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A review of membrane contactors applied in absorption refrigeration systems

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ABSTRACT

The use of membrane contactor technology is well-known in the process industry and can be employed in many important fields; such as separation and absorption processes, membrane distillation, pervaporation, biotechnology, food industries etc. In recent years, research has been carried out regarding the use of membrane contactors in the components of absorption refrigeration systems. The use of membrane contactors makes it realizable to design compact components with improved heat and mass transfer. Heat and mass transfer performance of the components is significantly enhanced due to the higher area to volume ratio available. Membrane based absorber and desorber allow the reduction in size of the absorption refrigeration systems to a great extent and thus absorption refrigeration technology can be used in transport and small scale applications. In this paper, the applications of membrane contactors in absorption refrigeration systems are reviewed. The application of membrane contactors in the components of absorption refrigeration systems, the configurations of refrigeration cycles that employ membrane contactors and the characteristics of the membrane contactors used in absorption refrigeration systems are all reviewed in detail. Information is collected on the choice of working fluid mixture to be used in absorption refrigeration systems that use membrane based components and the compatibility of working fluid mixtures with the membrane contactor material is discussed. The significance and limitations of using membrane contactors in absorption refrigeration systems is included in this paper.

Contents

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1. Introduction

The application of membranes in the process industry is growing. This is due to the relative simplicity, reliability, high parameters of separation, large interfacial area and lower energy consumption with improved heat and mass transfer. The cost of the membrane based components is also lower under short time of capital recurring and suffers negligible corrosion. Membrane contactors can be utilized in many important fields. These include separation and absorption processes, membrane distillation, pervaporation, biotechnology and food industries among others. Hydrophobic porous membranes are extensively utilized in the field of distillation technology and in air-conditioning systems to remove excess moisture, carbon dioxide and organics. Air moisture content and carbon dioxide concentration can be independently and simultaneously controlled efficiently with the help of membrane contactors. One of the emerging applications of membrane contactors lies in the field of absorption refrigeration systems.

Absorption refrigeration technology, which has the ability to utilize heat directly for cooling purposes, has been one of the most widely used technologies for refrigeration and cooling applications since the early stages of refrigeration technology. Vapour compression systems can achieve high values of the coefficient of performance (COP) but at a cost of very high mechanical energy input. However, absorption refrigeration systems can efficiently utilize the renewable energy sources, such as solar energy and low grade thermal energy (i.e. waste heat energy) as a source of energy input instead of using costly mechanical energy. Moreover, the refrigerants used in conventional vapour compression refrigeration systems are not environmental friendly and can contribute to ozone depletion and greenhouse effects, whereas in the absorption refrigeration systems the working fluid mixtures are environmental friendly. Currently, the world is facing an energy shortage problem and it is predicted that the interest in absorption refrigeration systems will increase in the future due to the fact that they can use renewable energy sources and refrigerants that are environmental friendly and do not contribute to Ozone depletion. Absorption refrigeration systems have a high capital cost when compared to vapour compression systems, but for large scale applications the lifecycle cost is very low. However, the absorption refrigeration technology is still relatively little used for cooling applications. In particular, in the sector of mobile refrigeration/air-conditioning, absorption refrigeration has not yet gained much interest. The main drawback of absorption refrigeration systems is the large volume per unit of cooling capacity which has limited their use in mobile applications and small commercial and residential buildings. There is a growing need to design an absorption refrigeration system which has a smaller space requirement for small scale applications. Drost et al. [1] reported that the development of compact absorbers could permit the use of absorption refrigeration systems in small scale heating and cooling applications, heat-actuated automotive air conditioning, and portable cooling. Thus, the success of absorption technology mainly depends on reducing the cost of investment and the size of the components.

Depending on the working fluid mixture used, absorption refrigeration systems are broadly classified into ammonia/water (NH_3/H_2O) and water/lithium bromide ($H_2O/LiBr$) systems. The basic components of both types of refrigeration systems are the absorber, desorber, condenser, evaporator and solution heat exchanger. However, in the case of NH_3/H_2O absorption refrigeration systems, a rectifier is also used at the exit of the desorber to purify the ammonia vapour by condensing the water vapour from the refrigerant vapour. As ammonia and water are both volatile, the refrigerant vapour may contain significant amount of water vapour that has a negative effect on the system performance. Therefore, a rectification process is required for the NH_3/H_2O absorption refrigeration systems. NH_3/H_2O absorption refrigeration systems operate at higher pressures and are commonly used for low temperature (-40 °C to $+5$ °C) cooling applications. $H_2O/LiBr$ absorption refrigeration systems operate under vacuum conditions and are used in air-conditioning applications where the cooling temperature requirement is above 7 °C. The basic single-stage cycle configurations of both $H_2O/LiBr$ and NH_3/H_2O absorption refrigeration systems are shown in Fig. 1.

The performance of absorption refrigeration systems is primarily dependent on the absorber and desorber which are the major components of this kind of refrigeration system. The design of these components is crucial for efficient performance of the absorption refrigeration system. Both the absorber and desorber used in absorption technology are relatively expensive and are large in size. In the case of $H_2O/LiBr$ absorption refrigeration systems the absorber operates under static vacuum pressure accompanied by a high

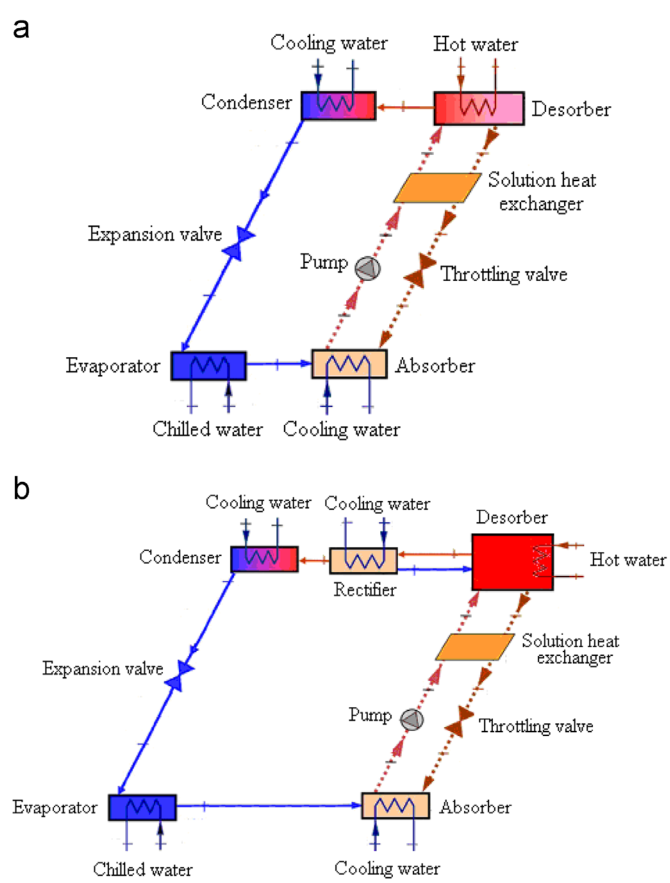

Fig. 1. Basic absorption refrigeration cycle configuration. (a) $H_2O/LiBr$ (b) NH_3/H_2O.