INTERNATIONAL JOURNAL OF REFRIGERATION 32 (2009) 596–606

available at www.sciencedirect.com

journal homepage: www.elsevier.com/locate/ijrefrig

Solar heating and cooling system with absorption chiller and low temperature latent heat storage: Energetic performance and operational experience

*M. Helm, C. Keil, S. Hiebler, H. Mehling, C. Schweigler**

Bavarian Center for Applied Energy Research (ZAE Bayern), Germany

ARTICLE INFO

Article history:
Received 12 November 2008
Received in revised form
26 January 2009
Accepted 12 February 2009
Published online 27 February 2009

Keywords:
Air conditioning
Absorption system
Heating
Solar energy
Experiment
Heat storage
Material
Phase change-performance

ABSTRACT

Absorption cooling systems based on water/lithium bromide (LiBr) solution typically require an open wet cooling tower to transfer the reject heat to the ambient. Yet, water consumption, the need for water make-up and cleaning, formation of fog, and the risk of *Legionella* bacteria growth are hindering factors for the implementation of small solar cooling systems. The application of a latent heat storage supporting the heat rejection of the absorption chiller in conjunction with a dry cooling system allows eliminating the wet cooling tower. By that means heat rejection of the chiller is shifted to periods with lower ambient temperatures, i.e. night time or off-peak hours.

The system concept and the hydraulic scheme together with an analysis of the energetic performance of the system are presented, followed by a report on the operation of a first pilot installation.

Système de chauffage et de conditionnement d’air à base d’une machine frigorifique à absorption et d’un stockage de chaleur latente à basse température : performance énergétique et résultats opérationnels

Mots clés : conditionnement d’air ; système à absorption ; chauffage ; énergie solaire ; expérimentation ; accumulation thermique ; matériau ; changement de phase - performance

---

* *Corresponding author*. Bavarian Center for Applied Energy Research (ZAE Bayern), Division 1, Technology for Energy Systems and Renewable Energy, Walther-Meissner-Str. 6, D-85748 Garching, Germany. Tel.: +49 (0) 89 329 442 19; fax: +49 (0) 89 329 442 12.

E-mail address: schweigler@muc.zae-bayern.de (C. Schweigler).

URL: http://www.zae-bayern.de

doi:10.1016/j.ijrefrig.2009.02.010

Nomenclature

u	overall heat transfer coefficient ($W\,m^{-2}\,K^{-1}$)
A	surface area (m^2)
ΔT	temperature range (K)
Q	heat duty (kW)

Abbreviations

COP	coefficient of performance
PCM	phase-change material

Subscripts

max	maximum
E	evaporator
G	generator (desorber)
A/C	absorber and condenser
Aux	auxiliary
el	electrical
th	thermal

1. Introduction

In solar thermal installations with large capacity, both solar cooling and solar heating are provided synergistically yielding a complete annual utilization. During the cold season solar heat serves for space heating. During the warm season solar heat is converted into useful cold by means of sorption cooling devices avoiding overheating of the solar thermal system. Solar cooling installations predominantly cover cooling capacities in the range of 10–30 kW, requiring solar systems of about 30–100 m^2 collector surface area. Wet cooling towers designed for coolant supply/return temperature about 27/35 °C are applied to transfer the heat rejected by absorber and condenser to the ambient. Yet, water consumption, the need for water make-up and cleaning, formation of fog, and the risk of *Legionella* bacteria growth are hindering factors for their use. This is a crucial aspect for the implementation of solar cooling systems, especially when small capacity installations are in question. When a dry air cooler is to be used, cooling water temperatures have to be increased to 40/45 °C. As a consequence of the increase of the cooling water temperature, the temperature level of the driving heat supplied to the generator of the absorption chiller has to be increased accordingly. The above notation for the temperatures of the coolant loop represents the supply/return temperature of the coolant entering and leaving the respective cooling device. This notation will be used for all further discussion of heat sink and heat source temperatures within this publication.

A respective cooling tower device for 10 kW chilled water capacity including the required controls costs about 2000–2500 Euro. For about the same price dry air coolers are available with the capability to cool a glycol–brine coolant cycle of 45/40 °C at ambient air temperatures up to about 32 °C, which is a proper design value for air-conditioning systems in many parts of Europe according to ASHRAE tables.

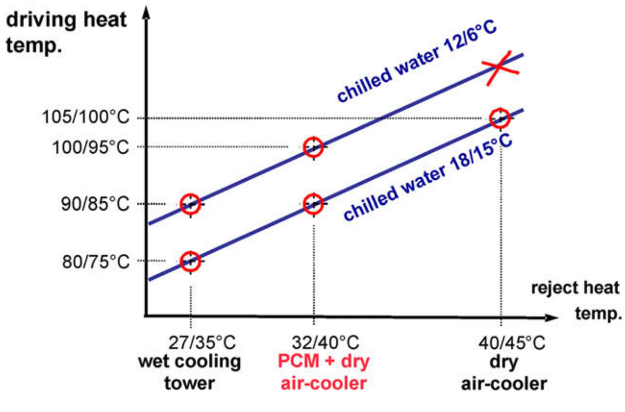

Fig. 1 – Impact of chilled water temperature and reject heat temperature on driving heat temperature.

Both systems, wet cooling towers and dry air coolers allow for significantly lower coolant temperatures during off-peak hours with moderate ambient air temperatures, of course.

If a latent heat storage is integrated in the coolant loop in addition to the dry air cooler, coolant cycle temperatures at design point operation can be reduced to about 40/32 °C. Thus referring to the above standard design with 45/40 °C coolant temperature, the same dry air cooler will be able to operate at reduced coolant temperatures of about 40/36 °C at 32 °C ambient temperature, providing about half of its nominal capacity specified for cooling water temperature 45/40 °C. The latent heat storage then would have to cool the brine from 36 to 32 °C, which is reasonable for internal phase-change temperatures about 29 °C. A further reduction of the coolant cycle temperatures during off-peak hours with moderate ambient air temperatures is possible for this configuration, too. The general dependency of the required driving temperatures on the coolant temperatures of an absorption chiller can easily be estimated from the linear "characteristic-equation" model (Furukawa, 1983; Hellmann et al., 1998). The external heat carrier parameters for the discussed system configuration – governed by linear correlation according to the characteristic-equation model – are given in Fig. 1. The model reflects the general characteristics of a sorption cycle with a strong influence of the external

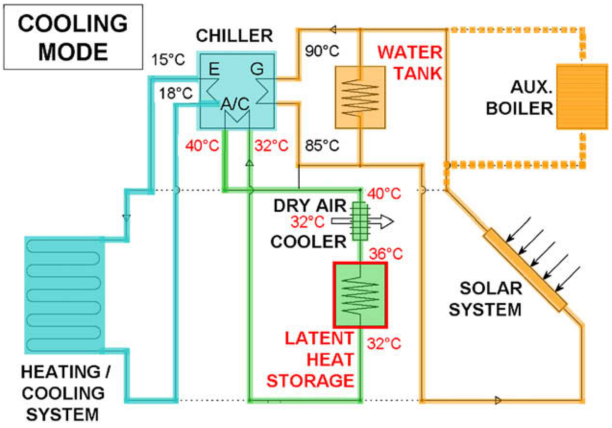

Fig. 2 – System structure of a solar heating and cooling system with absorption chiller (with main components evaporator E, absorber/condenser A/C and generator G) and latent heat storage in cooling mode.