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Hourly performance prediction of ammonia–water solar absorption refrigeration

Muammer Ozgoren [a,*], Mehmet Bilgili [b], Osman Babayigit [c]

[a] Selcuk University, Faculty of Engineering and Architecture, Mechanical Engineering Department, 42079 Selcuklu, Konya, Turkey
[b] Cukurova University, Faculty of Ceyhan Engineering, Mechanical Engineering Department, Adana, Turkey
[c] Selcuk University, Hadim Vocational School, Konya, Turkey

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ABSTRACT

This paper deals with the hourly performance investigation of solar absorption refrigeration (SAR) system with evacuated tube collector and ammonia–water (NH_3–H_2O) solution. The SAR system is presented to simulate the system characteristic variations using hourly atmospheric air temperature and solar radiation data for Adana province in Turkey. The evaluation is performed for the maximum temperature occurrence day on July 29. First, the variations of various parameters, such as absorption refrigeration machine efficiency, condenser capacity and heat transfer rate in the generator and absorber during the day, are calculated for different cooling capacities and generator temperatures. Later, the minimum evacuated tube collector surface area is determined. According to the obtained results, the SAR system is considerably suitable for home/office-cooling purposes between the hours 09:00 and 16:00 in the southern region of Turkey such as Adana province. The most suitable performance of the absorption cooling system is calculated for the generator temperature values equal to or higher than 110 °C. The performance coefficient of the cooling ($COP_{cooling}$) varies in the range of 0.243–0.454 while that of the heating ($COP_{heating}$) changes from 1.243 to 1.454 during the day. Evacuated tube collector area for a 3.5 kW cooling load capacity is found to be 35.95 m^2 for the region at 16:00 whereas it is 19.85 m^2 at 12:00.

1. Introduction

Energy is considered as a major agent in the generation of wealth and an important factor in economic development [1–4]. With developing technology, the rapid increase in world population, increasing thermal loads, life standards and comfort demands in conjunction with architectural characteristics and trends, the demand for energy and its use for cooling are ever increasing [5]. In a world of continuously growing scarcity of primary energy as well as of an insurmountable irreversible environmental impact, due to human activity onto the biosphere, it is of utmost importance to look for alternatives to traditional energy sources [6]. The main advantages concern the reduction of peak loads for electricity utilities, the use of zero ozone depletion impact refrigerants, the decreased primary energy consumption and decreased global warming impact [7].

In summer, particularly under tropical climate, air conditioning has the highest energy expenditure in buildings [8]. During recent years, research aimed at the development of technologies that can offer reductions in energy consumption, peak electrical demand, and energy costs without lowering the desired level of comfort conditions has intensified. Alternative cooling technologies that can be applied to residential and commercial buildings, under a wide range of weather conditions, are being developed [9]. Reduction of energy consumption for refrigeration, however, cannot be relied solely on the improvement of efficiency. Another method of reducing the amount of energy consumption is solar cooling. Solar cooling applied in buildings is without a doubt an interesting alternative for solving problems of electrical over-consumption in traditional compression vapor air conditioning. Solar energy usage for cooling purpose in buildings offers the advantage of using an inexhaustible and free heat source to meet cooling needs most of the time [8,10]. Considering that cooling demand increases with the intensity of solar radiation, solar refrigeration has been considered as a logical solution [11].

Solar energy occupies one of the most important places among various alternative energy sources [12]. In particular, it has been identified as a convenient renewable energy source, because it is

* Corresponding author. Tel.: +90 332 223 2764; fax: +90 332 241 0635.
E-mail addresses: mozgoren@gmail.com, mozgoren@selcuk.edu.tr (M. Ozgoren), mbilgili@cu.edu.tr (M. Bilgili), obabayigit@selcuk.edu.tr (O. Babayigit).

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more widely available and can be stored in batteries via photovoltaic (PV) arrays, and converted to heat or mechanical energy with reasonable efficiency [13]. The direct use of solar energy as primary energy source is interesting because of its universal availability and low environmental impact. Different technologies can be adopted to get refrigeration from solar energy: thermal and electric solar systems, and some new emerging technologies. The solar thermal systems include absorption, adsorption, solar ejector, thermo-mechanical and regenerative desiccant solutions [14]. Absorption cooling has been one of the first and oldest forms of air-conditioning and refrigeration systems since it was invented in eighteen century. Absorption systems are thermally activated, and they do not require high input shaft power. Therefore, where power is unavailable or expensive or where there is waste, geothermal, or solar heat available, absorption machines could provide reliable and quiet cooling. As no chlorofluorocarbons (CFCs) are used, absorption systems are friendlier to the environment [15–17]. In addition, they do not contribute to the ozone depletion or to global warming [18,19]. Although absorption systems seem to provide many advantages, its COP is too low and its investment cost is very expensive [20,21]. The most usual combinations of fluids include lithium bromide–water ($LiBr–H_2O$), where water vapor is the refrigerant, and ammonia–water ($NH_3–H_2O$) systems, where ammonia is the refrigerant. The $NH_3–H_2O$ system is more complicated than the $LiBr–H_2O$ system, since it needs a rectifying column to assure that no water vapor enters the evaporator, where it could freeze [22–24]. Contrary to compression refrigeration machines, which need high-quality electric energy to run, ammonia–water absorption refrigeration machines use low-quality thermal energy. The temperature of the heat source does not usually need to be so high (80–170 °C) that the waste heat from many processes can be used to power absorption refrigeration machines [9].

Turkey has high solar energy potential because of its location in the northern hemisphere with latitudes 36–42° N and longitudes 26–45° E. Yearly average solar radiation in Turkey is 3.6 kWh/m^2 day and the total yearly radiation period is ~2610 h. Solar radiation, which reaches a maximum value around noontime during summer season, can be ~900 W/m^2 in the southern region of Turkey. Consequently, it is of worth to investigate and conduct research on this solar energy source [7].

In the present study, a solar absorption refrigeration system using evacuated tube collector and $NH_3–H_2O$ absorption unit is analyzed to simulate the system by using meteorological data such as hourly atmospheric air temperature and solar radiation for Adana province in Turkey. The evaluation is performed for the maximum temperature occurrence day on July 29. The analysis reason for Adana province is that cooling season period can be extended as many as eight months and solar energy potential is fairly high level in the southern region of Turkey. Moreover, Turkish

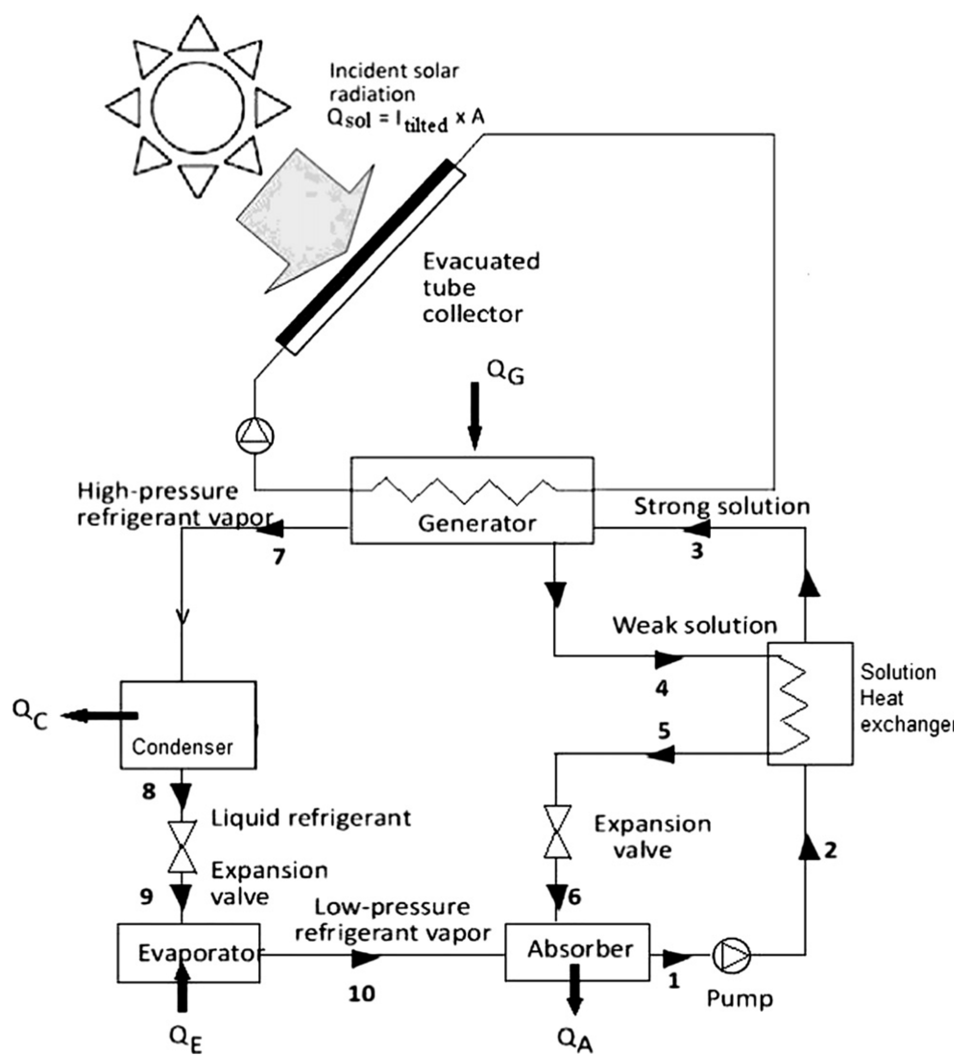

Fig. 1. Components of the solar absorption refrigeration (SAR) system.