INTERNATIONAL JOURNAL OF REFRIGERATION 36 (2013) 892–903

Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: www.elsevier.com/locate/ijrefrig

Performance comparison of R410A and R32 in vapor injection cycles

Xing Xu, Yunho Hwang*, Reinhard Radermacher

Center for Environmental Energy Engineering, University of Maryland, 4164 Glenn L. Martin Hall Bldg., College Park, MD 20742, USA

ARTICLE INFO

Article history:
Received 28 July 2012
Received in revised form
12 November 2012
Accepted 10 December 2012
Available online 19 December 2012

Keywords:
R410A
R32
Vapor
Injection
Heat pump

ABSTRACT

As global warming has raised more critical concerns in recent years, refrigerants with high global warming potentials (GWP) are facing the challenges of being phased out. R410A, with a GWP of 2088, has been widely used in residential air-conditioner and heat pump systems. A potential substitute for R410A is R32, which has a GWP of 675. This paper investigates the performance difference using R410A and R32 in a vapor-injected heat pump system. Through experimentation, it was found that the capacity and coefficient of performance (COP) improvements using R32 can reach up to 10% and 9%, respectively, as compared to an identical cycle using R410A. It is concluded that R32 is an excellent alternative to replace R410A in terms of performance and can be further enhanced by component optimization.

Comparaison de la performance du R410A et du R32 dans des cycles à injection de vapeur

Mots clés : R410A ; R32 ; Vapeur ; Injection ; Pompe à chaleur

1. Introduction

As global warming has raised more critical concerns in recent years, refrigerants with high global warming potentials (GWP) are facing the challenges of being phased out. In 1997, Kyoto Conference announced that the production and use of hydrofluorocarbons (HFCs) should be regulated due to their high GWPs. In Europe, refrigerants with GWPs over 150 from 2011 are banned for use in new mobile air-conditioners. As a result, R134a, with a GWP of 1430, which is currently widely used in the automobiles, will be phased out in the automobile industry. In the residential application, R410A, with a GWP of 2088 (IPCC, 2007), is also facing the challenge to be phased out. Research efforts have been performed to search for substitutes for R410A. Yajima et al. (2000) investigated the performance and total equipment warming impact (TEWI) of a 16 kW prototype with a variable speed compressor. Test results showed that the COP of R32 was higher than that of R410A not only under the rated capacity condition, but also under partial load conditions by compressor speed control. In Tokyo area, its TEWI dropped by 18% in comparison with that of R410A, and the direct impact portion of R32 decreased to 7%

* *Corresponding author*. Tel.: +1 301 405 5247.
E-mail address: yhhwang@umd.edu (Y. Hwang).
0140-7007/$ – see front matter
http://dx.doi.org/10.1016/j.ijrefrig.2012.12.010

Nomenclature

ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
COP	coefficient of performance
DB	dry bulb, °C
DP	dew point, °C
EB	energy balance
EES	engineering equation solver
EEV	electronic expansion valve
GWP	global warming potential
h	refrigerant enthalpy, kJ kg^{-1}
HFC	hydrofluorocarbons
HTC	heat transfer coefficient
IPCC	intergovernmental panel on climate change
$\dot{m}$	mass flow rate, kg s^{-1}
$\dot{Q}$	cooling and heating capacity, W
R1234yf	refrigerant 1234yf, 2,3,3,3-tetrafluoropropene
R1234ze	refrigerant 1234ze, 1,3,3,3-tetrafluoropropene
R134a	refrigerant 134a, 1,1,1,2-tetrafluoroethane
R22	refrigerant 22, trifluoromethane
R32	refrigerant 32, difluoromethane
R410A	R32/R125 (50/50 wt.%)
R410B	R32/R125 (45/55 wt.%)
RH	relative humidity, %
RPM	revolution per minute
TEWI	total equivalent warming impact
TXV	thermostatic expansion valve
$\dot{W}$	power consumption, W
W_{out}	outlet air humidity ratio, kg kg^{-1}
WB	wet bulb, °C

Greek letters

α	injection ratio
ε	difference between R32 and R410A using R410A as baseline

Subscripts

air	air side
in	inlet condition
inj	injection
out	outlet condition
ref	refrigerant side
suc	suction
vi	vapor injection

of the total impact. Taira et al. (2011) proposed a notion of diversity of refrigerant choice, and suggested that R32 is a refrigerant enabling quick action against global warming. Tu et al. (2011) compared the performance using R32 and R410A in a thermodynamic model and conducted experiments at different operating conditions in a 3.2 kW residential heat pump unit. The thermodynamic cycle showed that R32 outperformed R410A by 15% in cooling capacity and 6% in cooling COP. Experiment results showed 8% and 3% higher in cooling and heating capacities, respectively, and 3% and 2% higher in cooling and heating COPs, respectively. Huang et al. (2011) tested an air-to-water heat pump with tube-bundle-double-pipe heat exchanger. Test results showed that the charge of R32 was 66% of R410A. Cooling performance of R32 was close to that of R410A, and the heating COP was 14% higher than that of R410A. The displacement of an R32 compressor should be reduced 7% compared to a compressor for R410A.

Due to the property difference between R32 and R410A, the volumetric capacity of R32 is higher than that of R410A. Therefore there are also research efforts on mixing R32 with other refrigerants as the substitute for R410A. Cawley (2003) filed a patent proposing adding a small portion of R134a to R32 as a drop-in replacement for R410A in terms of volumetric capacity at typical air-conditioning system operating conditions. Koyama et al. (2010) performed drop-in experiments of R410A, R1234ze (E) and the mixture of 50/50 wt.% R1234ze (E)/R32 at the heating mode, using a vapor compression heat pump system developed for R410A. The COP was found to be 7.5% lower than that of R410A at the same heating load of 2.8 kW. Mixture of R1234ze (E)/R32 is considered to be applicable as low-GWP alternatives for R410A by adjusting the composition of the mixture and by reconsidering the design parameter of components of a room air-conditioning system. Gebbie et al. (2007) tested a heat pump unit with a refrigerant mixture of 30/70 wt.% R32/R134a. They examined transient performance trends using refrigerant mixture and compared that with pure refrigerant R32. It was observed that R32/134a tests exhibited capacity oscillations early in each transient test that were not present during R32 tests. They concluded that circulating refrigerant mass and composition are the primary controlling factors with regard to transient capacity oscillations.

In recent years, vapor injection cycle has been studied by different research groups due to its prominent performance enhancement compared to a convention single-stage cycle (Xu et al., 2011). Wang et al. (2009) tested the flash tank cycle at −18 °C and found the maximum heating capacity and COP improvements to be 33% and 23%, respectively. Ma and Zhao (2008) investigated the vapor injection heat pump cycle employing a flash tank coupled with a scroll compressor. The system demonstrated sufficient heating capacity of 8.15 kW at a condensing temperature of 45 °C and an evaporating temperature of −25 °C. They concluded that the system could provide sufficient heating in severely cold regions. Bertsch and Groll (2008) tested a two-stage heat pump system at low ambient temperature of −30 °C. The heating COP was found to be 2.1, and the heating capacity almost doubled as compared to a single-stage cycle. However, most of the work done on a vapor injection cycle was focused on utilizing R22 and R410A. With the trend of phasing out R22 and R410A, it's necessary to investigate new refrigerant candidates for a vapor injection cycle. As can be seen in research efforts in the literature, although R32 has been studied experimentally and theoretically, all works have been conducted on a conventional single-stage vapor compression cycle. Employing refrigerant R32 in a vapor injection two-stage system is worth for investigation, since there was no open publication on such research effort. This paper focuses on comparing the performance between R410A and R32 in a vapor injection system with a flash tank at different operating conditions.