Applied Thermal Engineering 38 (2012) 124–130

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

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

Three adsorbers solar cooler with composite sorbent bed and heat pipe thermal control

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ARTICLE INFO

Article history:
Received 5 July 2011
Accepted 20 December 2011
Available online 28 December 2011

Keywords:
Adsorption
Chemical reactions
Heat recovery
Heat pipes
Solar heating

ABSTRACT

Three adsorbers solar cooler was experimentally investigated. Ammonia was chosen as a working fluid. Two adsorbers (twins) were filled with the same complex compound (activated carbon fiber with $MnCl_2$ microcrystals on the filament surface). The third low temperature adsorber has second complex compound (activated carbon fiber with $BaCl_2$ microcrystals on the filament surface). The cycle of physical adsorption and chemical reactions in the sorbent bed of adsorber was followed by condensation/evaporation of ammonia inside the pores. This combination of adsorption/condensation and evaporation/desorption is a novelty of cooler design, which increases the heat and cold generation in adsorber. The specific feature of third adsorber is the time of its cold generation. This time includes the liquid evaporation and desorption/regeneration time of ammonia in the sorbent bed. The cooler thermal management is based on heat pipes. The solar heating is a source of energy for cooler. The sink of the cold is the air flow.

1. Introduction

Refrigeration technologies have been critical in the evolution of production and distribution systems a long period of time. Reduction in use of synthetic refrigerants and production of CO_2 provide a new opportunity for solar cooling and refrigeration. The concept of solar-powered refrigeration cycles is known at least two decades and several refrigerators operating on this principle are commercially available.

There were many projects for the development or demonstration of solar refrigeration technologies and solar refrigeration continued to be an important issue, J. Bougard, G. Veronikis, 1992 [1]. Adsorbents like zeolite, silica gel, activated carbon and alumina oxide are considered as physical adsorbents having highly porous structures with surface-volume ratios in the order of several hundreds that can selectively catch and hold refrigerants. When saturated, they can be regenerated simply by being heated. If an adsorbent and a refrigerant are placed in the same vessel, the adsorbent would maintain the pressure by adsorbing the evaporating refrigerant. The process is intermittent because the adsorbent must be regenerated when it is saturated. For this reason, multiple adsorbent beds are required for continuous operation. Conventional working pairs include activated carbon and methanol, or ammonia, Pons and Guilleminot, 1986 [2]; Wang et al., 1997, 2001 [3,4], Critoph, 2002 [5], and silica gel-water, Grenier et al., 1988 [6]. Current solar adsorption technology can provide a daily ice production of 4–7 kg per unit square meters of solar collector with a solar-to-cooling COP between 0.1 and 0.15, Wang and Oliveira, 2005 [7]. Different small-capacity silica gel-water adsorption chillers have been developed for solar air conditioning, Saha et al., 2001 [8]. Its cooling capacity was reported between 3.2 and 3.6 kW; COPs ranged from 0.2 to 0.6 for the working temperature diapason from 55 to 95 °C. Unlike the more common single-staged double-bed systems, Saha et al. (2001) [8], developed a double-staged four-bed cycle machine to use at very low driving temperatures. The machine produced 3.2 kW cooling and 55 °C hot water output with COP of 0.36.

However, there has been a little research made into the integration of short time cycles sorption machines of solar power with natural gas, or electrical immersion heater as a back-up, Vasiliev at al., 1999 [9].

The combined action of physical adsorption and chemical reactions for the cold production in the same space and at the same time is attractive initiative to enhance the COP of a system, Vasiliev et al., 1994 [10]. The use of heat pipes to improve the performance of carbon-ammonia adsorption refrigerator was suggested by Vasiliev et al., 1996 [11]. It was shown that heat transfer in the sorbent bed

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1359-4311/$ – see front matter
doi:10.1016/j.applthermaleng.2011.12.031