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# Solar heating and cooling system with absorption chiller and latent heat storage - A research project summary -

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**Abstract**

A reliable solar thermal cooling and heating system with high solar fraction and seasonal energy efficiency ratio (SEER) is preferable. By now, bulky sensible buffer tanks are used to improve the solar fraction for heating purposes. During summertime when solar heat is converted into useful cold by means of sorption chillers the waste heat dissipation to the ambient is the critical factor. If a dry cooler is installed the performance of the sorption machine suffers from high cooling water temperatures, especially on hot days. In contrast, a wet cooling tower causes expensive water treatment, formation of fog and the risk of legionella and bacterial growth. To overcome these problems a latent heat storage based on a cheap salt hydrate has been developed to support a dry cooler on hot days, whereby a constant low cooling water temperature for the sorption machine is ensured. Therefore the need of a wet cooling tower is avoided and neither make-up water nor maintenance is needed. The same storage serves as additional low temperature heat storage for heating purposes allowing optimal solar yield due to constant low storage temperatures. Four pilot installations between 7 kW and 90 kW nominal cooling capacity were equipped with latent heat storages between 80 kWh and 240 kWh energy content. Annual in situ measurement data shows a positive effect on the seasonal energy efficiency ratio (SEER) for cooling up to 11.4. Furthermore simulation results under different climatic conditions indicate raising efficiency up to 64% compared to a system with solely dry re-cooling. Long-term test bench measuring data concerning performance and durability as well as a new approach for a state of charge detection for latent heat storages are presented as well.


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*Keywords:* sorption chiller; latent heat storage; phase change material; dry re-cooling;seasonal performance; annual simulation

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## 1. Motivation and solution approach

In reliable solar thermal installations for heating, cooling and domestic hot water preparation a high solar fraction with minimum effort on auxiliary electricity and primary energy consumption is preferable.

During the heating season the solar yield is directly used for space heating or stored in buffer and hot water tanks for later use. In order to achieve high solar fractions bulky sensible storages up to a specific volume of 100 liter per square meter collector area are installed. Due to the increase in temperature up to 95 °C of the sensible heat storage medium (mostly water) during loading the average solar thermal collector temperature rises resulting in diminished total collector system effectiveness. Furthermore the high buffer tank temperatures cause high radiation and convective losses if no enhanced insulation is applied. This deteriorates the specific electricity consumption of the useful heat supplied to the building and for domestic hot water preparation.

In summertime when chilled water for climatisation is needed the harvested solar thermal energy is converted into useful cold by means of Ab- and Adsorption machines starting at driving heat temperatures above 60 °C, whereby their performance is mainly influenced by the temperature level of the three main hydraulic circuits namely chilled water, cooling water and driving heat. While the chilled water supply temperature is defined by the HVAC installation of the building and material properties limit the driving heat temperature to 100 °C, the cooling water temperature depends on the climatic conditions and cooler type.

In most sorption cooling installations wet cooling towers are applied for waste heat dissipation to the ambient allowing a minimum cooling water return temperature of about 8 K above the wet bulb air temperature. This approach can be reduced by disproportional increase of the heat exchanger surface and/or air flow in the cooler, whereas less than 4 K will be extremely cost-intensive and/or auxiliary electricity consuming. On the one hand the low cooling water temperatures, even below the ambient air temperature, have a beneficial effect on the chilling capacity and thermal Coefficient of Performance (COP) of the sorption chiller. But on the other hand due to the open water system of wet cooling towers the risk of legionella and bacterial growth as well as calcification and fouling require a costly water treatment system and high maintenance/inspection effort. Furthermore legal restrictions concerning vapor plumes, noise prevention and bacterial monitoring as well as limited market availability of wet cooling towers for small scale sorption cooling systems are hindering facts for their use.

If an almost maintenance-free dry air cooler is installed cooling water return temperature increases significantly and is in economic terms limited to 4 K above the ambient air temperature. As a consequence of the increase in cooling water temperature the thermal Coefficient of Performance (COP) falls as well as the chilling capacity if the driving heat temperature is not increased accordingly. Due to the solely sensible heat transfer a huge specific heat exchanger surface resulting in an enormous footprint and a high air flow through the cooler is needed.

Hybrid cooler combine the advantages and disadvantages of aforementioned cooler types. But due to the high investment costs and the open water system a comprehensive implementation especially in small to medium sized solar heating and cooling systems is questionable.

A favorable situation is given when low temperature heating and cooling facilities, e.g. floor or wall heating systems, activated ceilings or fan coils, are applied in the building. Especially for this kind of low exergy space heating systems a latent heat storage allows low operating temperature of the solar thermal system, yielding efficient operation with solar gain due to constant low storage temperatures. High amounts of thermal energy can be stored at a certain phase change temperature while the storage material changes its phase (e.g. solid to liquid). Particularly at small temperature differences between loading and unloading the volumetric storage density of latent heat storages is significantly higher compared to common sensible water buffer tanks.

During summertime when chilled water is provided by the sorption chiller, the same storage can be used in combination with a low-maintenance dry cooling tower to avoid an unpreferable wet cooling tower. By partly absorbing the waste heat of the chiller during daytime the latent heat storage supports the dry cooler and ensures constant low cooling water temperatures even on hot days. The accumulated waste heat is then dissipated to the ambient during nighttime. By that means heat dissipation of the chiller is shifted partly to periods with lower ambient temperatures, i.e. night time, or to off-peak hours.