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Experimental performance study of a small wall room air conditioner retrofitted with R290 and R1270

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ABSTRACT

An original R22 wall room air conditioner with a cooling capacity of 2.4 kW and energy efficiency ratio (EER) of 3.2 is retrofitted with a compressor of a 20% larger displacement to charge R290 and R1270 for performance experiments. The results show that for R1270, only adopting a same kind mineral lubricant of higher viscosity would supply 2.4% higher cooling capacity and 0.8% higher EER than those of the original R22 system under normal condition, and for R290, adopting the larger displacement compressor simultaneously would also obtain better performance. Alternative systems all have higher increase rate and greater increment in both cooling capacity and EER than the original R22 system when outdoor temperature decreases. The R1270 system has great increase in cooling capacity and negligible decrease in EER. Refrigerant charge distribution is also investigated and it indicates that the charge within both heat exchangers and compressor ought to be reduced.

Etude expérimentale sur un petit conditionneur d'air individuel converti au R290 et au R1270

Mots clés : R290 ; R1270 ; Conditionneur d'air individuel ; Performance ; Distribution de la charge

1. Introduction

Owing to the negative environmental impact of R22, which is widely used in heating, ventilation and air conditioning (HVAC) nowadays, a series of Montreal Protocol contracting meetings have decided to rank R22 into the phase out list, and there has been an accelerated hydrochlorofluorocarbon (HCFC) phase out plan approved by the Montreal Protocol parties (UNEP, 2007). Therefore, it is urgent to search for proper alternatives to R22. In early years, some countries insisted on using R410A, R407C and other hydrofluorocarbons (HFCs), which don't deplete the stratospheric ozone, however, have equivalent or even higher global warming potential (GWP) than R22 (GWP for the time horizon of 100 years: 2000 for R410A, 1700 for R407C and 1780 for R22 (Calm and Domanski, 2004)), and are hence regulated under the Kyoto

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Nomenclature

A	area, m^2
DBT	dry bulb temperature, °C
EER	energy efficiency ratio
GWP	global warming potential
HC	hydrocarbon
HCFC	hydrochlorofluorocarbon
HFC	hydrofluorocarbon
HVAC	heating, ventilating and air conditioning
LFL	lower flammable limit, kg m^{-3}
ODP	ozone depletion potential
SEER	seasonal energy efficiency ratio
WBT	wet bulb temperature, °C

Protocol. There have been researches accomplished by several influential agencies, claiming that the projected HFC emissions would be 9–45% of projected global CO_2 emissions in 2050 if HFCs, mainly R410A and R407C, were not restricted in use, which would undoubtedly aggravate the greenhouse effect badly (Velders et al., 2009). The international societies have already agreed unanimously that HFCs couldn't be a long term choice, and through continuous and deep consideration, now, people's interest has been focused on hydrocarbons (HCs), especially on R290 and R1270.

As natural substances, R290 and R1270 have zero ozone depletion potential (ODP) and negligible GWP, doing no harm to the environment (Calm and Domanski, 2004). Moreover, they have favorable characteristics as refrigerants from the point of view of both thermodynamic and transport properties. Furthermore, many experiments indicate that R290 and R1270 offer equivalent or even better performance than R22. In addition, R290 and R1270 have extensive sources and low cost, and are perfectly compatible with the lubricants and materials commonly being used in HVAC (Granryd, 2001). The only problem with R290 and R1270 is that their high flammability would induce dangerous incidents if not properly handled, just as all other flammable substances, for which the international societies always take their use seriously while once prohibiting any use (Corberan et al., 2008b). However, seeking environmental friendly refrigerants is a trend now, and R290 and R1270 have eventually been back to people's view thanks to public growing environmental awareness.

R290 and R1270 have been successfully used as substitutes to R22 in heat pumps in Europe and some Asian countries, where the risk associated with their high flammability is under good control and the performance is satisfying (Palm, 2008). Fernando et al. (2004) used R290 in a water-to-water heat pump with a heating capacity of 5 kW and determined the optimum charge with the use of mini-channel aluminum heat exchangers at 200 g without any loss in EER. Hoehne and Hrnjak (2004) carried out charge studies to R290 in a heat pump with a heating capacity of 1–1.5 kW and discovered that refrigerant lay most in compressor, and then in condenser and evaporator. Park and Jung (2007, 2008) and Park et al. (2010) adopted R290, R1270 and other pure HCs and their mixtures as refrigerants in an original R22 heat pump with a heating capacity of 3.5 kW while taking water/ethylene glycol as the secondary fluid for heat exchangers. They found that for both R290 and R1270, EER was up to 11.5% higher and discharge temperature and refrigerant charge were largely reduced when compared to R22 in all tests. They also found that the R290 system showed up to 8.2% lower capacity under normal condition and 5% higher capacity under extremely cold condition, and R1270 system showed higher capacity under all conditions with respect to the R22 system.

For air conditioners, Devotta et al. (2005) measured the performance of a R22 window air conditioner with a capacity of 5.13 kW, EER of less than 2.5, and heat exchangers of 10 mm tubes and found that the R290 system showed 6.6% and 9.7% lower in cooling capacity, respectively, and 7.9% and 2.8% higher in EER, respectively, under lower and higher operating conditions when compared to the R22 system. Padalkar et al. (2010) retrofitted the 5.13 kW capacity split air conditioner to charge with R290, and reported that the larger condenser supplied 1.6% lower cooling capacity and 10% higher EER with respect to the original R22 system, and the higher capacity compressor improved cooling capacity by 2.8% and reduced EER by 1.1%. Zhou and Zhang (2010) tested R290 in a split air conditioner which had a capacity of 3.2 kW, an EER of 2.4 and 9.53 mm smooth tubes for the condenser and 7 mm internally spiral groove tubes for the evaporator, and stated that the R290 system had 4.7–6.7% lower cooling capacity and 8.5% higher EER when compared to the R22 system. Teng et al. (2012) experimentally investigated the performance of a 2 kW capacity window air conditioner using R290 as a substitute to R22 under various refrigerant charge and outdoor temperatures (26, 29, 32 °C). The results showed that the optimum charge for R290 is 50–55% of that for R22, and the EER of R290 increased by up to 20% with the outdoor temperature.

The above studies indicate that R290 and R1270 can be used in heat pumps and air conditioning systems with equivalent or even better performance, providing good guidance and reference for their application in room air conditioners which are widely used in households and offices.

The technology progress has promoted the efficiency improvement of air conditioners. Now, for a split air conditioner with a capacity of 4.5–7.1 kW, EER ought to be no less than 3.1, and for that with a capacity of less than 4.5 kW, EER ought to be above 3.2. Most of the existing studies are focused on air conditioners of low EER; however, the structure, cycle parameters and energy loss distribution of air conditioners of high EER are different from the ones of low EER. On the other hand, small air conditioners with capacities of less than 3.6 kW are commonly used in East and Southeast Asia, for which it is probably possible to satisfy the safety requirements of EN 378 criterion, etc. However, available researches on the split air conditioners of high EER and with capacities of the above range are relatively few. In this study, a small R22 wall room air conditioner with a capacity of 2.4 kW and an EER of 3.2 is proposed to retrofit with a compressor of a larger displacement. The performance is experimentally investigated when adopting R290 and R1270 as alternatives to R22.