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Testing of PCM heat storage modules with solar collectors as heat source

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Abstract

A latent heat storage based on the phase change material Sodium Acetate Trihydrate (SAT) has been tested as part of a demonstration system. The full heat storage consisted of 4 individual modules each containing about 200 kg of sodium acetate trihydrate with different additives. The aim was to actively utilize the ability of the material to supercool to obtain long storage periods. The modules were charged with solar heat supplied by 22.4 m^2 evacuated tubular collectors. The investigation showed that it was possible to fully charge one module within a period of 270 minutes with clear skies. In long periods with high level of irradiance several modules were charged in parallel due to the limited heat exchange capacity of the integrated heat exchanger of the modules. After the modules were heated to more than 80° C they were set to passively cool down. Modules reached 30°C in a period of parallel cool down without the sodium acetate trihydrate solidified in 3 of the 4 modules. Further tests showed that stable supercooling at ambient temperature is possible.

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Keywords: Phase change material; PCM; Seasonal heat storage; Sodium acetate trihydrate; Compact thermal energy storage; Stable supercooling

1. Introduction

To integrate more solar energy into existing energy supply systems, long term heat storage is desired. The investigated heat storage concept is based on the principle of utilizing stable supercooling of a Phase Change Material (PCM). If Sodium Acetate Trihydrate (SAT), which has a melting point of 58 °C, has been fully melted, it

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can cool down to ambient temperature in its liquid phase without releasing the heat of fusion. Having a PCM rest in supercooled state in temperature equilibrium with the ambient allows principally seasonal heat storage in compact systems [1]. To achieve stable supercooling in heat storage modules with SAT, a minimum material temperature of 80 °C must be achieved during the heating in all parts of the material volume, according to the experimental experience. The principle is shown in Fig.1.

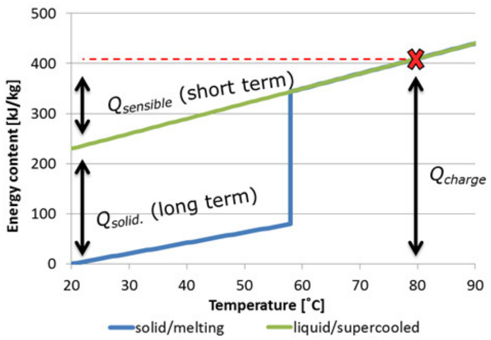

Fig. 1. Principle of stable supercooling with sodium acetate trihydrate.

The PCM heat storage can be used for short term heat storage by utilizing the sensible heat ($Q_{sensible}$) of the melted and supercooled PCM. The heat storage module can be left at ambient temperature with no heat loss until there is a heat demand (as long term heat storage). In that case solidification is activated, the heat of fusion ($Q_{solid.}$) is released, and the module temperature increases almost immediately to the melting temperature.

In this paper data from initial testing of heat storage modules, containing different mixtures of the PCM sodium acetate trihydrate, are presented. Modules in different material configurations have previously been tested under laboratory conditions to prove the concept [2]. The modules form a long term heat storage as a part of a solar combi-system including additionally a solar collector field and a water buffer storage. The solar combi-system was connected to an automated tapping system simulating domestic hot water tapping and space heating demands. The overall system design and its functionality were explained by J. B. Johansen et al. [3].

2. Method

Four modules were tested with different phase change materials based on SAT. The modules were assembled to a heat storage stack and charged via a plate heat exchanger by heat from the solar collector loop.

2.1. PCM modules

A schematic drawing of the PCM module is shown in Fig.2. The modules were fabricated with an internal height of 5 cm of a closed material chamber (volume: 150 litre) by Nilan A/S. Two of the modules were in stainless steel. The other two modules were in steel. The water volume in the heat exchanger of each module was 32 litres. An air expansion volume, connected to the expansion vessel, ensured limited change of pressure during material expansion (about 10%) from solid to liquid state. A PCM temperature sensor was placed in a probe on one end of the module.

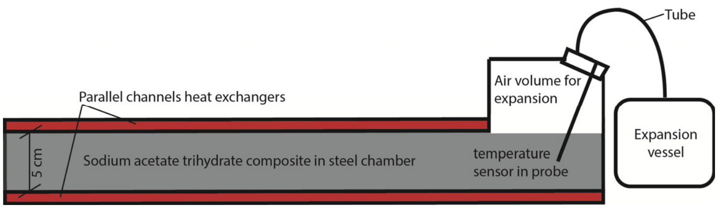

Fig. 2. Schematic module design with expansion vessel.