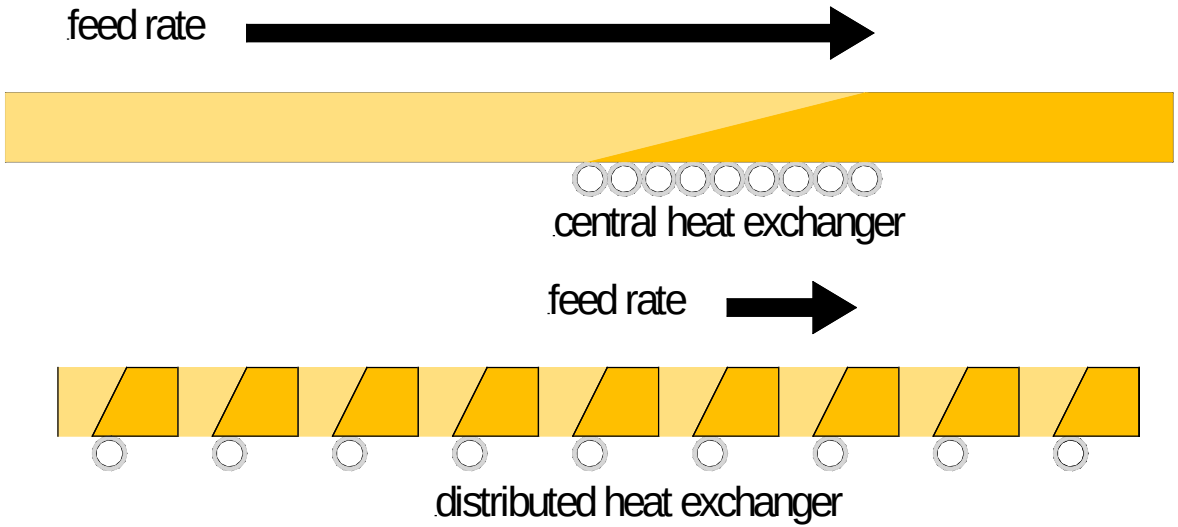
Basic principle



- Separation of PCM from heat transfer surface by an intermediate fluid layer
- Conductive heat transport through intermediate fluid layer
- Transport of PCM in thin walled containers

PCMflux Concept

Basic principle

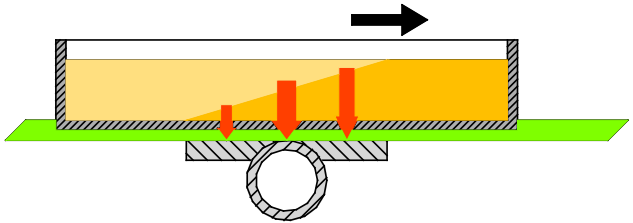


Typical feedrate: 50-100 mm/h

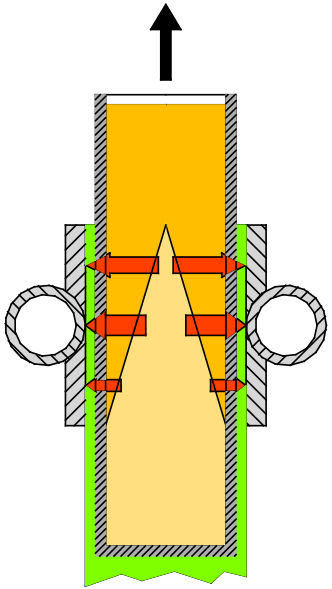
PCMflux Concept

Basic geometry options

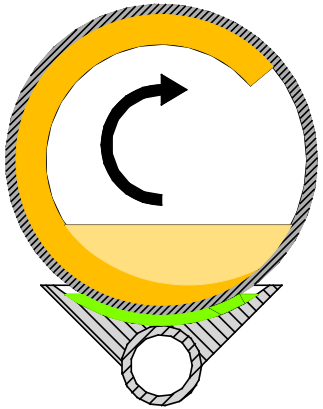
horizontal



vertical

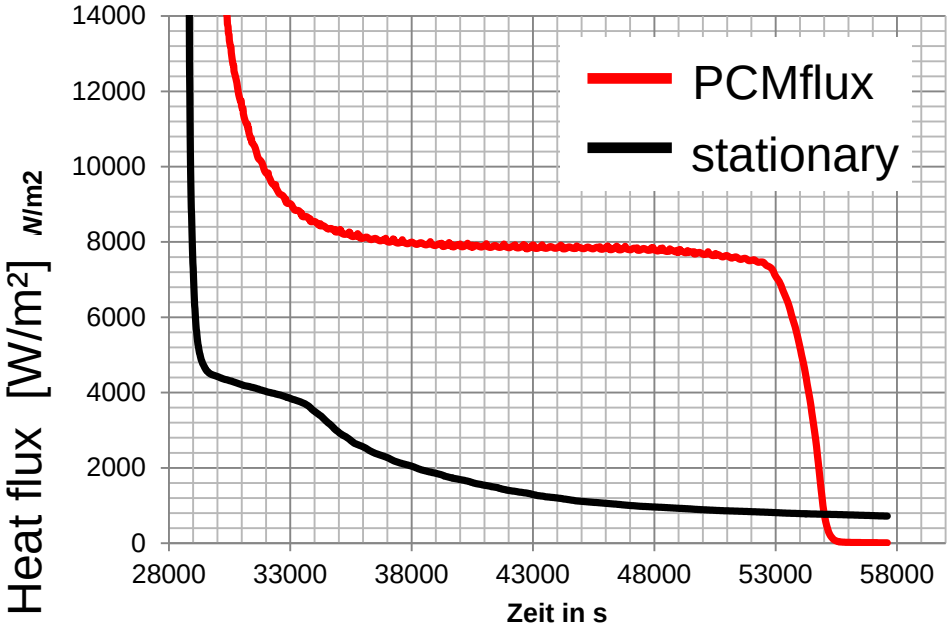


tubular



Theoretical analysis

Comparison of PCMflux to state of the art

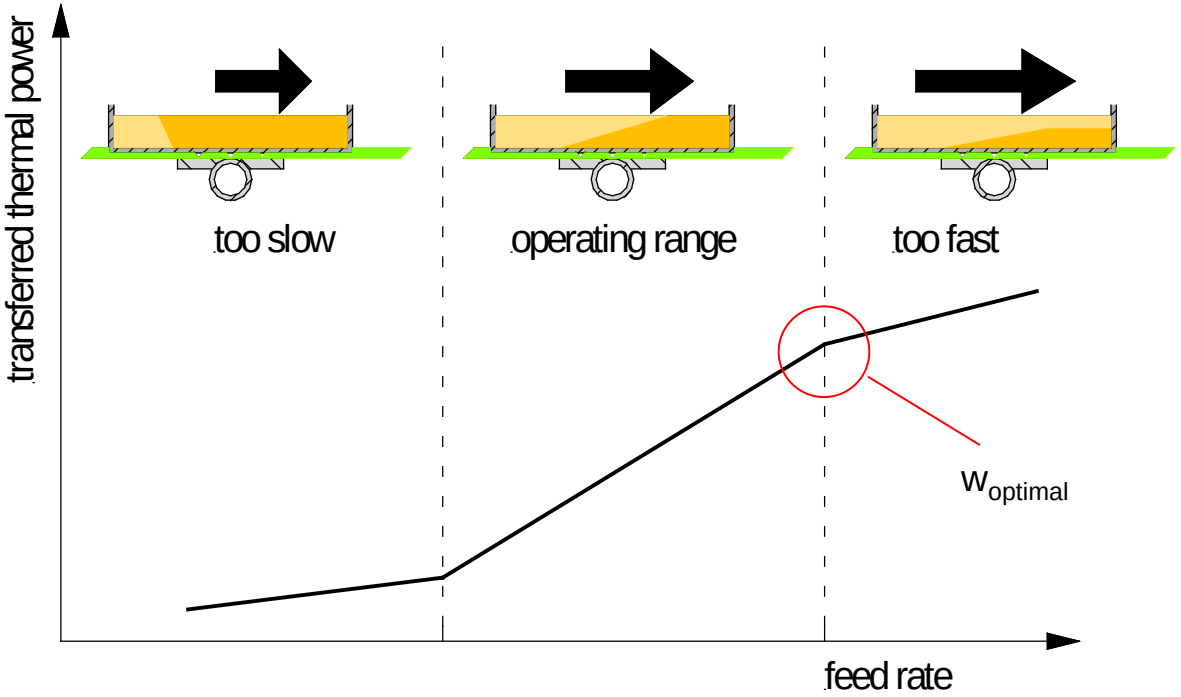


Time [s]

- PCMflux provides constant power
- PCMflux requires less tubes for the same average power

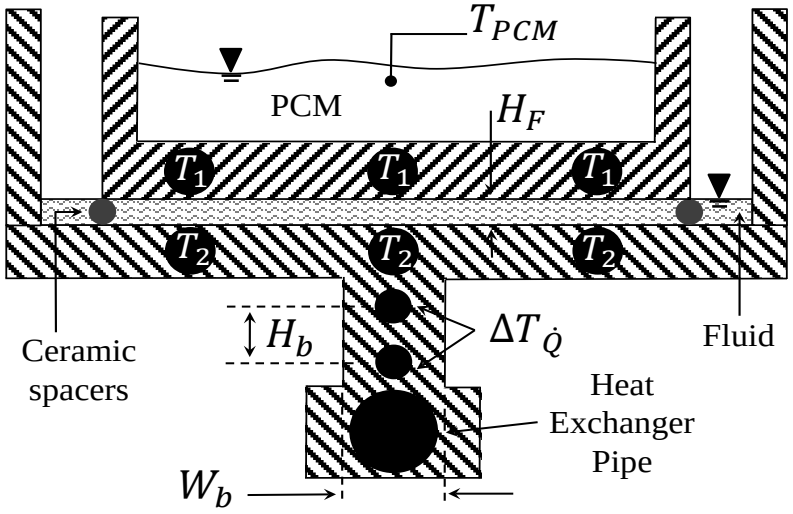
Theoretical analysis

Dependence of power on feed rate



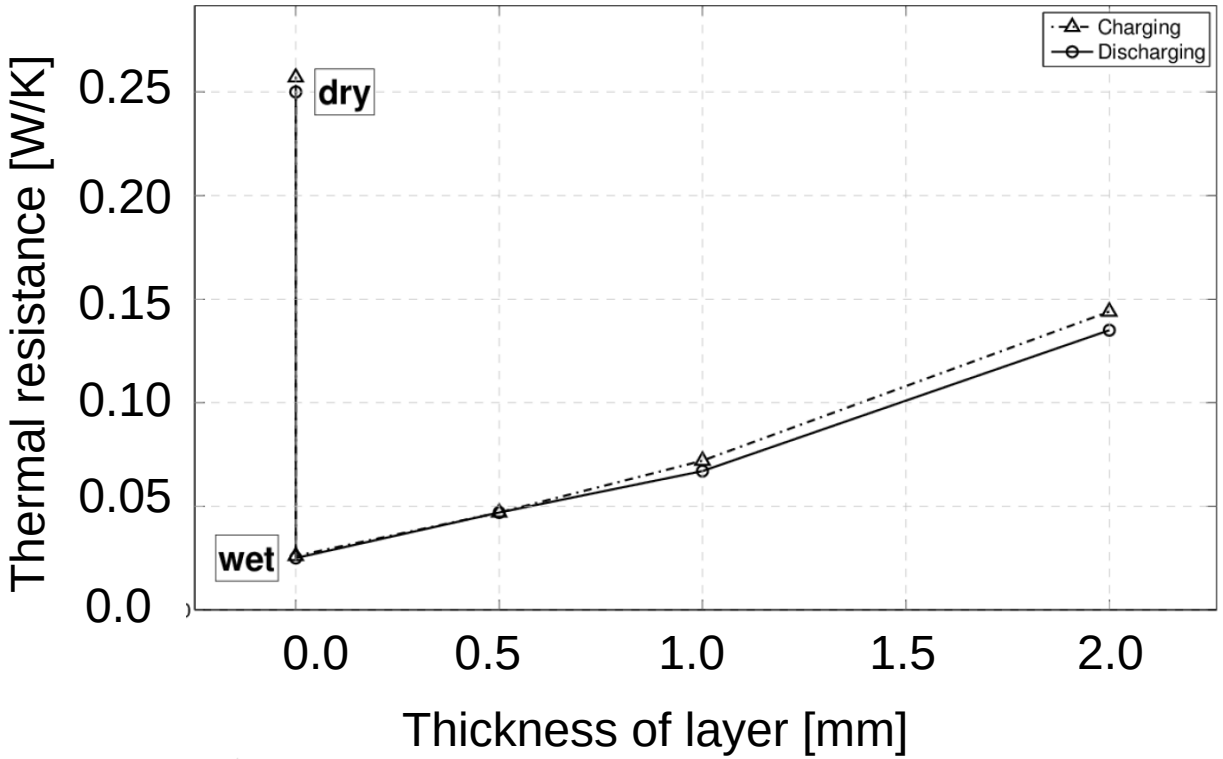
Thermal resistance of intermediate fluid layer

Lab scale experiment



Thermal resistance of intermediate fluid layer

Experimental results: Hitec as intermediate fluid



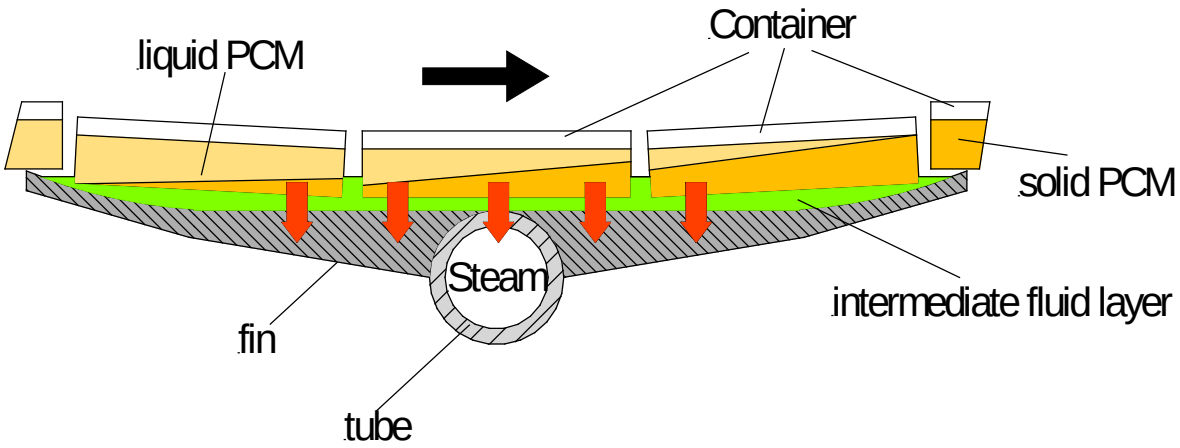
Thermal resistance

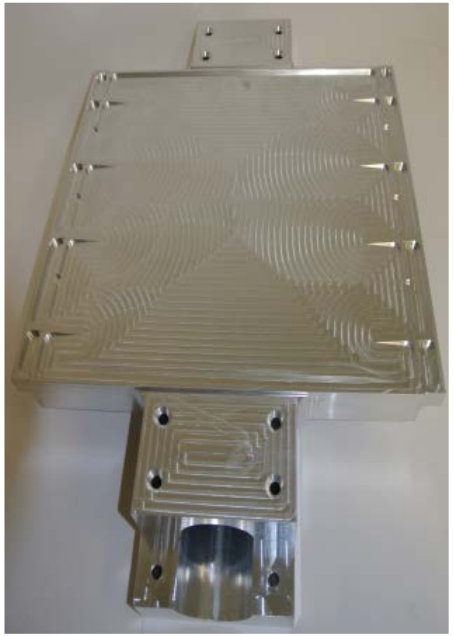
$$R_{th} = \frac{\Delta T_F}{\dot{Q}}$$

Direct contact:
resistance without fluid
= 10 × resistance with fluid

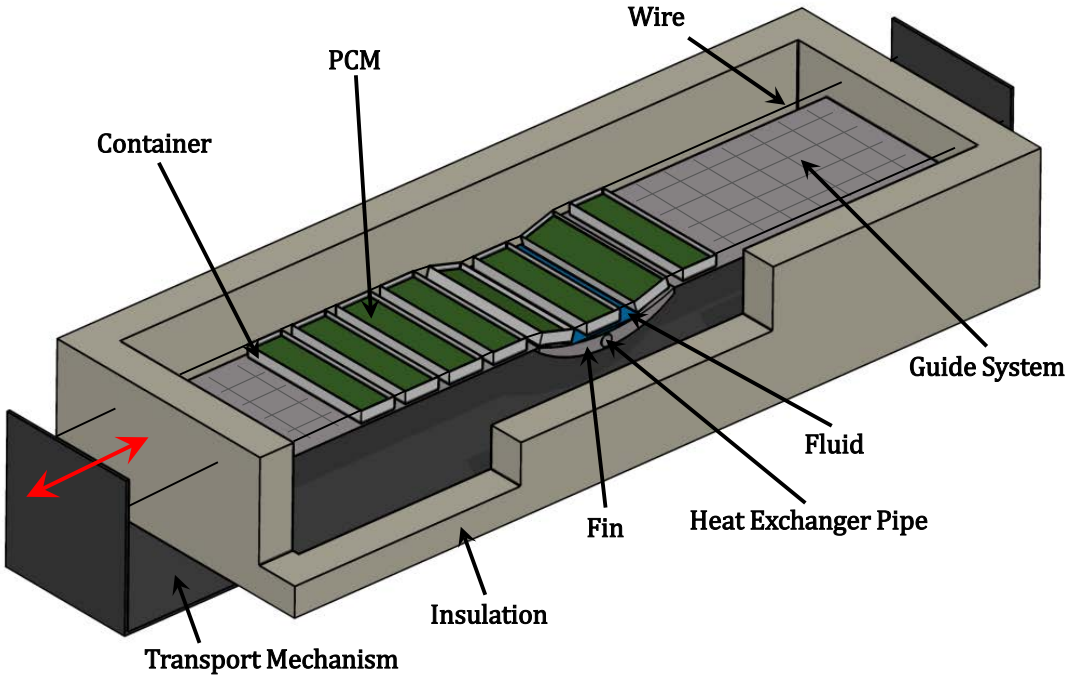
Lab-scale experiment with moving PCM

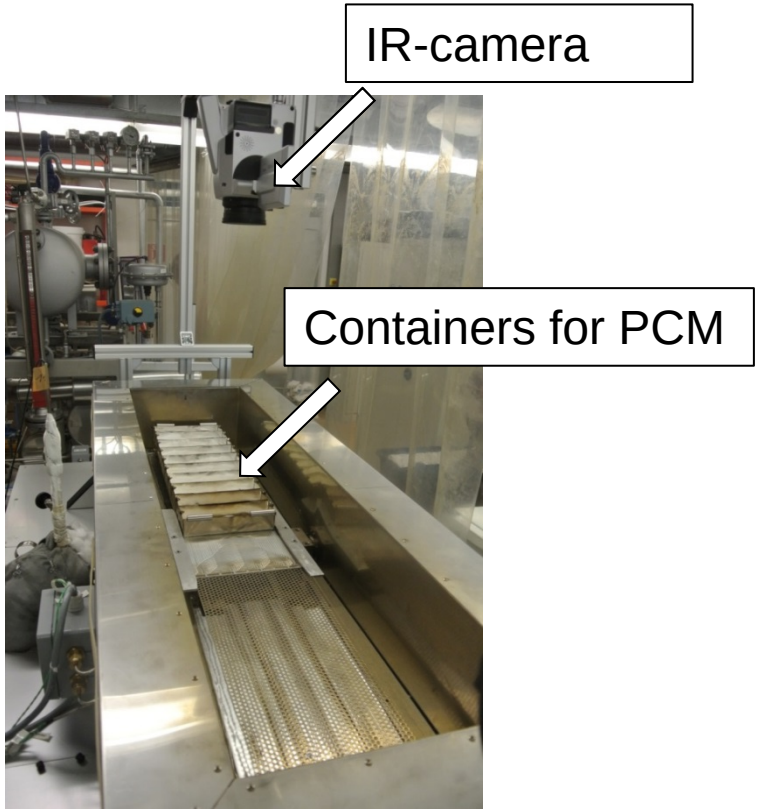
Trough shaped horizontal fin with integrated tube





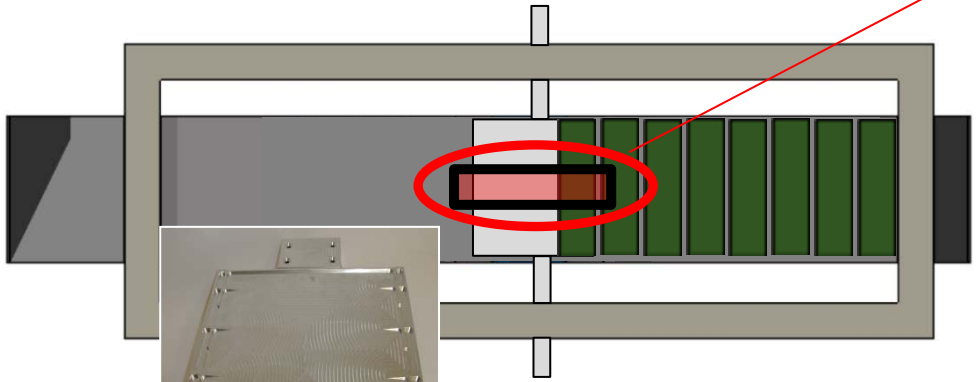
Lab-scale experiment with moving PCM





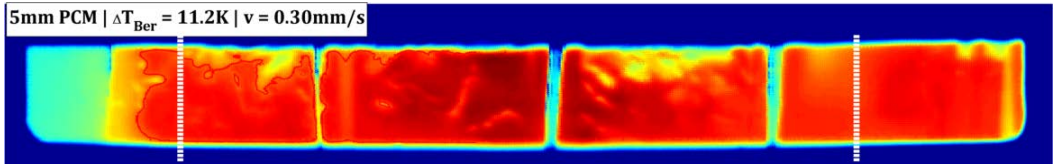
Lab-scale experiment with moving PCM

Principle of measurement



Sight glass for IR-camera

tube with fin



Processed image

solid

liquid

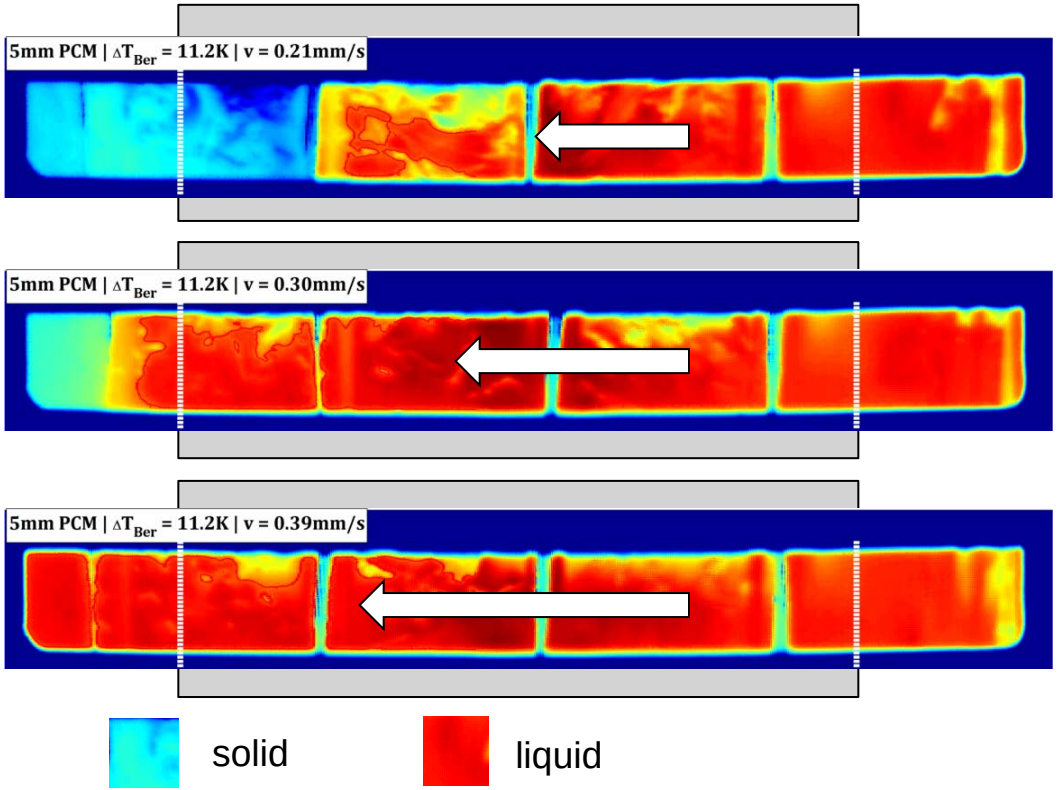
Lab-scale experiment with moving PCM

Position stationary phase front dependent on feed rate (discharging)

Feed rate = 0.7 $w_{optimal}$

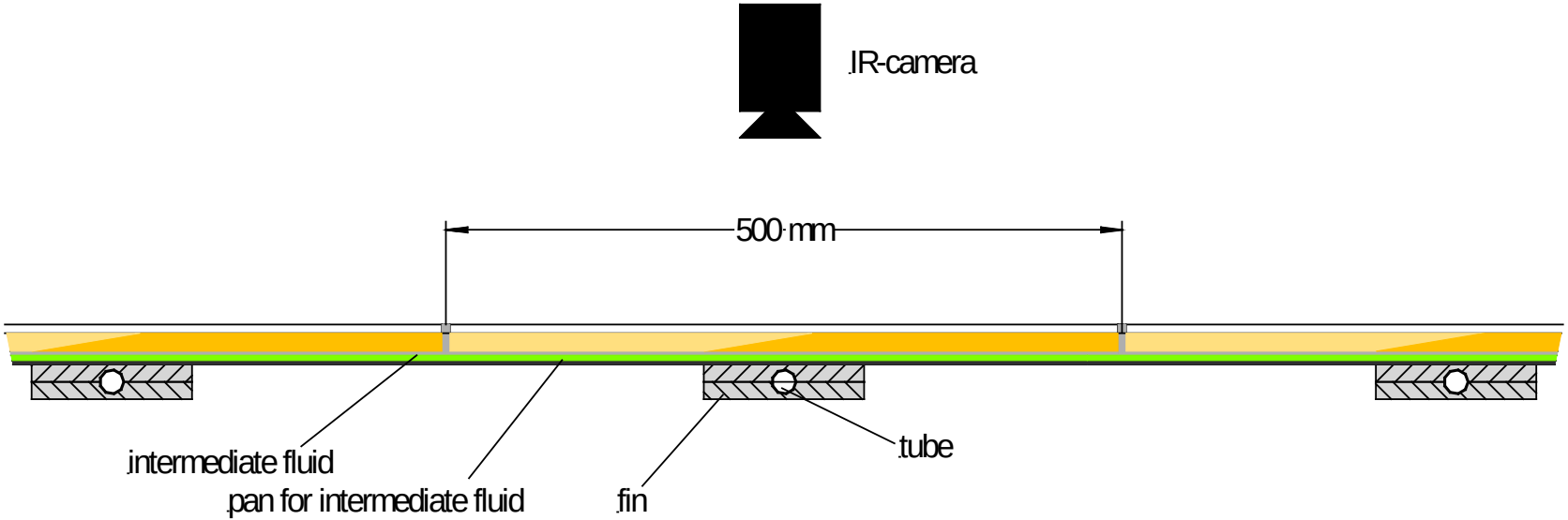
Feed rate = $w_{optimal}$

Feed rate = 1.3 $w_{optimal}$

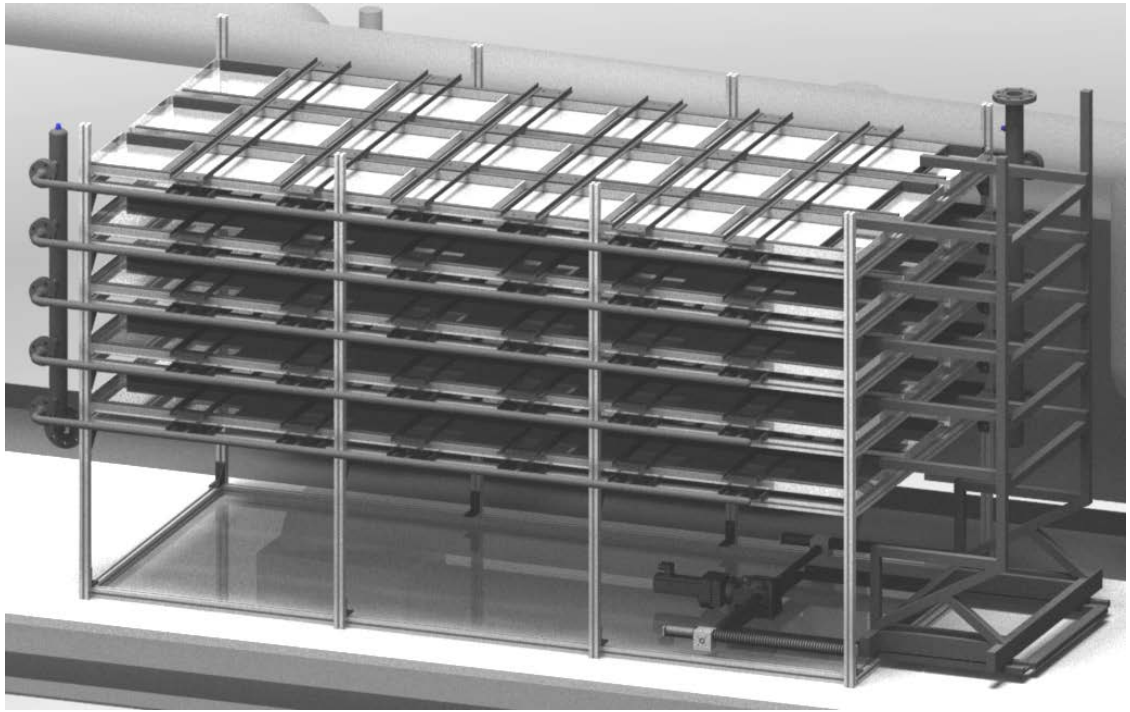


Demonstration of 10 kW test rig

Design of test rig



Construction of 10 kW test storage



- 30 parallel tubes
- Eutectic $NaNO_3/KNO_3$ as PCM
- Distance for movement 0.5 m
- 400 kg PCM

Conclusions and Outlook

- PCMflux offers varius advantages:
  - constant power
  - reduced heat exchanger (accessible)
  -no direct contact between PCM and pressure tubes
  - only slow movements over limited distances required
  - flexibility in power by adjustment of feed rate

- Status:
  - Fundamentals for design of PCM have been elaborated by experiments and numerical analysis
  - Lab-scale proof of concept
  - Construction of 10 kW test rig has been almost completed

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Outlook

- Extension to PCM also in solid state
- Integration of heat transfer structures to increase the thickness of PCM layers
- Utilization of different PCMs

The nextPCM project is funded by the
German Federal Ministry for Economic Affairs and Energy

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