NEW COLD STORAGE SYSTEMS BASED ON LIQUID FLUIDIZATION OF PCM SPHERES

Miguel Á. Alfaro-López[1*], Juan F. Belmonte[1,2], José A. Almendros-Ibáñez[1,2]

[1] *Universidad de Castilla-La Mancha, Renewable Energy Research Institute, Section of Energy Efficiency and Thermal Systems (EnerSys), Albacete, Spain*
[2] *Universidad de Castilla.-La Mancha, E.T.S. de Ingeniería Industrial de Albacete, Dpto. de Mecánica Aplicada e Ingeniería de Proyectos, Albacete, Spain*
** MiguelAngel.Alfaro@uclm.es*

Introduction

The use of phase change materials (PCMs) allows for increased energy density in cold thermal energy storage (TES) systems. This research aims to investigate new cold TES technologies using a liquid fluidized bed of large-scale PCM spheres to enhance the heat transfer process. An experimental liquid-solid fluidized bed and a commercial bulk PCM tank were investigated under different conditions to evaluate their performance. A comparison between the different cold TES solutions will be performed and the TRNSYS software will be used to analyse its integration into building air conditioning systems.

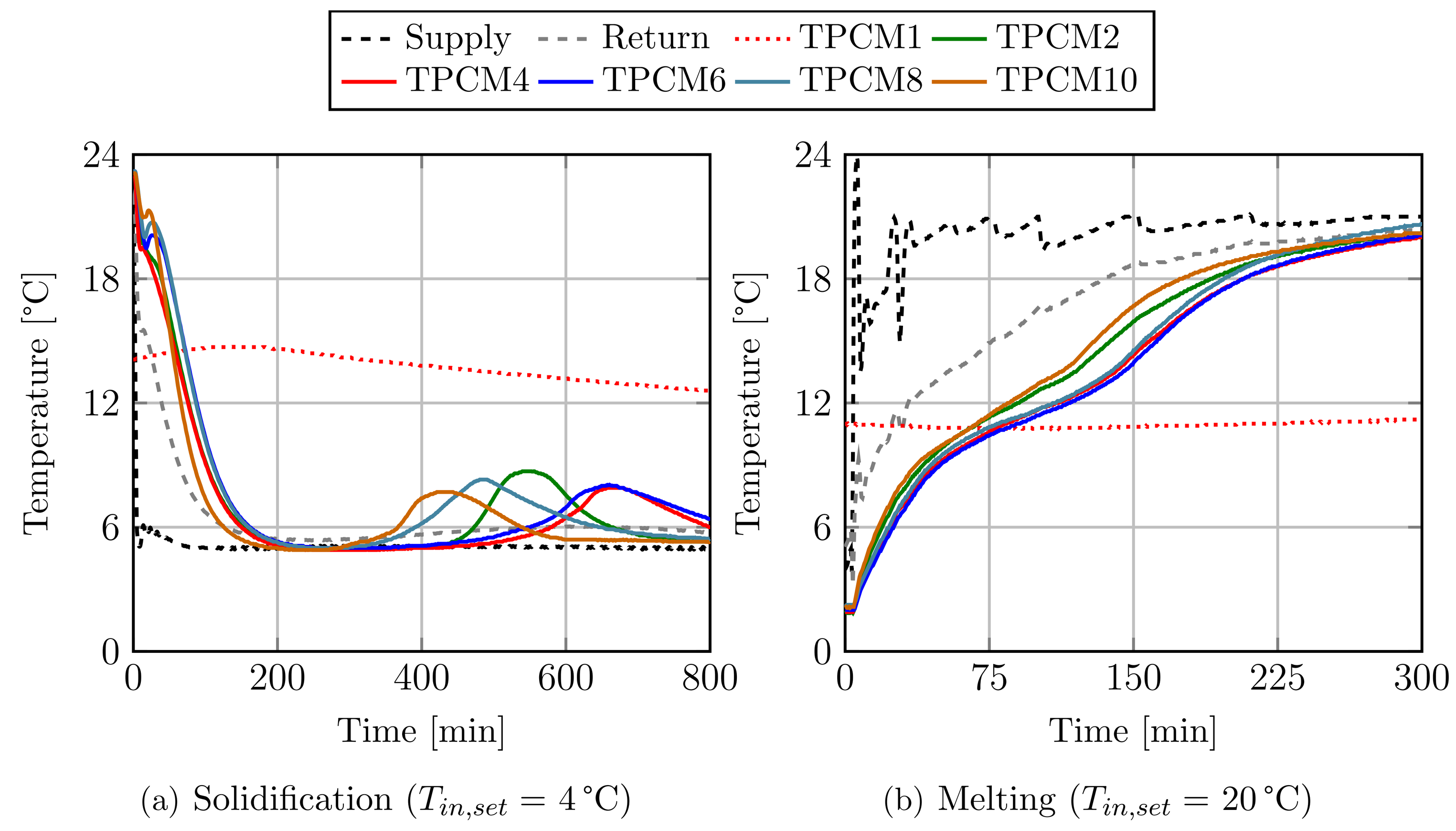

Fig. 2. PCM temperatures during solidification (charging) and melting (discharging) tests at ΔT= 8ºC

Bulk PCM Tank

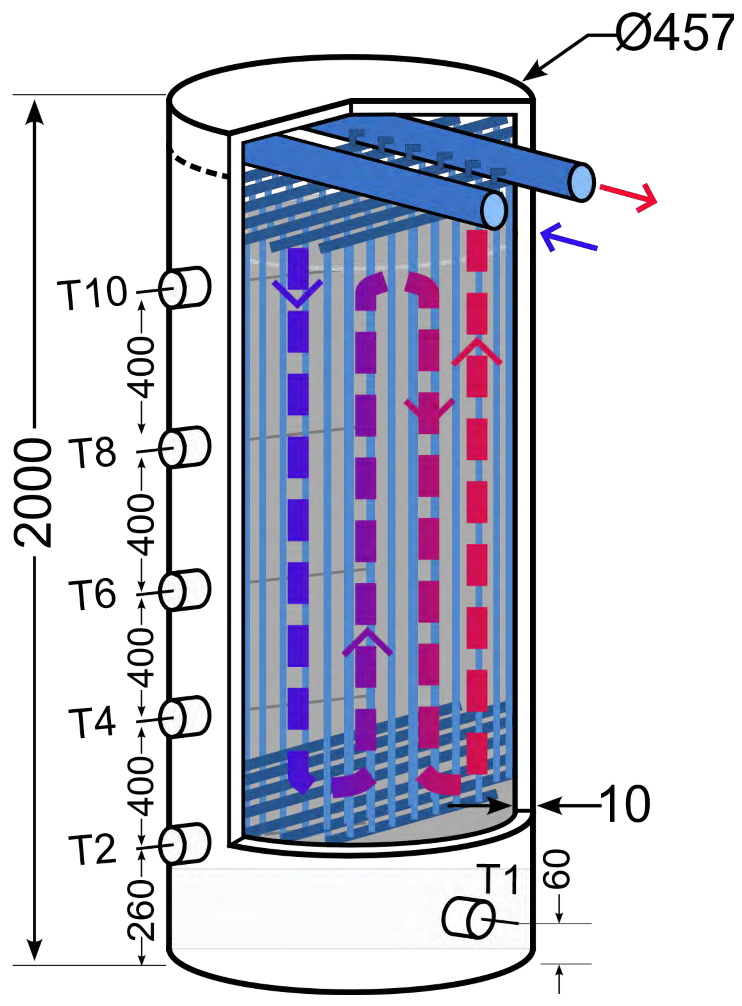

Fig. 1. Scheme of the experimental bulk PCM tank and flow pattern in the HX. Dimensions in mm.

A commercial PhaseTube tank manufactured by Rubitherm was studied. It consists of a polypropylene heat exchanger (HX) composed of 228 tubes (total heat transfer area: 4.44 m^2), surrounded by 322 kg of inorganic gel PCM (SP12SK, Rubitherm; theoretical melting temperature: 12ºC). PCM temperatures were measured using six vertically distributed PR100B RTDs located at the centre of the tank, as shown in Fig. 1, together with the main dimensions of the experimental tank.

Solidification and melting tests at different inlet temperatures and flow rates were carried out. Fig. 2 shows the evolution of PCM and heat transfer fluid (HTF) temperatures during solidification and melting at a flow rate of 900 l/h. The bottom region (TPCM1) acts as a dead zone due to the low thermal conductivity of the PCM and its distance from the HX. No clear vertical stratification was observed. Phase change was more clearly identified during melting, while solidification showed indications of secondary phase formation after 6 hours, supported by visual analysis (solidification videos available via the QR code below).

Liquid-Solid Fluidized Bed

A schematic diagram of the pilot-scale liquid-solid inverse fluidized bed is shown in Fig. 2. It consists of a vertical stainless-steel column with an inner diameter of 20.4 cm and a variable height, achieved using an adjustable perforated distribution plate, which is installed at the upper section to equalize the velocity profile of the incoming fluid. The bed is filled with 273 spheres of 4 cm diameter, each containing 20 g of organic PCM (savE®OM08, PLUSS®; theoretical melting temperature: 8ºC). A 20% vol. water-monopropylene glycol mixture was used as HTF and fluidizing agent. Flow direction is from top to bottom, as the PCM spheres are less dense than HTF, resulting in inverse liquid fluidization.

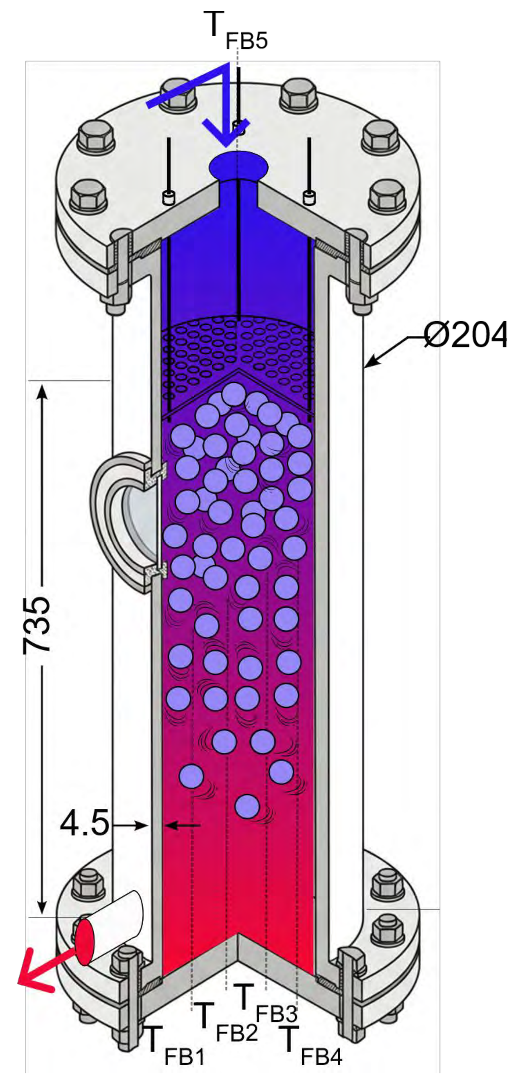

Fig. 3. Scheme of the experimental liquid fluidized bed. Dimensions in mm.

Liquid fluidized beds of encapsulated PCM spheres offer a dual pathway for performance improvement: enhanced external convection and mechanically agitated internal phase change. Currently, visual and pressure drop analysis are being conducted to characterise the hydrodynamic behaviour of the system (fluidization videos available via the QR code below). Subsequently, solidification and melting tests will be carried out to assess the performance enhancement of the fluidized bed.

Scan for experimental videos

URL

Acknowledgements

Cofinanciado por la Unión Europea

This work was partially funded by the project PID2024-159711OB-I00, CPP2023-010989 and RED2024-153629-T, by the Spanish Ministry of Science and Innovation MCIN/AEI/10.13039/5011000 11033/, by European Regional Development Fund "A way of making Europe", by European Union NextGenerationEU/PRTR, grant SBPLY/24/180225/000071, funded by the European Union through the ERDF and by the Regional Government of Castilla-La Mancha, Spain, through INNOCAM, and grant 2025-GRIN-38585, funded the University of Castilla-La Mancha, Spain. This work has been carried out as part of the predoctoral contract 2024-UNIVERS-12844 at the University of Castilla-La Mancha (UCLM), funded by the European Union through the European Social Fund Plus (FSE+).