Universitat de Lleida

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

Innovació concurrent GREA

Thermal energy storage implementation using phase change materials in a solar cooling and refrigeration applications

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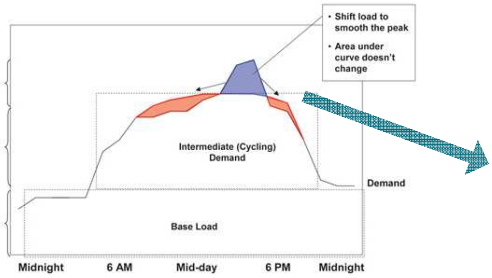
Introduction

- Nowadays, solar cooling and refrigeration technology have become vital for both human comfort since solar energy is the cheapest and most extensively available renewable energy
- In solar vapor absorption systems, the energy received from the solar collector is given as heat input to the generator; hence it has to assure a constant heat input to the absorption chiller during all the process

Introduction

- Here the main disadvantage of this energy resource is the mismatch between the energy supply and the energy demand
- Therefore, when energy is available but cannot be given to the process, thermal energy storage (TES) may become an important issue



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Objective

- To select and to test different phase change materials (PCM) candidates in lab scale
- To compare the PCM selected at pilot plant scale in a real high temperature system

Contents

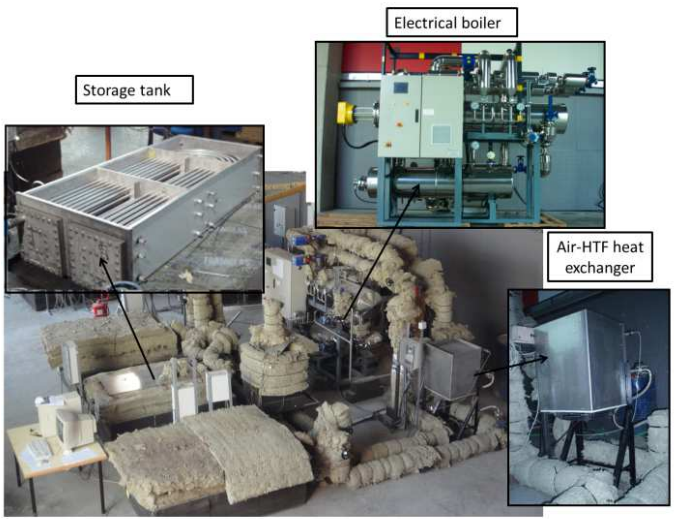
Materials and methodology

- Selection of the PCM
  - Storage temperature 140 – 200 ºC
  - Heat of fusion > 150 kJ/kg

Material	Experimental phase change temperature [ºC]	Experimental phase change enthalpy [kJ/kg]
Salicylic acid	159.1 (m) / 111.3 (s)	161.5 (m) / 109.4 (s)
Benzanilide	163.6 (m) / 136.1 (s)	138.9 (m) / 129.4 (s)
D-mannitol	**166.8 (m) / 117 (s)**	**260.8 (m) / 214.4 (s)**
Hydroquinone	**172.5 (m) / 159.5 (s)**	**235.2 (m) / 178.7 (s)**
Potassium thiocynate	176.6 (m) / 156.9 (s)	114.4 (m) / 112.5 (s)

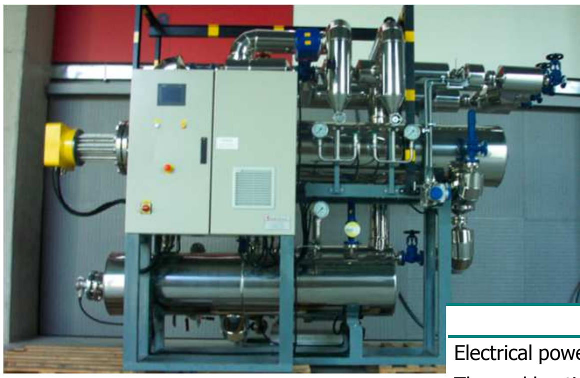
Materials and methodology

- High temperature pilot plant



Materials and methodology

- High temperature pilot plant - boiler



	Value
Electrical power [kW]	24
Thermal heating power [kW]	20
HTF flow rate [m^3/h]	0.3 - 3
Maximum pressure of work [bar]	15
Maximum temperature of work [ºC]	400

Materials and methodology

- High temperature pilot plant – air heat exchanger

	Value
Thermal cooling power [kW]	20
Air flow rate [m^3/h]	1800
Air inlet temperature [ºC]	ambient
Exterior dimensions [mm]	700x540x440

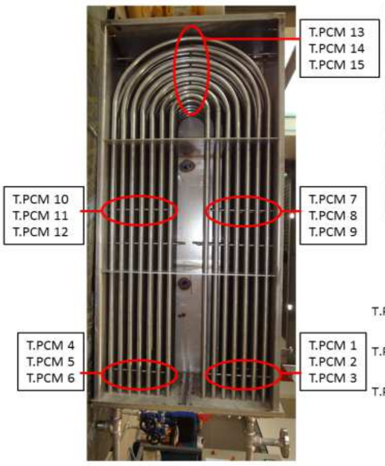
Materials and methodology

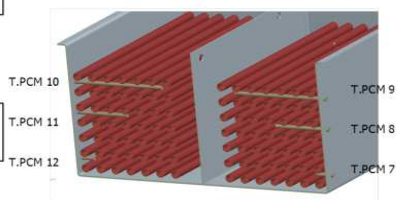
- High temperature pilot plant - tank

	Value
Storage tank width [m]	0.527
Storage tank height [m]	0.273
Storage tank depth [m]	1.273
Number of HTF tubes [-]	49
HTF pipes average length [m]	2.90
Heat transfer surface [m^2]	6.568
Total d-mannitol mass [kg]	160

Materials and methodology

- High temperature pilot plant - tank





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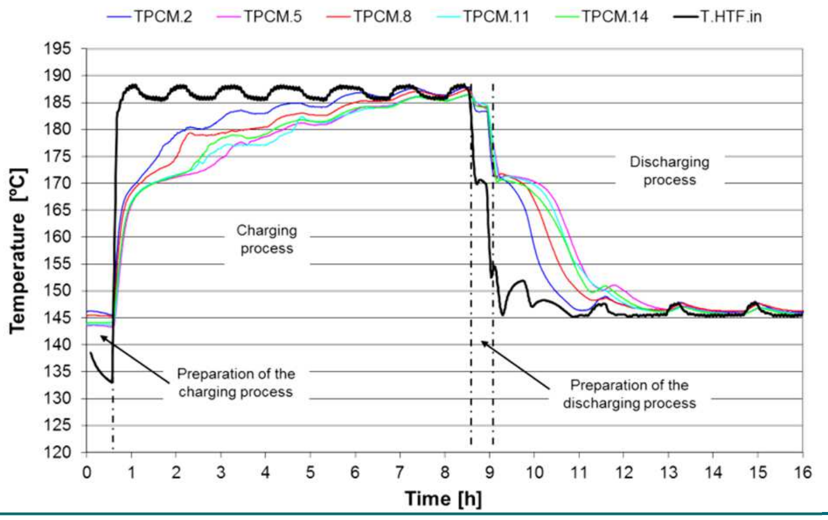
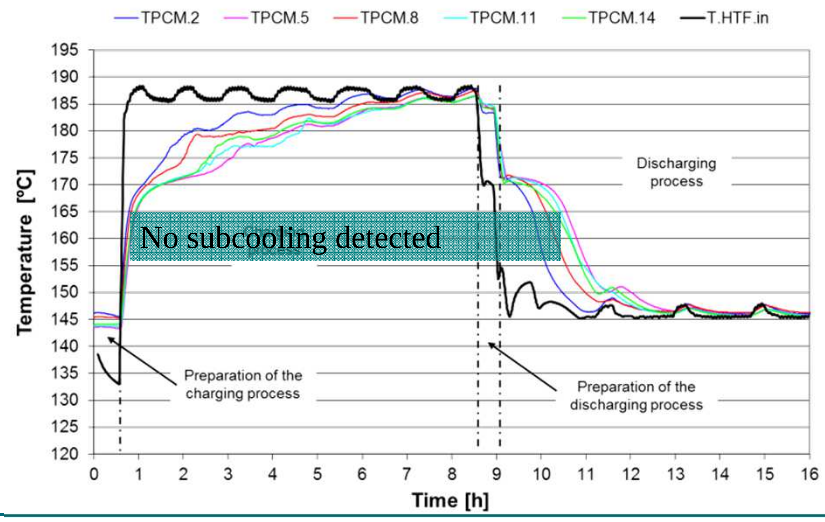
Results

- Hydroquinone – temperature profile



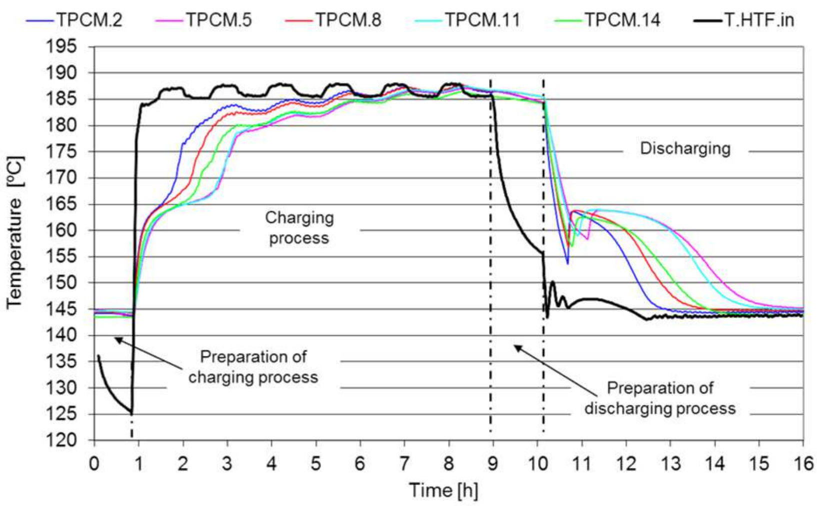
Results

- Hydroquinone – temperature profile



Results

- D-mannitol – temperature profile



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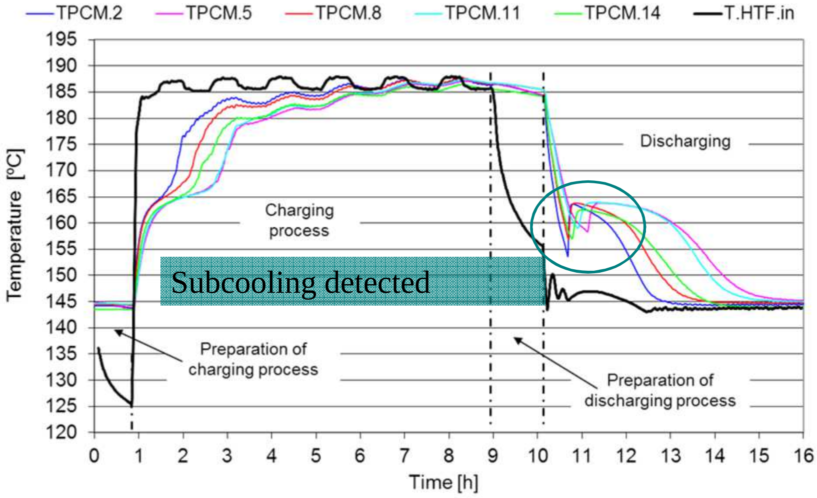
Results

- D-mannitol – temperature profile



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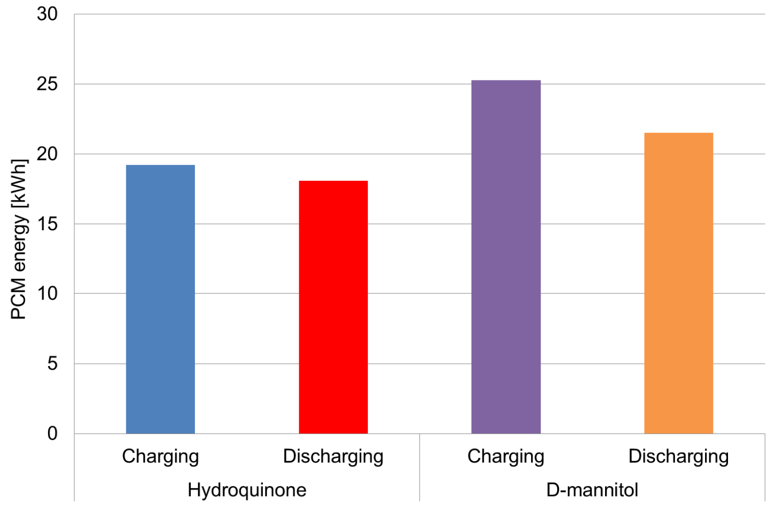
Results

- Energy balance in the storage tank
  - $Q_{HTF} = Q_{PCM} + Q_{tank} + Q_{loss} + Q_{acc\ HTF} + Q_{insulation}$
  - $\varepsilon_{cha} = \frac{Q_{PCM}}{Q_{HTF}}$ $\varepsilon_{dis} = \frac{Q_{HTF}}{Q_{PCM}+Q_{steel}}$

	Hydroquinone		D-mannitol	
	Charging	Discharging	Charging	Discharging
Time [min]	476	362	486	354
ΔE_{HTF} [kWh]	21.5	17.9	27.7	21.4
ΔE_{PCM} [kWh]	19.2	18.1	25.3	21.5
ΔE_{loss} [kWh]	1.4	1.2	1.3	0.8
ΔE_{steel} [kWh]	0.8	0.5	0.9	0.5
ε [-]	0.9	0.96	0.91	0.97

Results

- Energy accumulated and given by the PCM



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Results

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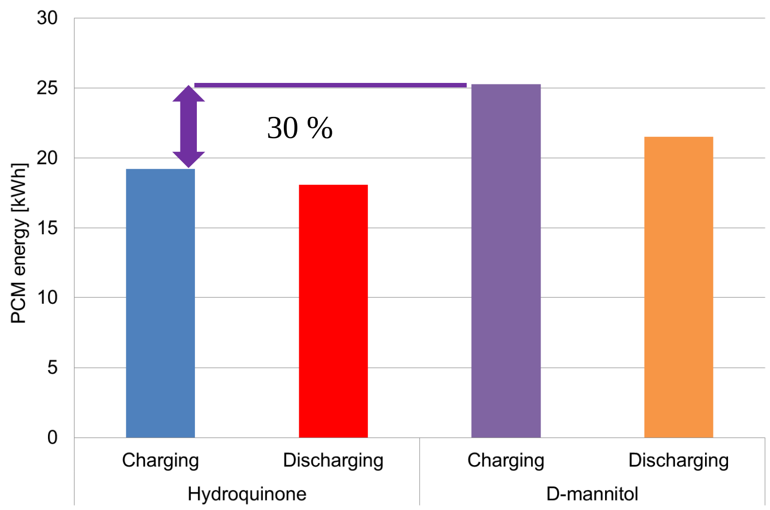

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Results

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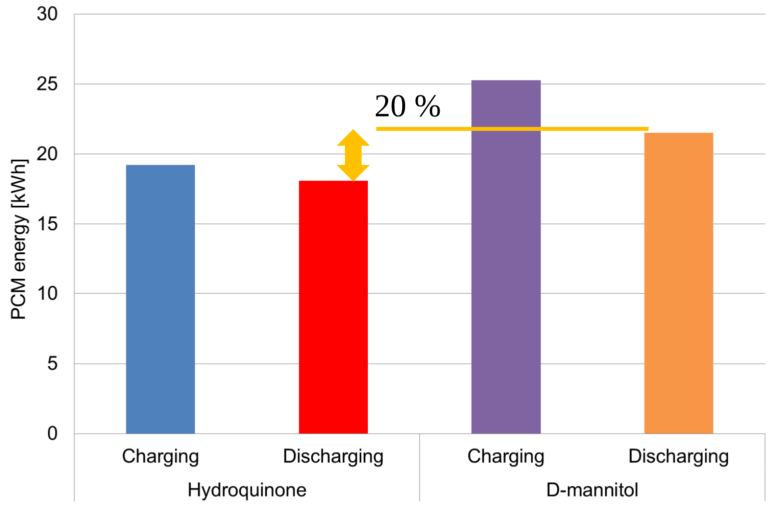

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Conclusions

- A high temperature pilot plant with TES system based on shell-and-tubes heat exchanger were designed and built at the University of Lleida
- Literature and DSC research of some PCM candidates for solar cooling applications were done
- Hydroquinone and d-mannitol were the PCM selected to test them at pilot plant scale
- Different charging and discharging experiments with different flow rates and HTF temperatures were performed

Conclusions

- For both PCM, no hysteresis was detected, and even though hydroquinone presented subcooling in the DSC, it did almost not appear in pilot plant scale, however, when d-mannitol was used big subcooling was detected
- For the same boundary conditions, the energy stored by d-mannitol was higher than that for hydroquinone
- The enhancement was about 30% and 20% during the charging and the discharging processes even though the enhancement of the latent heat was only 10 and 16%, respectively

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- To all co-authors of this work

Thank you for your atention

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