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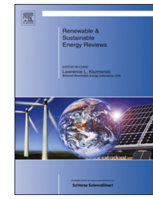

Review of diffusion–absorption refrigeration technologies

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ABSTRACT

A review of diffusion–absorption refrigeration technologies has been done in this work in order to promote their main characteristics in terms of the refrigeration process, their applications, work fluids, current trends and limitations, among others. Over 70 publications in the field were analyzed concluding that diffusion–absorption technology represents a complementary and viable alternative in the field of refrigeration technologies for small cooling capacity, due to an increase in the current demand of refrigeration and air-conditioning devices.

Contents

1. Introduction

In the last decades there has been an inevitable increase in the demand in refrigeration and air-conditioning devices to fulfill basic and comfort needs in different sectors of society. Refrigeration technology based on vapor compression is the leading technology in the world, which is an indirect cause of greenhouse effect gases due to the type of energy it uses. It consumes nearly 30% of the final energy in the world [1]. Furthermore, developing countries continue to use compression systems based on refrigerant fluids that damage the ozone layer, ODP, and represent a high global warming potential, GWP.

New technologies have emerged in response to the search for better alternatives that would not have damaging effects on the environment. These technologies are characterized by the type of activation energy, such as the use of renewable energy including solar, geothermal, residual heat, etc., which can be translated to a reduction of greenhouse gas emissions, and the working fluids that they use do not contribute to global warming.

Among these technologies, refrigeration systems by absorption are the most commonly used for refrigeration and air conditioning applications [2], which ones have been demonstrated that under the same cooling capacity, the total energy consumed and total cost is less than a vapor compression system [3]. A large number of absorption refrigeration units have been designed and commercialized around the world with refrigeration capacities between 10 and 1000 kW [4]. Small capacity absorption refrigeration systems have problems in the solution pump which results in an inefficient performance of the device and therefore of the global system. Diffusion–absorption refrigeration systems have been developed as a response to such problems. This type of technology uses three working fluids in its refrigeration process, which are distinctive of this technology. Among these fluids are $NH_3/H_2O/H_2$, in which ammonia is used as a refrigerant, the water is used as an absorbent and hydrogen as an auxiliary gas.

The first diffusion–absorption refrigeration system was developed and patented in the 1920s [5] and since then millions of units

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have been manufactured for domestic refrigeration devices, caravans, camps, recreational vehicles, hotel rooms and areas with no electricity.

The activation energy for these devices can come from liquefied gas (LPG), natural gas or kerosene. Even when these systems can run for numerous continuous hours, its application is limited to small capacity refrigerators. They have low efficiency; traditionally a refrigerator based on this technology provides a cooling capacity between 200 and 400 W, with a coefficient of performance, COP, between 0.2 and 0.25.

Therefore research has been done through the years in order to find significant increases in energy efficiency for domestic appliances [6–8], but the best COP that has been found is around 0.3 [9]. The bubble pump is among the most studied components of the diffusion–absorption systems, which is a critical component that has a positive effect in the energy efficiency of the system. Other studies show that geometric parameters and the characteristics of the flux regime are also factors that affect efficiency [10–15].

Based on the latter, the main objective of this work is to provide knowledge regarding the history and existing works based on diffusion–absorption refrigeration technology, its main characteristics, applications and trends as an alternate technology in the field of refrigeration and air-conditioning. This information will allow researchers and developers to understand and improve this technology, as well as provide greater impulse for it to be considered a viable alternative in this area.

2. Cooling process and components

Fig. 1 shows a schematic diagram of a diffusion–absorption refrigeration system (DAR). The main components of the DAR system are: generator/bubble pump, condenser, evaporator, solution heat exchanger (SHE), gas heat exchanger (GHX), reservoir and absorbent. This system can be grouped into three working circuits called: refrigeration circuit, dissolution circuit and gas circuit. The cycle operates under Dalton's law principle based on partial pressures and the pressure in each point of the system is maintained constant using a gas auxiliary. The DAR system operates in two pressure levels while in operation, similar to a conventional refrigeration system.

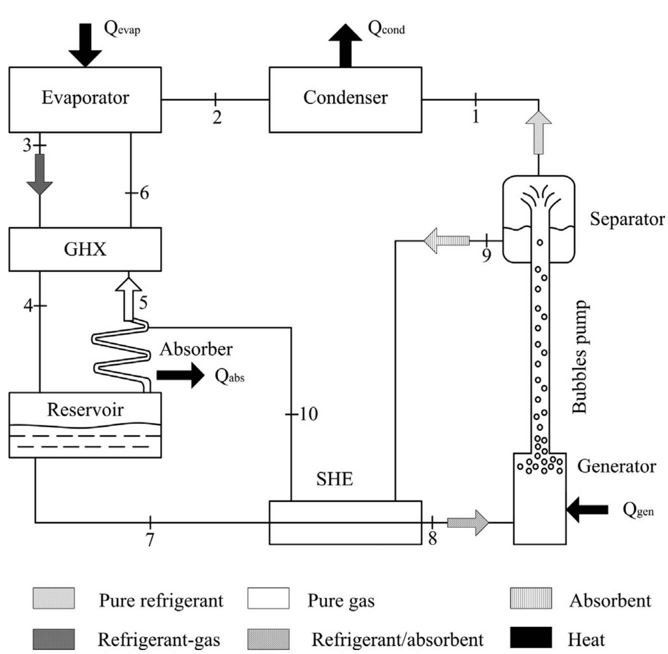

Fig. 1. Refrigeration process for a diffusion–absorption system.

Activation energy for the system, Q_{gen}, is provided by the generator in order to start heating the solution which is rich in refrigerants and comes from the deposit (8); this results in the formation of vapor bubbles that are dragged though the bubble pump tube with a small amount of liquid, until they are separated. The solution which is poor in refrigerant (9) flows towards the solution heat exchanger (SHE) where it yields heat to the solution rich in refrigerant (7) and is then sent to the absorber (10). The vapor rich in refrigerant (1) is then sent to the condenser, where it is condensed through an exothermal process (Q_{cond}), therefore the resulting liquid is introduced in the evaporator (2). Since the evaporator is loaded with gas (6), the liquid's partial pressure diminishes rapidly and as a result low temperature evaporation begins, producing the refrigerant effect, Q_{evap}. Once out of the evaporator, (3), the mixture of refrigerant and gas flows towards the gas heat exchanger (GHX), whose objective is to reduce the temperature of the gas (4) in order to send it to the deposit. In the absorber, the refrigerant is absorbed by the absorbent, and heat is freed either by cooling water or from the exterior (Q_{abs}); since the gas is less dense than the refrigerant, it is separated (5) and sent back to the gas heat exchanger in order to continue the cycle and the refrigerating effect.

Since its invention the diffusion–absorption refrigeration system had been used for small refrigeration capacity units (minibars). Its main benefits are that it does not need a pump to circulate the solution from the absorber to the generator, it does not have mobile parts, and it is noise free, portable, safe and low cost [16]. The generator/bubble pump is the most critical component and the heart of the diffusion–absorption systems. The purpose of this component is to separate the larger amount of the refrigerant from the solution; therefore the efficiency of the system is dependent most of all on the characteristics of the bubble pump [17]. The design and construction of the generators/bubble pump is based on concentric heat exchanger tubes in which the solution rich in refrigerant flows in the inner tube while the poor solution flows in the outer tube. In order to dissipate the heat in the rectifier and condenser, finned tubes are used as heat exchanger equipment. The process of production of cold takes place in the evaporator, which is formed by two coaxial tubes in which the refrigerant and the gas are mixed in a small chamber. Finally, the absorber aims to absorb as much refrigerant as possible. Coaxial exchangers are widely used as heat exchange equipment, and the heat transfer process is done by natural convection with the surroundings (systems cooled by air). In equipments with larger capacity (0.5–3 kW), shell and tubes heat exchangers are also used. They use water as the secondary fluid. In some experimental prototypes the use of plate or coaxial heat exchanger has been introduced to reduce heat loss and size and increase its efficiency, therefore increasing the system's energetic efficiency [18].

3. Main working fluids

The NH_3/H_2O mixture has extended its use in diffusion–absorption refrigeration systems. This is due to the fact that the mixture is chemically stable within a large range of operating pressures and temperatures. Besides, ammonia presents a high latent evaporation heat and a low freezing point (−77 °C) making it possible to use it in other applications that require low evaporation temperatures. Since NH_3/H_2O is volatile, a rectifier should generally be used to separate the water that evaporates with the ammonia, which increases heat loss and reduces the global energy efficiency. Additionally, NH_3/H_2O has the advantage of not affecting the environment and its production cost is 10–20% less than a synthetic refrigerant [19]; its thermophysical properties