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Short communication

Experimental performance of R432A to replace R22 in residential air-conditioners and heat pumps

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ABSTRACT

In this study, thermodynamic performance of R432A and HCFC22 is measured in a heat pump bench tester under both air-conditioning and heat pumping conditions. R432A has no ozone depletion potential and very low greenhouse warming potential of less than 5. R432A also offers a similar vapor pressure to HCFC22 for 'drop-in' replacement. Test results showed that the coefficient of performance and capacity of R432A are 8.5–8.7% and 1.9–6.4% higher than those of HCFC22 for both conditions. The compressor discharge temperature of R432A is 14.1–17.3 °C lower than that of HCFC22 while the amount of charge for R432A is 50% lower than that of HCFC22 due to its low density. Overall, R432A is a good long term 'drop-in' environmentally friendly alternative to replace HCFC22 in residential air-conditioners and heat pumps due to its excellent thermodynamic and environmental properties.

1. Introduction

For the past few decades, HCFC22 has been predominantly used in residential air-conditioners and heat pumps. The parties to the Montreal protocol, however, decided to phase out HCFC22 eventually since it contains ozone depleting chlorine [1]. Hence, the regulation for HCFC production has begun from 1996 in the developed countries and for new equipment HCFC22 is not currently used in European Union and it can not be used in United States from 2010.

For the past years, various alternatives for HCFC22 have been proposed [2–4] and tested [3,4] in an effort to comply with the Montreal protocol. At this time, HFC refrigerant mixtures such as R410A and R407C are used in some countries to replace HCFC22 [2,5]. At the same time, many companies expend much effort to develop their own alternatives for HCFC22. Especially, refrigerant mixtures composed of environmentally safe pure refrigerants have gotten a special attention from the industry with the expectation of possible energy efficiency without major changes in the system [6].

These days, greenhouse warming has become one of the most important global issues and Kyoto protocol was proposed to resolve this issue, which classified HFCs as greenhouse gases [7]. With this global trend in view, HFC134a will be banned in mobile air-conditioners of new vehicles from 2011 according to EU F-Gases Regulation and MAC directive which specifically bans the use of refrigerants having global warming potential (GWP) of more than 150 [8]. For reference, the GWP of HFC134a is 1300. At this time, many EU countries seriously consider the ban of the use of even HFCs in residential air-conditioners and heat pumps [9]. Even though HFC refrigerants of R410A and R407C are used in some systems, their future is not certain since their GWPs are 1700–2000 which is even higher than that of HFC134a.

One of the possible solutions to avoid HFCs of high GWP is the use of natural refrigerants such as hydrocarbons. For the past few decades, flammable hydrocarbon refrigerants have been prohibited in normal air-conditioning applications due to a safety concern. These days, however, this trend is somewhat relaxed because of the environmental and energy issue. Therefore, some of the flammable refrigerants have been applied to certain applications [10,11]. Propane (R290) and propylene (R1270) are used for heat pumping applications in Europe [12]. It is well known that hydrocarbons offer low GWPs of less than 5, low cost, availability, compatibility with the conventional mineral oil, and environmental friendliness [10,11]. Furthermore, dimethylether (DME, RE170) is a good environmentally friendly refrigerant having excellent thermodynamic properties [13].

Recently, ASHRAE listed R432A as a possible candidate to replace R22 [14]. R432A is a near azeotropic mixture composed of 80% propylene (R1270) and 20% dimethylether (RE170) by mass. It has no ozone depletion potential and very low GWP of less than 5. Its gliding temperature difference during phase change is 1 °C with normal boiling point of −46.6 °C. Even though this is a mixture, heat transfer degradation is not expected since its gliding temperature difference is very small [15]. In this study, thermodynamic performance of R432A was measured in an attempt to

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Nomenclature

COP	coefficient of performance
GWP	global warming potential
PR	pressure ratio
Q	capacity (W)
T	temperature (°C)
W	compressor work (W)

Subscripts

c	condenser
dis	discharge
e	evaporator

examine the possibility of 'drop-in' substitution of HCFC22 for air-conditioning and heat pumping applications.

2. Experiments

2.1. Experimental apparatus

In this study, 'drop-in' performance of R432A is measured using the similar experimental apparatus as described in Ref. [3]. As seen in Fig. 1, the apparatus has the water cooled condenser and water heated evaporator with a nominal capacity of 3.5 kW. A rotary compressor designed originally for HCFC22 was used to lift the pressure while a hand expansion valve was used for regulating the mass flow rate. Since Ref. [3] contains all the details of the test apparatus, measurements, test procedures, data verification etc., an interested reader is referred to Ref. [3]. In this paper, test procedure and test condition will be described.

2.2. Test procedure

Test procedure is as follows:

(1) The system was evacuated for 2–3 h before charging.
(2) The temperatures in the chiller and heating bath were set and the secondary heat transfer fluid (HTF) was pumped into the evaporator and condenser, and the system was charged with a specific refrigerant. For R22, the system was charged with a vapor refrigerant at the compressor inlet. For R432A, the system was charged with a lower vapor pressure refrigerant, RE170, at the compressor inlet, which was followed by a higher vapor pressure fluid, R1270. A digital scale of 0.1 g accuracy was employed to measure the amount of charge.
(3) The expansion valve was controlled, and simultaneously the amount of charge was adjusted to maintain the constant superheat and subcooling, usually 5 °C each, at the exits of evaporator and condenser.

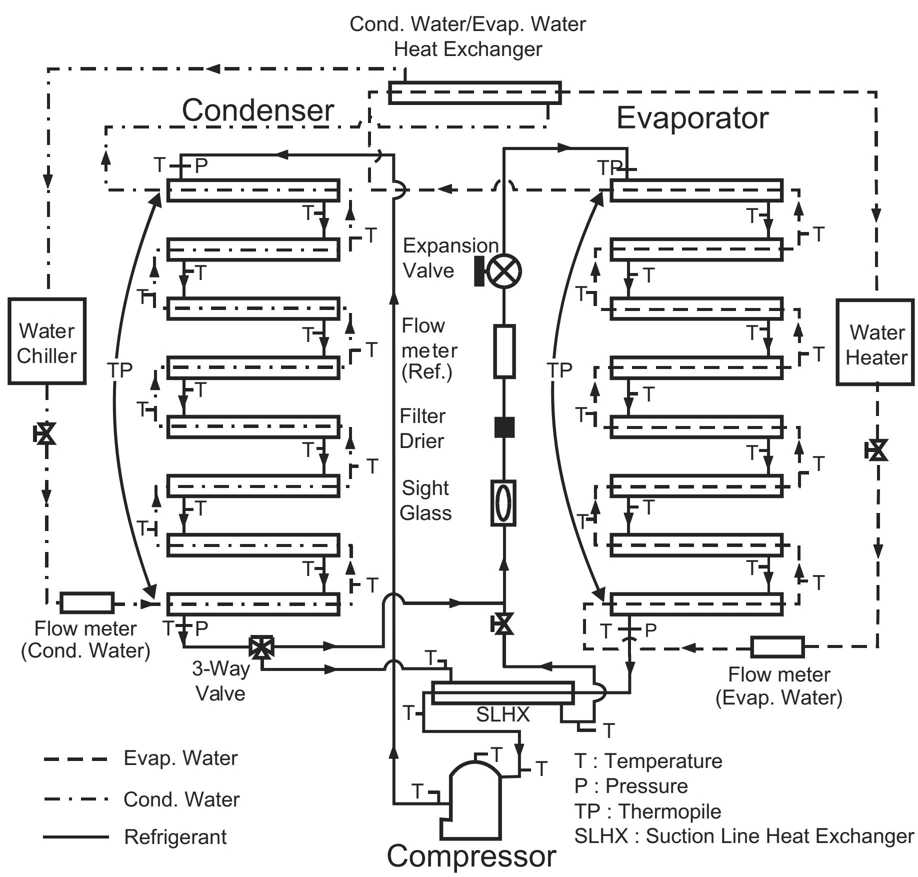

Fig. 1. Schematic of a heat pump bench tester (Ref. [3]).