Experimental Evaluation of a Pilot-Scale Thermocline Thermal Energy Storage Combining Latent and Sensible Materials

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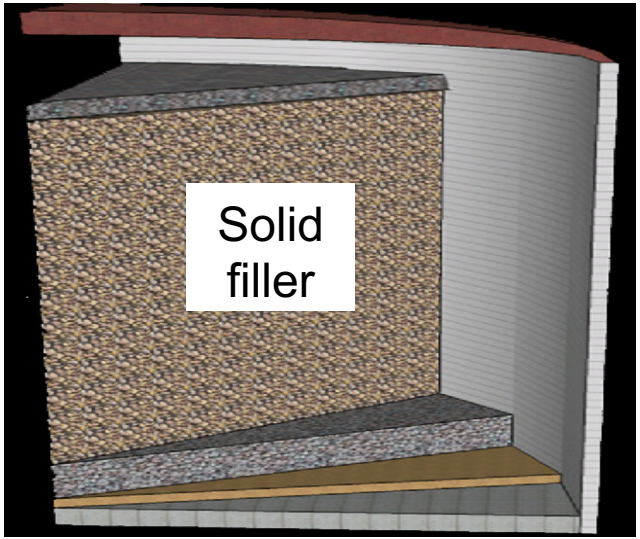
Introduction

Two-tank versus one-tank TES

More than 30% cost reduction if one can manage the loss of efficiency due to thermocline thickness increase during operation



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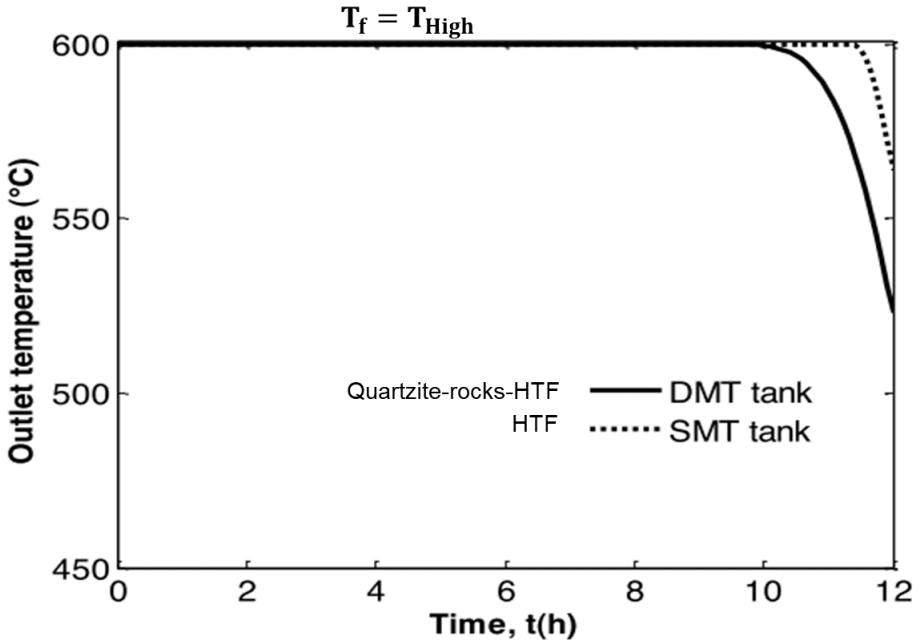
Introduction

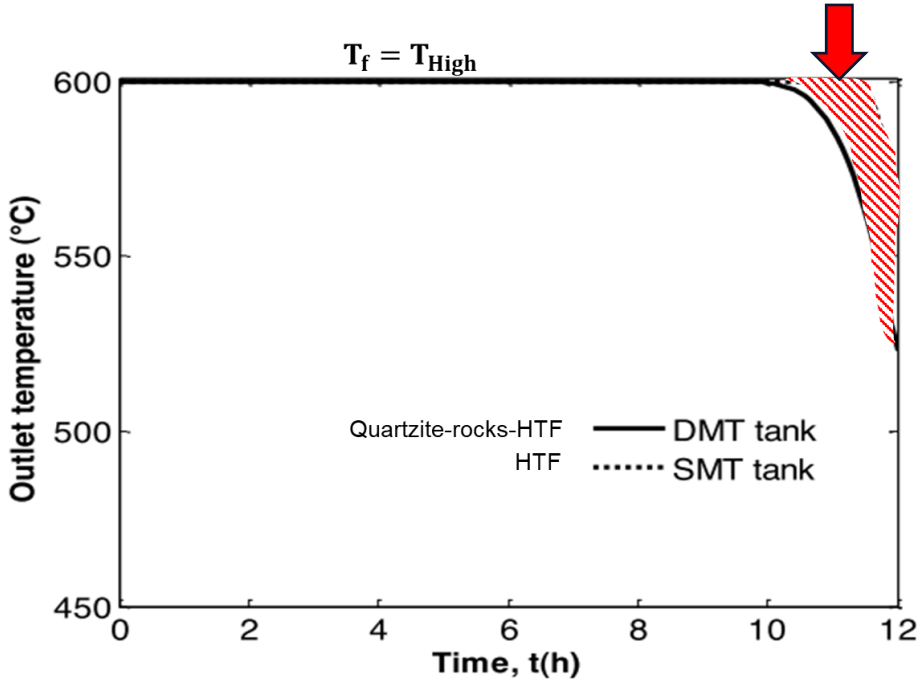
Single / dual medium thermocline TES. Comparison of typical evolution of outlet temperature with time



Outflow temperature history for dual-media and single-medium thermocline tanks.

Introduction

Energy « loss » due to thermal diffusion (fluid-solid exchange) → **reduction of efficiency**

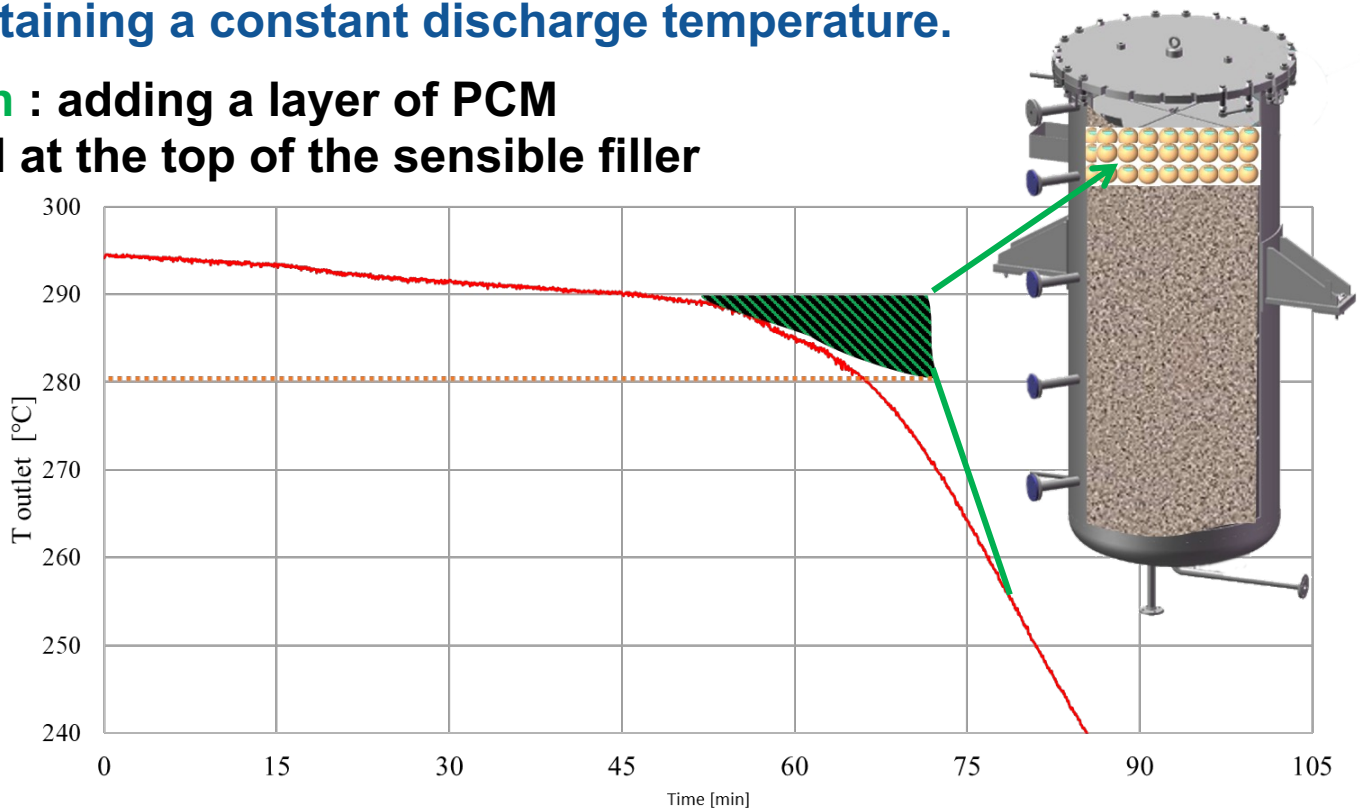


Outflow temperature history for dual-media and single-medium thermocline tanks.

Objectives

To improve the energy quality (exergy) during discharge by maintaining a constant discharge temperature.

Solution : adding a layer of PCM material at the top of the sensible filler



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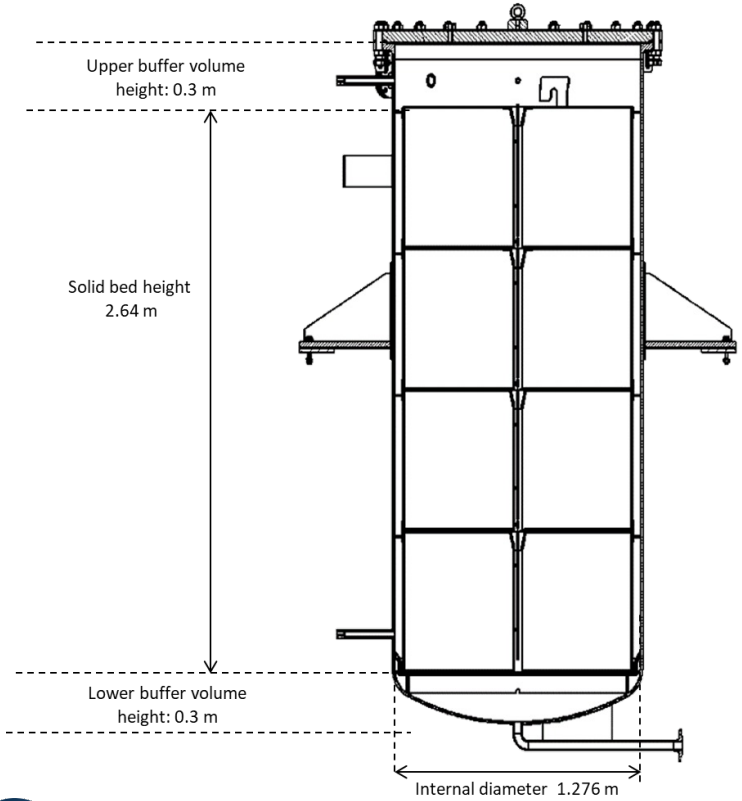
Experimental Setup

The storage tank / 5.5% PCM



The thermocline vessel

A 3.3 m^3 tank filled with
4.66 tons of alumina spheres as sensible heat storage,
and 337 kg of $NaNO_3$ as PCM (T_m = 306°C).
PCM envelop: Stainless Steel (304&316)

HTF: Jarytherm® DBT
0 °C - 350 °C
In operation,
Charge 285-330°C
Discharge 220-330°C

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Experimental Setup

The storage tank

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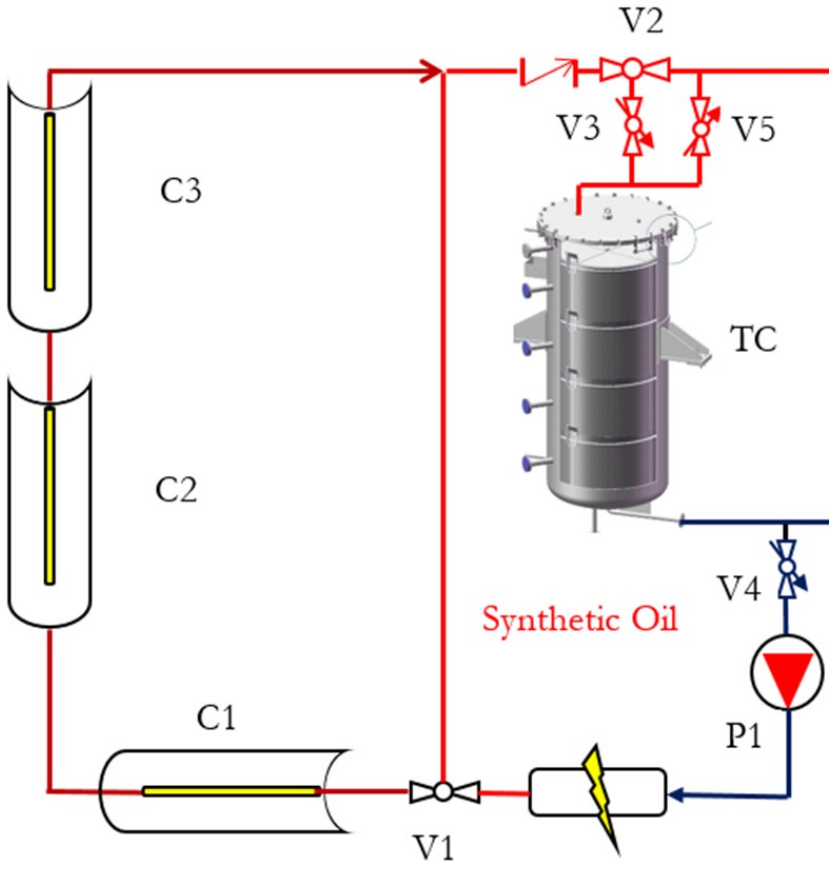
Experimental Setup

The thermal loop



Charging circuit

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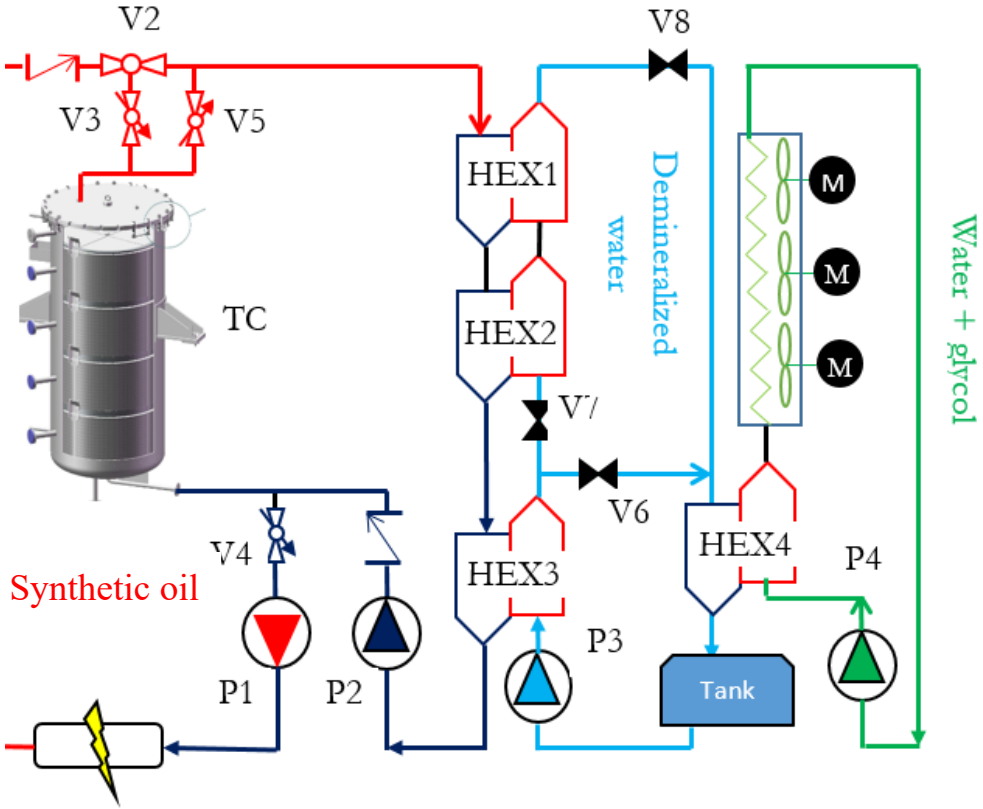
Experimental Setup

The thermal loop



Discharging circuit

Performance indicators

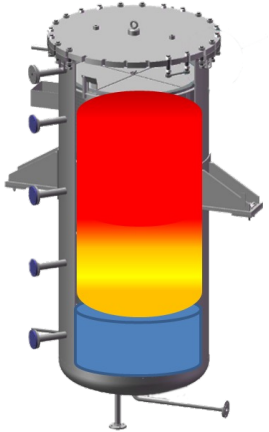
The thermocline thickness

$$\delta = \frac{h\left(T_{thr,d,20\%}\right) - h\left(T_{thr,c,20\%}\right)}{H_{Tank}}$$

With

$$T_{thr,d,k_d} = T_{high} - k_d\left(T_{high} - T_{low}\right)$$

$$T_{thr,c,k_c} = T_{low} + k_c\left(T_{high} - T_{low}\right)$$



Objective: to minimize δ

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Performance indicators

The charge and discharge efficiencies

$$\eta_{charge} = \frac{E_{accumulated}}{E_{max}}$$

$$\eta_{Discharge} = \frac{E_{discharge}}{E_{max}}$$

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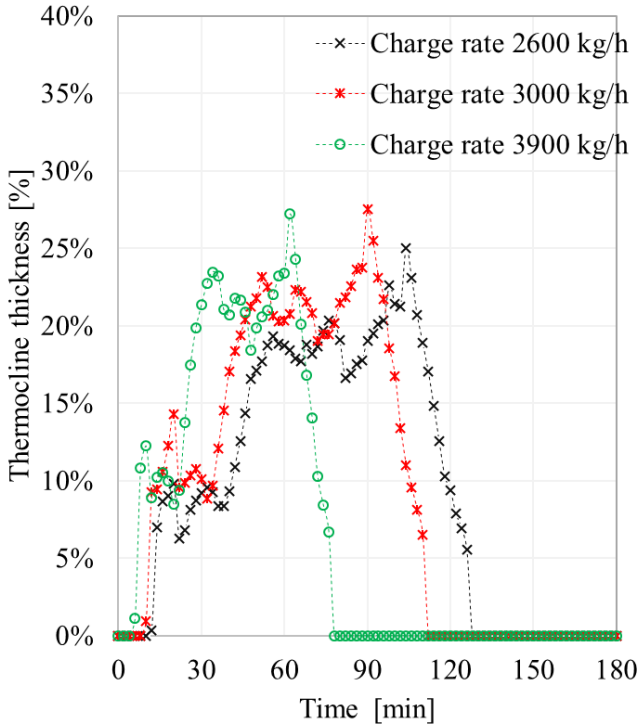
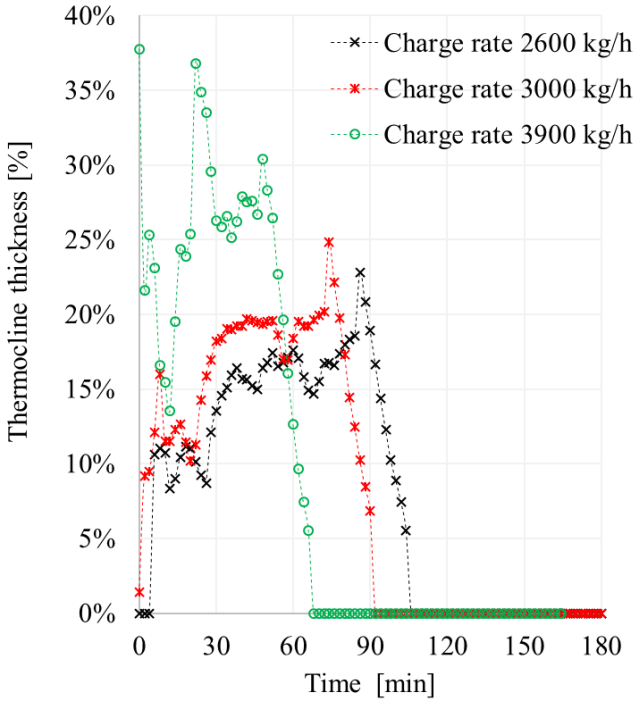
Experimental results Thermocline thickness

Charge 285-315 °C

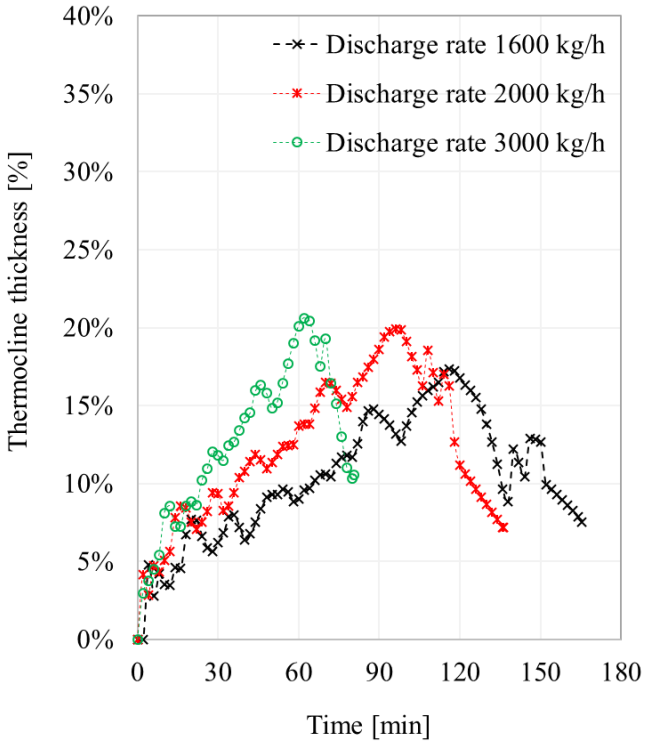


Charge 295-330 °C

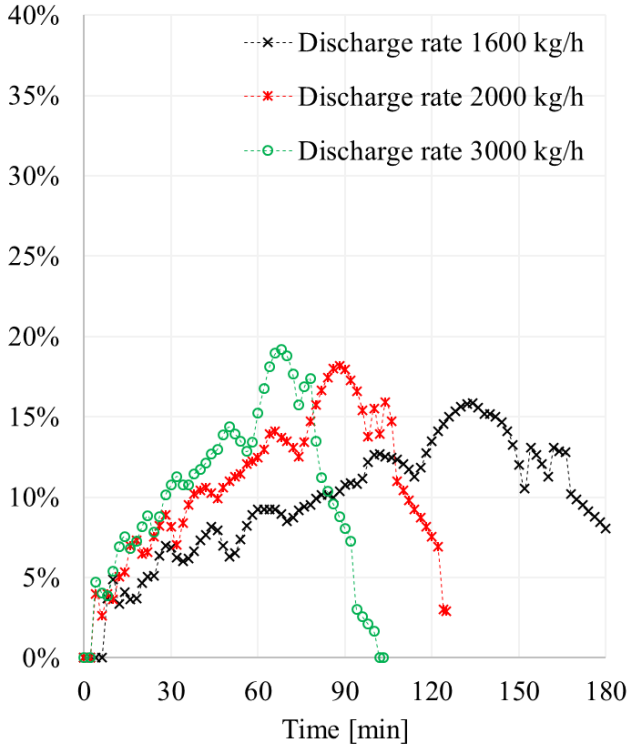


Experimental results Thermocline thickness

Discharge 315-220 °C

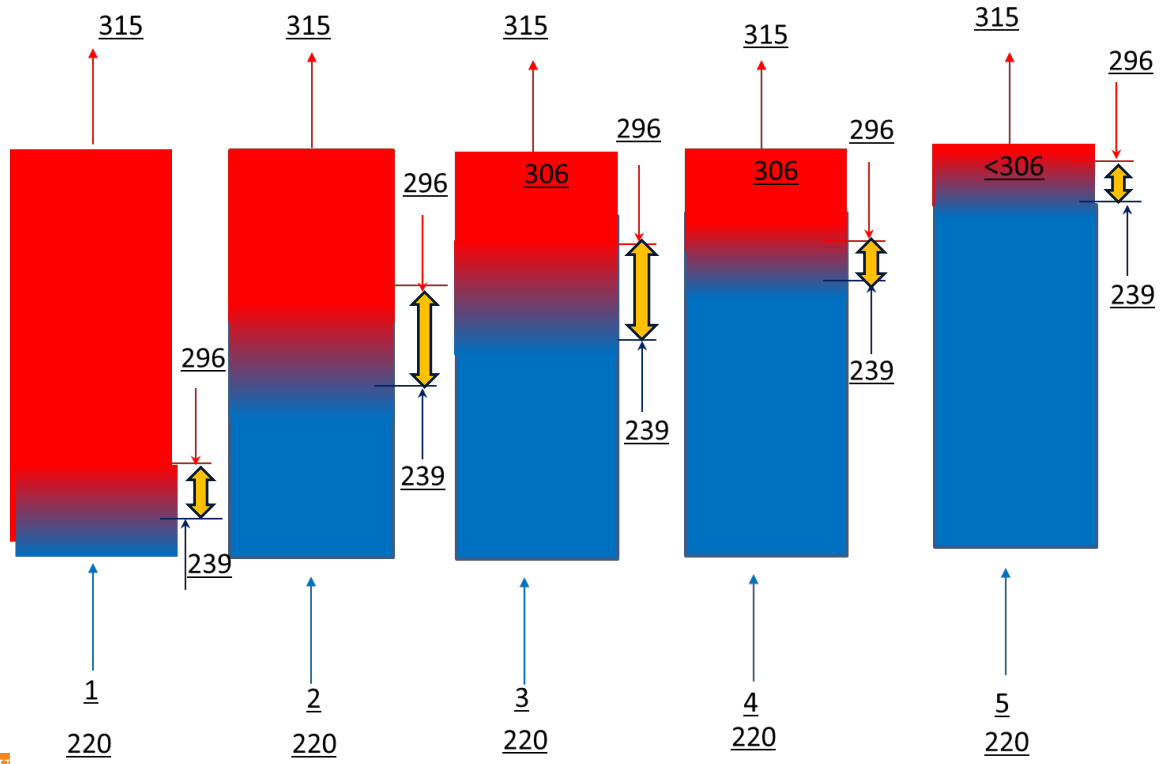


Discharge 330-225 °C



Experimental results Thermocline thickness

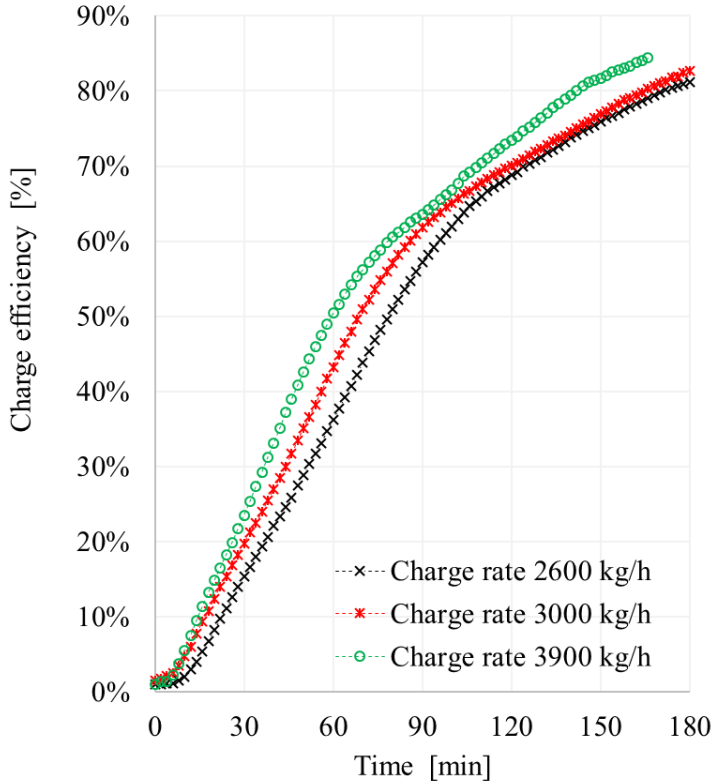
Thermocline evolution during discharge. Effect of the PCM



Experimental results

Charge efficiency

Charge 285-315 °C



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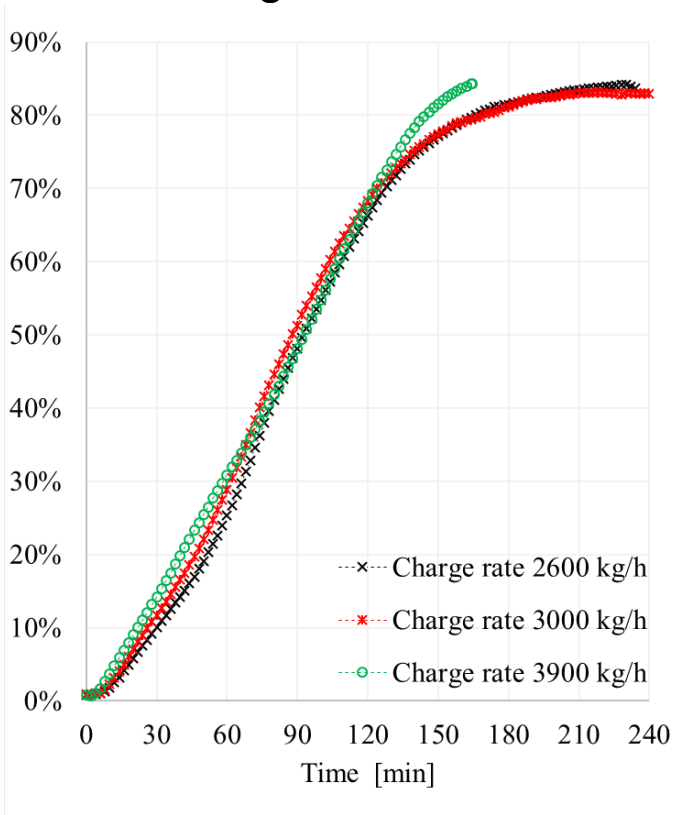

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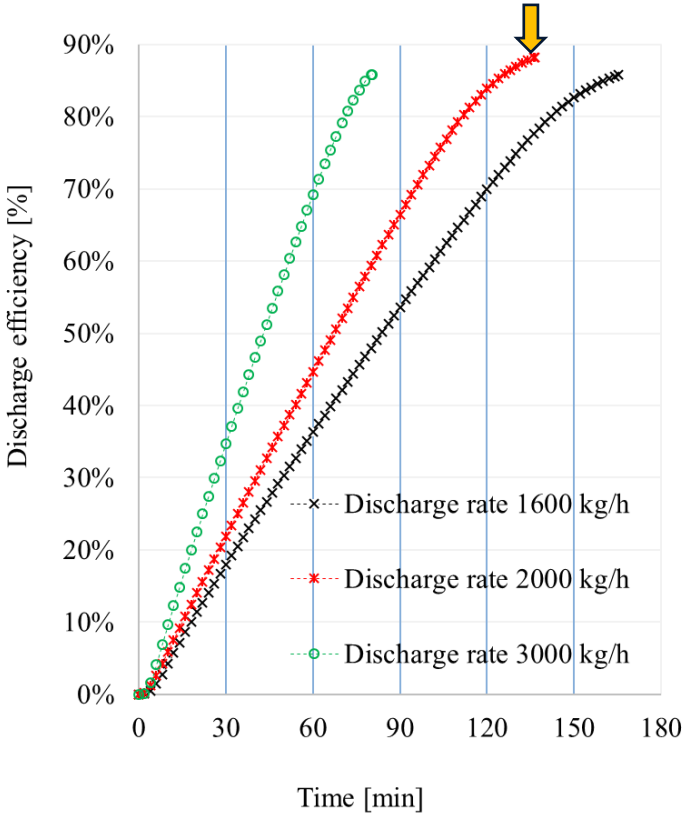
Experimental results

Discharge efficiency

Discharge 315-220 °C



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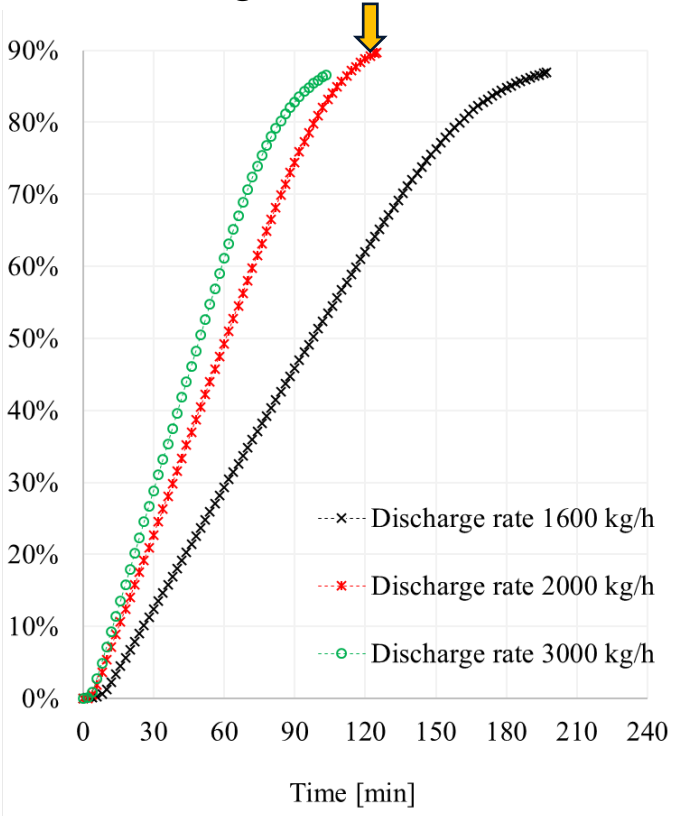

Conclusion

- Thermoline thickness depends on the HTF mass flow rate
- In particular, PCM reduces the thermocline thickness during discharge
- The control of the discharge HTF mass flow rate results in maximizing the thermocline efficiency during discharge

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Thank you for your attention

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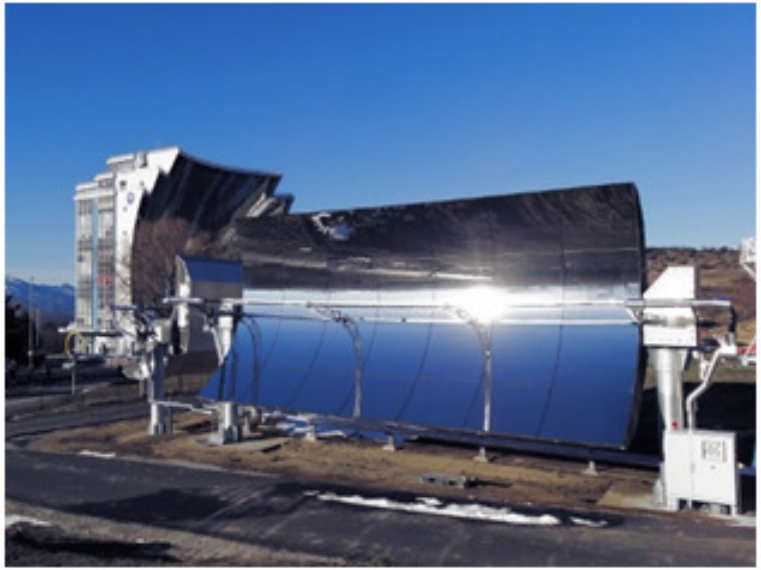

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