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Comparisons of different working pairs and cycles on the performance of absorption heat pump for heating and domestic hot water in cold regions

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ABSTRACT

In order to explore the suitable working pair and cycle style for heating and domestic hot water in cold region, single-stage and double-stage air source absorption heat pump (ASAHP) and ground source absorption heat pump (GSAHP) are modeled in this paper. Based on these models, the performance of absorption heat pump (AHP) at different generating temperatures, evaporating temperatures and condensing temperatures is simulated respectively when using NH_3–H_2O, NH_3–$LiNO_3$ and NH_3–NaSCN as working fluid. The results indicate that NH_3–$LiNO_3$ requires lower generating temperature, and at the same time can work at lower evaporating temperature and higher condensing temperature than other solutions for the same heat pump cycle. Besides, the double-stage AHP is advantageous over single-stage AHP in utilizing low temperature driving source, operating in very cold climate and producing higher temperature hot water. Finally, combining the simulated performance with required hot water temperature and climate conditions, the applicability of different AHP cycles (single-stage or double-stage), heat sources (air source or ground source) and working pairs (NH_3–H_2O, NH_3–$LiNO_3$ or NH_3–NaSCN) is analyzed in different regions respectively.

1. Introduction

The energy consumption for heating in urban area of north China accounted for 23% of the total building energy consumption in 2008 and was doubled from 72 million ton of standard coal equivalent (tce) in 1996 to 153 million tce in 2008. As for domestic hot water, the energy consumption in urban area is about 28.1 million tce, taking up 23.4% of the total building energy consumption in 2008. Besides, the average energy consumption for domestic hot water over the country is 2.2 kg standard coal equivalent per square meter per year (kgce/(m^2.a)), and the current building area is more than 8.8 billion square meter in north China urban area, which is still increasing rapidly [1]. In a word, the energy used for heating and domestic hot water in north China is huge.

At present, air source heat pump (ASHP) and ground source heat pump (GSHP) are widely used for heating in buildings [2,3]. However, electricity ASHP performs badly or even refuses to work when the weather is very cold. To solve this problem, a heating and domestic hot water system based on air source absorption heat pump (ASAHP) was proposed by Li et al. [4]. The system combines traditional boiler with absorption heat pump (AHP), and theoretical analysis indicates that there is great potential of energy saving for its application. Similarly, ground source absorption heat pump (GSAHP) can also be a promising heating system. However, the outdoor temperature or the soil temperature is very low for a long time in cold regions, which leads to very low evaporating temperature of ASAHP or GSAHP. Therefore, the selection of suitable working pairs and absorption cycles that can be used for heating in cold regions is very necessary.

Absorption working pairs are environmentally friendly and the commonly used working pairs are H_2O-LiBr and NH_3–H_2O [5,6]. For ASAHP using H_2O-LiBr as working fluid, the air infiltration to the negative pressure system will have a great influence on the operation performance. And it cannot work when the air or soil temperature is below 5 °C because of the limitation of freezing point of water refrigerant [7]. The risk of crystallization is also a problem for H_2O-LiBr. Consequently, H_2O-LiBr is not suitable for ASAHP or GSAHP to supply heat in cold region. However, NH_3–H_2O, which is of positive pressure in AHP and can work at low evaporating temperature as well, is also limited in application because of the need of rectifying [8,9].

For these reasons, many researches on NH_3–salt pairs had been carried out, among which NH_3–$LiNO_3$ and NH_3–NaSCN are the most popular. NH_3–$LiNO_3$ and NH_3–NaSCN cannot only work at very low evaporating temperature but also avoid a rectifier since

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