2011 HIGHLIGHTS

SHC/ECES Task 42/24
Thermal Energy Storage: Material Development for System Integration

THE ISSUE

To reach high solar fractions, it is necessary to store heat or cold efficiently for longer periods of time. At this time, there are no cost-effective compact storage technologies available. For high solar fraction systems, hot water stores are expensive and require very large volumes of space. Alternative storage technologies, such as phase change materials (PCMs), sorption materials and thermochemical materials (TCMs) are only available at the laboratory scale, and more R&D is needed before they are available commercially.

OUR WORK

The objective of this joint Task with the IEA Energy Conservation through Energy Storage Programme is to develop advanced materials for compact storage systems, suitable not only for solar thermal systems, but also for other renewable heating and cooling applications such as solar cooling, micro-cogeneration, biomass, or heat pumps. The Task covers phase change materials (PCMs), thermochemical and sorption materials (TCMs), and composite materials and nanostructures. It includes activities on material development, analysis, and engineering, numerical modelling of materials and systems, development of storage components and systems, and development of standards and test methods.

The main added value of this Task is to combine the knowledge of experts from materials science with that of experts in solar/renewable heating and energy conservation.

PARTICIPATING COUNTRIES

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Task Date	2009-2013
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KEY RESULTS OF 2011

Material Development

In this area, the activities under materials engineering and processing were grouped into high temperature sensible storage materials, phase change materials and thermochemical materials.

In 2011, important steps were made in the development of measurement procedures used to determine the properties of phase change materials (PCM). The Fraunhofer Institute for Solar Energy is leading the working group on Testing and Characterisation and organised the PCM characterisation work. Knowledge about the characteristics of storage materials is the basis for a good design of storage systems and for thermal simulations. Unfortunately, the type of performance measurement has a large influence on the measurement result. Therefore, it is very difficult to compare measurement results that were generated at different institutes. Here, the introduction of measurement-standards could improve the situation significantly.

At the beginning of work on a standard for DSC (differential scanning calorimetry) characterization of PCMs the paraffin octadecane was selected as reference material. The work began with a comparative measurement, in that each participant characterized the paraffin as usual in his lab using a DSC device and his standard data evaluation. The result of this first measurement shows large deviations (**Figure 1**). After this first experiment, the paraffin was measured again with a prescribed measurement procedure. This resulted in a significant improvement in the comparability of the enthalpy values but the difference in melting temperature still was high. Despite some changes in the measurement procedure no improvement was achieved. Therefore it came to suspect that something was wrong with the calibration of the DSCs. So the participants of the group decided to make a workshop on DSC measurement which was held in Freiburg at Fraunhofer ISE in May 2011. There DSCs were available from different manufacturers, making it possible to calibrate them in parallel using the same method. After this calibration the octadecane was measured again and here a significant improvement of the results for the heating curves was reached. Since the deviations for the cooling curve are still big, we are also searching for materials to calibrate the DSCs in cooling mode. In summary it can be said that in drafting a standard for the DSC measurement the focus has shifted to the development of a calibration standard for the characterization of PCM. Thus, the development work became much more fundamental than assumed at the beginning of the project.

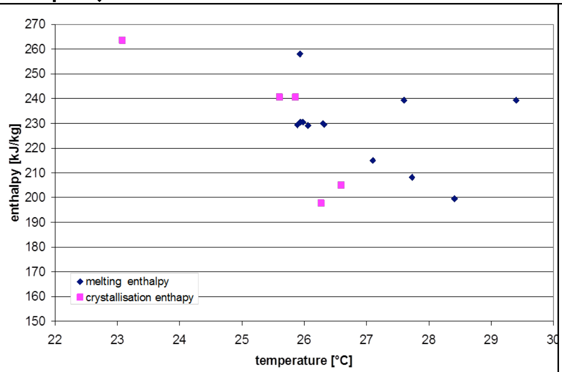

Figure 1: State of the art: Results of different institutions measured octadecane as reference material

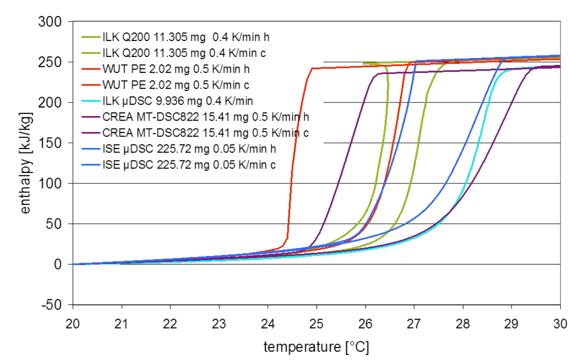

Figure 2: Result of DSC measurement using a draft standard procedure

Applications

This work is divided into three application areas 1) cooling, 2) heating/domestic hot water, and 3) high temperatures. Experts are considering a long list of applications in the different projects. Two highlights in the application developments are:

The University of Zaragoza has developed, experimentally analyzed and theoretically studied a real scale PCM-air heat exchanger.

In order to compare simulation results with experimental, an analysis of uncertainty in the theoretical model has been carried out as well as in the experimental results. This analysis has provided a range of uncertainties associated with the solution that is useful when comparing the experimental results and the simulations. In this sense there has been a great agreement comparing the two curves, obtaining a high degree of overlap between the different heat rate curves for most of the process.

Once the theoretical model was experimentally validated, the potential applications of interest of this kind of heat exchangers were selected; then the corresponding TES units were designed under the methodology of DOE applied to the numerical simulations by means of the response surfaces. The incorporation of the TES unit has been analyzed in three different cases: solar cooling (improving the system COP, although having an economic feasibility totally conditioned by the macro encapsulated PCM price), free cooling (improving the heat transfer rate and reducing the pressure drop), and temperature maintenance in rooms (extending time to reach threshold temperature and reducing the initial investment).

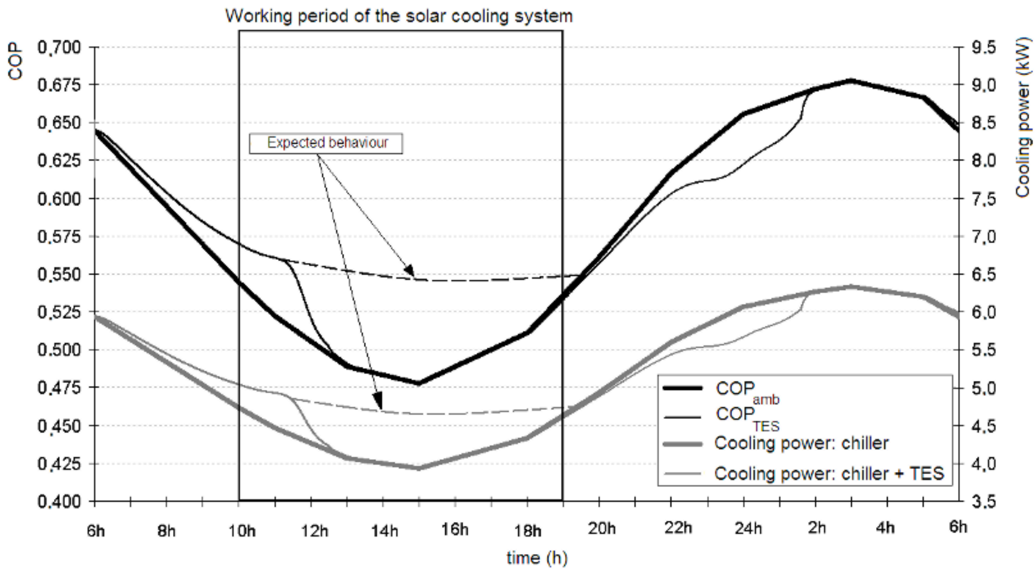

Figure 3: Expected behavior of the COP and cooling power with and without the TES unit incorporated in the solar cooling system.

VITO, the Flemish Institute for Technological Research, is investigating a short term compact thermal energy storage system for a heat pump or a micro combined heat and power system in a dwelling. The storage system's function is to make these systems more flexible and controllable in a smart grid.

One of the storage concepts uses 124 kg of spherical macro-encapsulated (ø 3-5 mm) salt hydrate capsules with a melt temperature of 52°C. The capsules are inserted into an insulated storage vessel in a packed bed manner, and the PCM is loaded and unloaded by means of an evenly distributed water flow, occupying 164 l of the 300 l total volume of the tank. Hence this concept combines the strengths of both latent and sensible heat storage.

When comparing the macro-PCM to a tank of the same volume completely filled with water, it was found that the increase in capacity due to the latent heat storage can amount to 50 % when the storage is used in a temperature interval of 10°C around the melting point of the PCM. The efficient heat exchange and high capacity make the macro-encapsulated PCM solution an attractive storage concept, in particular when it is integrated in a low temperature system and a PCM with adapted melting temperature is used.

Figure 4: Macro-encapsulated salt hydrate PCM capsules.