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ScienceDirect

Energy Procedia 91 (2016) 226 – 230

Energy Procedia

SHC 2015, International Conference on Solar Heating and Cooling for Buildings and Industry

IEA SHC Task 42 / ECES Annex 29

Compact thermal energy storage

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Abstract

The IEA SHC Task 42 / ECES Annex 29 concerns thermal energy storage technologies based on Phase Change Materials (PCM) and Thermo-Chemical Materials (TCM) as well as liquid and solid sorption processes. Sensible heat storages such as hot water tanks were not investigated in the task but served as benchmarks with respect to technical and economical evaluations. This IEA task is a joint task of the IEA Solar Heating and Cooling (SHC) program and the IEA Energy Conservation through Energy Storage (ECES) program and will run up to end of December 2015. This paper gives an overview on the topics and main results of IEA SHC Task 42 / ECES Annex 29.

Peer-review by the scientific conference committee of SHC 2015 under responsibility of PSE AG

Keywords: compact storage; storage engineering; storage materials; PCM; TCM; sorption technology; long term storage

1. Introduction

About half of the world's final energy demand is used for heating and cooling purposes. Therefore, technologies that can efficiently and effectively store heat are of key importance. They assist to increase the share of sustainable heat sources and improve the efficiency of thermal systems. Recent research results and technical developments show that thermal storage technologies will become even more important with increased use of Smart Grid developments.

Thermal energy storage technologies are needed to match the variable supply of sustainable heat and to optimize the performance of thermal systems. Innovative compact thermal energy storage technologies are based on the physical principles and properties of phase change materials (PCM) and on thermochemical materials (TCM). These

Peer-review by the scientific conference committee of SHC 2015 under responsibility of PSE AG
doi:10.1016/j.egypro.2016.06.208

materials offer the technical opportunities to store heat in a more dense form and with fewer losses than conventional, sensible heat storage technologies such as hot water storage tanks.

Some important application areas of compact thermal energy storage technologies are:

- seasonal storage of solar energy,
- "waste heat" recovery in industrial processes,
- temperature control in buildings,
- improved efficiency in the operation of Smart Grids, district heating- and low-temperature distribution networks using (micro)cogeneration plants, solar thermal collector systems and heat pumps, and
- thermal storage technologies that assist in the heat management of energy systems for hybrid and electric vehicles and transport systems.

The technology of compact heat storage systems is still under development. PCM products are already on the market for a number of niche applications. PCM is applied for temperature control in buildings and for transportation of vulnerable goods, such as medical items, food, etc. Although a number of TCMs exist (zeolites, salt hydrates and composite materials), their application in storage systems still needs more R&D work, especially with regard to process engineering.

2. Task description, task objectives and scope of the task

The objective of this joint Task was 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 covered phase change materials (PCMs), thermochemical materials (TCMs), and composite materials and nanostructures. It included activities on material development, analysis, and engineering, numerical modeling of materials and systems, development of storage components and systems, and development of standards and test methods.

The overall goal of this task was to develop advanced materials and systems for an improved performance of thermal energy storage. This goal can be subdivided into eight specific objectives:

- to identify material requirements for relevant applications, by means of numerical simulation of currently known storage technologies, using the simulation modules developed e.g. in Phase I.
- to identify, design and develop new materials and composites for compact thermal energy storage,
- to develop measuring and testing procedures to characterize new storage materials reliably and reproducibly,
- to improve the performance, stability, and cost-effectiveness of new storage materials,
- to develop multi-scale numerical models, describing and predicting the performance of new materials in thermal storage systems, and to compare them to conventional storage systems,
- to develop and demonstrate novel compact thermal energy storage systems employing the advanced materials,
- to assess the impact of new materials on the performance of thermal energy storage in the different applications considered, and
- to disseminate the knowledge and experience acquired in this task.
- to develop an approach for the economic evaluation of compact thermal energy storage systems.

This task dealt with advanced materials for latent and chemical thermal energy storage, and excluded materials related to sensible heat storage. However, the latter category was used as reference. The task dealt with these advanced materials on three different scales:

- material scale, focused on the behaviour of materials from the molecular to the ‘few particles’ scale, including e.g. material synthesis, micro-scale mass transport, and sorption reactions;
- bulk scale, focused on bulk behaviour of materials and the performance of the storage subsystem, including e.g. heat, mass, and vapour transport, wall-wall and wall-material interactions, and reactor design;
- system scale, focused on the performance of a storage within a heating or cooling system, including e.g. economical feasibility studies, case studies, and system tests.

Between 35 and 50 experts participated in the experts meetings that were carried out half-yearly. They came from the following countries: Austria, Australia, Belgium, Switzerland, Germany, Denmark, Spain, France, Italy, Japan, The Netherlands, Sweden, Slovenia, Turkey, United Kingdom.

3. Structure of task

The Task was organised in a matrix-like structure, see Figure 1. The horizontal axis represented materials-related categories. It was divided into 3 groups of similar activities in the working groups A1, A2 and A3. The vertical axis represented application and system related categories: Working group B on system development and working group C on economical evaluation of compact thermal energy storage systems.

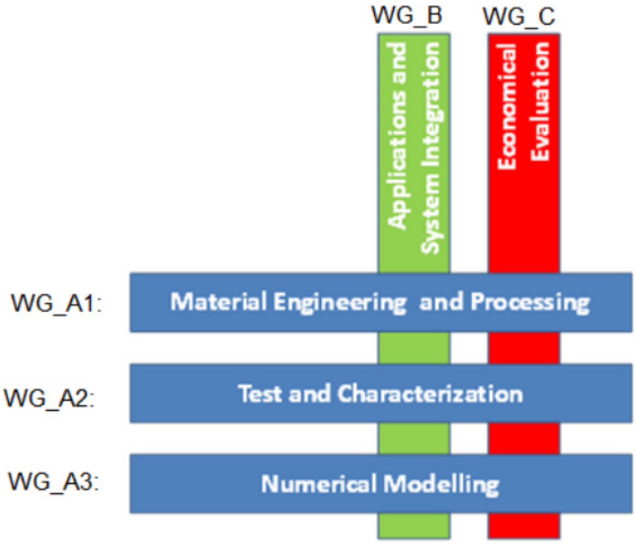

Fig. 1.Organisational structure of IEA SHC Task 42 / ECES Annex 29.

4. Results achieved

The key accomplishments of the task are summarized in the following 7 points:

1. A large number of modified and new PCM, TCM and sorption materials were investigated. New material-characterizing methods were investigated. Detailed information on the results of WG_A1 is given in the SHC2015 conference paper by Alenka Ristic et al. on “Engineering and processing of PCMs, TCMs and sorption materials” [1].

2. A new standard for an improved DSC(=Differential Scanning Calorimetry) measurement method has been developed in the task. It is described in the SHC2015 conference paper by Stefan Gschwander et al. on “Standardization of PCM characterization via DSC” [3]. More exactly known material properties will contribute to improve the possibilities for material developments and to provide a better basis for their application in thermal energy storage systems.

3. A data base for PCM, TCM and sorption materials was developed and established. The experts of the task recommended that in the future more experts of material science and chemists from the fields of organic and inorganic chemistry should be involved in order to strengthen the development of these materials.

4. Advances have been made in the numerical modelling of materials, see SHC2015 conference paper by Silvia Gaastrat-Nedea al. on “Advanced numerical modelling techniques to tune the properties of heat storage materials for optimal reactor performance” [3].

5. Material application and compact thermal storage system development is the final aim of the task’s research activities. A comprehensive summary on the system developments investigated within the frame of the task is given by the SHC2015 conference paper by Wim van Helden et al. on “Applications of Compact Thermal Energy Storage” [4].

6. A new approach is under development in order to assess the possible performance of a given material for a certain application. Andreas Hauer gave a presentation on this so-called “4-temperatures approach” at the SHC 2015 conference.

7. A tool for the economic evaluation of thermal energy storages has been developed. It has been validated against conventional thermal energy storages on the market and applied to the compact thermal storage systems under development in the task, see the SHC 2015 paper by Christoph Rathgeber et al. “A simple tool for the economic evaluation of thermal energy storages” [5].

5. Conclusions

In a “Position Paper on the current status of the development of Compact Thermal Energy Storage systems” [6] several barriers for the development of compact thermal energy storage systems were identified:

The development of Compact Thermal Energy Storage systems based on phase-change and thermo-chemical materials is still very much in its R&D phase. It therefore still faces strong technical, financial and non-financial challenges. The technical barriers are related to the fact that the technology needs further progress on three levels: 1) materials, 2) components, and 3) systems. The physical phenomena, which may be phase change processes, sorption processes or thermochemical reactions, take place on the molecular level. Basic and applied research is still necessary to fully understand the physics and chemistry involved in order to improve and synthesize storage materials. Modelling materials and the simulation of reactions and processes on the molecular scale will also contribute to this. While the reactions take place on the molecular scale, the energy to be stored or released is transported on a macroscopic scale. That means that process engineers need to be able to calculate and deal with the flow of liquids, gases or vapour. Moreover, very often components have to be designed to operate in vacuum conditions. In thermochemical reactions it is necessary to deal with heat and mass transfer, which leads to components that have to be controlled with respect to several different operational parameters in order to achieve a high energy storage performance.

This results in complex system operational conditions. They often include highly fluctuating environmental and meteorological conditions. Therefore, the systems under development still require highly complex control, which leads to high investment costs in developing prototype systems.

Therefore, the conclusion was that the following actions will be needed to drive market deployment effectively:

1. Strong support of R&D work by governmental and international research programs as described above. Compact thermal energy storage systems based on phase-change and thermo-chemical material technologies are to a large extent still in their development stage. The challenges cannot be addressed by single research groups and singularly achieved research results, but need a broad and internationally collaborative approach.
2. The companies involved in the development of compact thermal storage systems are often relatively small and highly innovative. They need strong support by governments to be able to apply their technology in the building and industrial processes sectors, in spite of the economic disadvantage they still may have.
3. Strong support of a growing number of demonstration projects is needed in order to gather operational experiences, to monitor and evaluate performance and to improve the performance of systems step-by-step. A much better basis for the further development and deployment of the huge potential of compact thermal energy storage systems will be established if these actions are taken.

It was therefore decided in December 2015 to initiate the necessary processes to establish a follow-on task within the frame of the IEA SHC and ECES programs. For further information you may contact the authors.

Acknowledgements

The authors would like to thank all the experts in the Task42/Annex29 for their valuable and sustained contributions to the further progressing of compact thermal energy storage technologies, systems, components, materials and methods. They also wish to thank the Swiss Federal Office of Energy (SFOE), the German Federal Ministry for Economic (BMWi) and the Netherlands Enterprise Agency (RVO.nl), respectively, for the financial support of their contributions to the work of the IEA SHC Task 42 and IEA ECES Annex 29.

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