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# INNOSTORAGE – USE OF INNOVATIVE THERMAL ENERGY STORAGE FOR MARKED ENERGY SAVINGS AND SIGNIFICANT LOWERING $CO_2$ EMISSIONS

Beneficiaries:

UNIVERSITAT DE BARCELONA

Universitat de Lleida

UNIVERSITÉ DE LYON

Ben-Gurion University of the Negev

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THE UNIVERSITY OF AUCKLAND NEW ZEALAND Te Whare Wananga o Tamaki Makaurau

University of South Australia

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## D7.2 - Report on Staff Exchanges

| | Name and Institution | Date |
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SEVENTH FRAMEWORK PROGRAMME

MARIE CURIE ACTIONS

## Contents

# 1 Objectives

The objectives of the secondment was to share the experiences of both teams on PCM heat storage. It was planned to develop a high temperature phase change storage system and a test facility. The data from the test facility have to be used to validate numerical models of high temperature heat storage developed by Barbara institute's team.

An additional goal of the secondment was the discussion of further ideas to develop within the project or in future collaborations.

# 2 Introduction

Thermal energy storage systems could make an important contribution in reducing our dependency on fossil fuels, but also in contributing to a more efficient and environmentally benign energy use [1]. However current thermal storage systems and materials have not demonstrated financial viability. The lack of a test facility for high temperature thermal storage research has limited the research effort and the validation of laboratory scale research outcomes in developing new materials and systems.

# 3 Description of work

This secondment involves the establishment of a high temperature thermal storage test facility to test prototype high temperature storage systems. The secondment also involves designing, constructing and testing two thermal storage systems that incorporate new phase change materials and heat transfer techniques with the aim of understanding heat transfer phenomena and validating numerical modelling.
The validation of numerical modelling will enable to run a high amount of simulation under several boundary conditions and several initial conditions. It will be possible to have a better understanding of the heat transfers inside the tank and then to perform an optimization of the heat storage tank.

# 4 Materials and Methodology

Based on the modelling work conducted in the Barbara institute's team, a shell-and-tube heat exchanger (without fins) was selected and a laboratory scale prototype has been designed and constructed as shown in Figure 1. The prototype storage system has a diameter of 0.323 m and a height of 0.790 m, which is able to contain 120 kg of sodium nitrate as the storage medium. The detailed drawing and the dimension of the prototype is presented in Figure 2. The prototype was fixed horizontally to a high temperature test rig as shown in Figure 3. This rig allows for testing the charging and discharging behaviours of the small prototype storage systems. A synthetic oil – DOWTHERM A supplied by the Dow Chemical Company was used as the heat transfer fluid (HTF). DOWTHERM A HTF is an eutectic mixture of two very stable organic compounds, biphenyl and diphenyl oxide, which is the common working fluid in the parabolic trough solar power plants. The thermo-physical properties of the fluid are given in

Table 1. Its normal application range is 15°C to 400°C and its pressure range is from atmosphere to 10.6 bar.

Temperatures of the HTF at the inlet and the outlet of the storage system and temperatures of the storage medium at two locations are recorded at a time interval of one second thanks to platinum RTD (PT100) probes.

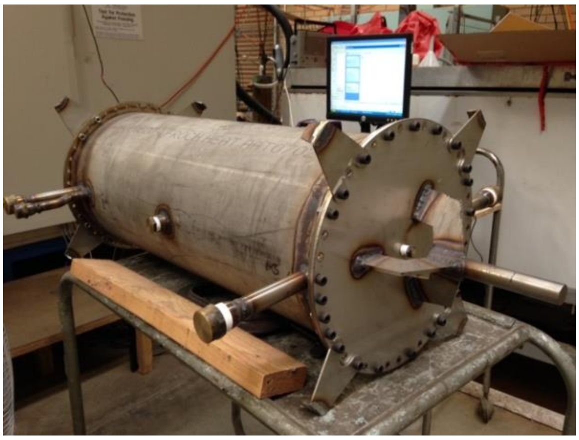

**Figure 1.** A laboratory scale prototype shell-and-tube phase change thermal storage system.

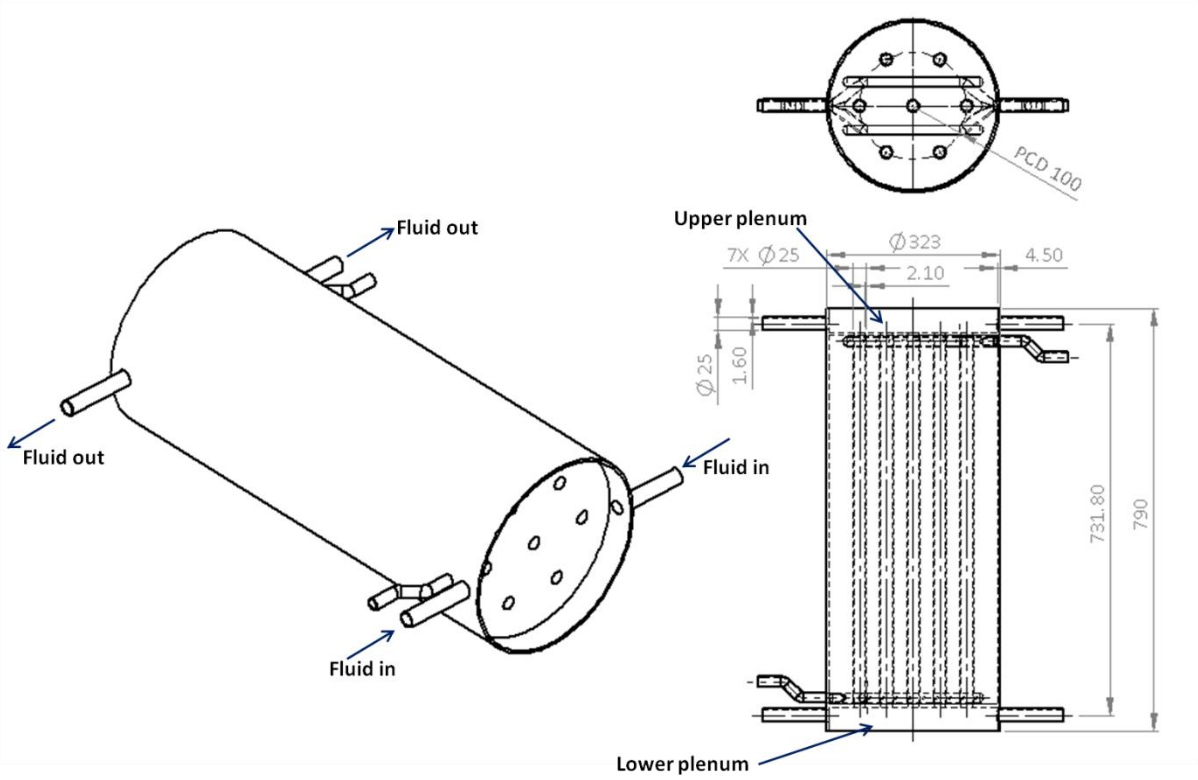


**Figure 2.** Dimensions of the prototype shell-and-tube phase change thermal storage system.

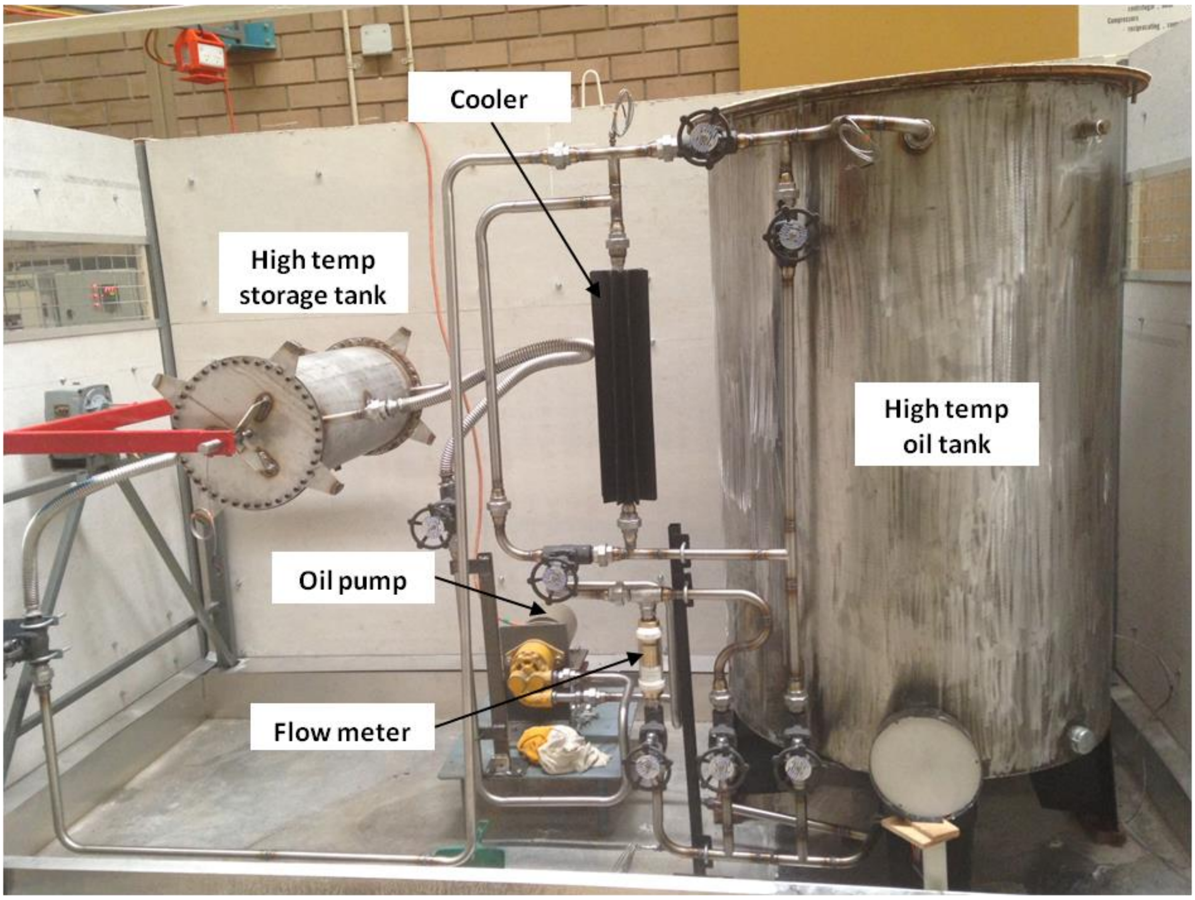


**Figure 3.** A high temperature test rig with a prototype phase change thermal storage tank.

**Table 1: Thermo-physical properties of sodium nitrate and DOWTHERM A at 300°C.**

| Material | elting temperature (°C) | nt heat of fusion (*kJ/kg*) | Specific heat (*J/(kg·K)*) | Thermal conductivity (*W/(m·K)*) | Density (kg/m$^3$) |
|---|---|---|---|---|---|
| Sodium nitrate | 306 | 178 | 1500 | 0.5(solid) .83(liquid) | 2000 |
| Material | Viscosity (mPa.s) | ensity (kg/m$^3$) | Specific heat (*J/(kg·K)*) | Thermal conductivity (*W/(m·K)*) | - |
| DOWTHERM A (at 300°C) | 0.21 | 806.8 | 2359 | 0.0939 | - |

To charge the storage system, the HTF has to be heated up to 350°C by a 15kW heating element located at the bottom of the high temperature oil tank (containing DOWHTERM A). The hot fluid is pumped to the storage tank and sodium nitrate changes from solid phase to liquid phase and therefore the energy is stored. In the discharge process, the cold fluid is circulated in the system and takes away the energy stored in the sodium nitrate, which changes from liquid phase to solid phase.

# 5 Results

During the secondment it was possible to achieve the construction of the test facility and to perform one test to compare the experimental results with the numerical results. The first test consisted in melting the PCM to store the energy. Figure 4 presents the comparison of the results.

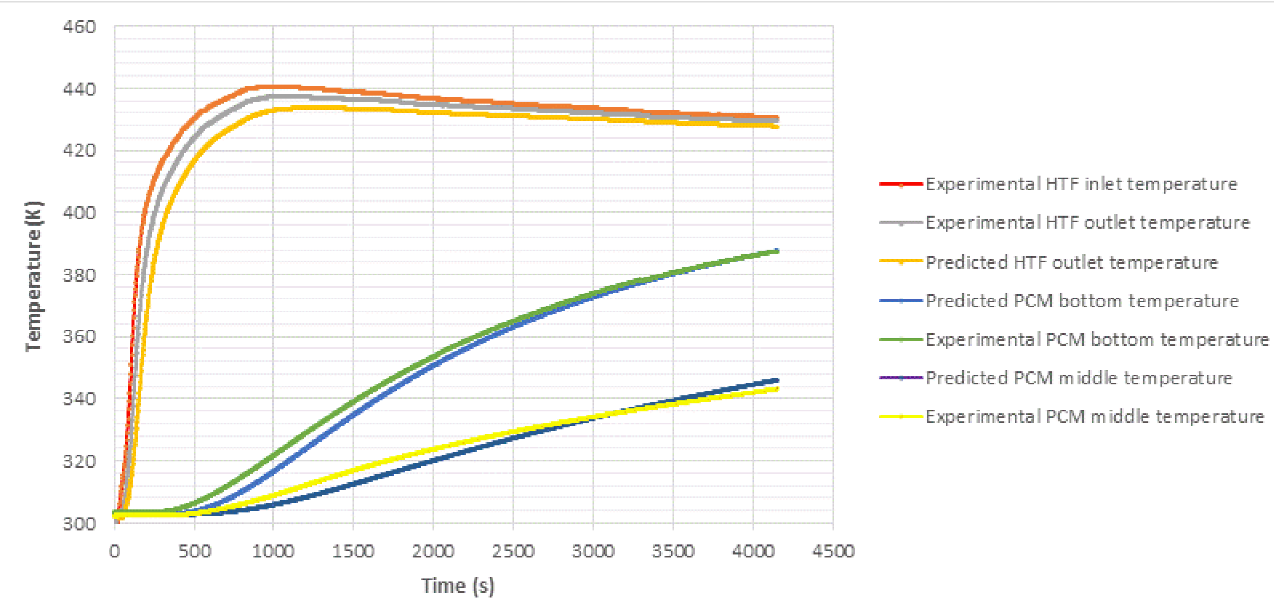


**Figure 5.** The comparison of the model prediction and the experimental results.

As can be seen, the predicted temperatures in the PCM are consistent with the experimentally monitored values and both the predicted and the measured HTF outlet temperatures present similar profiles. The discrepancy between the predicted and the experimental results could be due to the accuracy of the flow meter and the properties of the HTF. Also, in the experiment, the storage system was not fully filled to allow for the thermal expansion of the storage medium. Further testing work is being carried out to investigate the discrepancy.

# 6 Outcomes or future work

Concerning the experimental test facility, more experimental data are needed to perform a deep validation of the numerical modelling. It is also possible to change the PCM to obtain data with another PCM, at higher temperature for example.

A key point in such a system is to improve the heat transfers between the HTF and the PCM to decrease both the volume and the cost of the thermal storage. The only way to address this problem is to resort to numerical simulation. Because of the high calculation time it is not possible to continue with Navier-Stocks equations used in CFX in Barbara's team. Therefore the idea is to use the expertise of University of Lyon on high performance calculation to overcome the high calculation cost and to provide new research on shell-and-tube heat exchangers.

New collaborations are now started between Barbara Institute-University of South Australia and the University of Lyon.

# 7 References


[1] Dincer, M. Rosen, Thermal Energy Storage - Systems and Applications, Jhon Wiley and Sons, 2002.


# 8 Assessment

The objectives of the secondment were fulfilled. Although the research period was tight in time, a test facility was developed and experimental data were provided to make a comparison with numerical results. Therefore, the secondment is considered as successful. Moreover, the discussion and collaboration started between researchers and institutions will continue with ideas rising from discussions during this secondment.