

Thermodynamic performance of R32/R152a mixture for water source heat pumps

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ABSTRACT

Air-conditioning and heat pumping performance of R32/R152a mixture is measured in the composition range of 20–50% R32 with an interval of 10% for the comparison with HCFC22 in a water source heat pump bench tester. Tests are carried out under the same capacity in the bench tester equipped with a variable speed open type compressor at the evaporation and condensation temperatures of 7/45 °C and –7/41 °C for summer and winter conditions, respectively. Test results show that the compressor power of R32/R152a mixture is up to 13.7% lower than that of HCFC22 while the coefficient of performance (COP) of R32/R152a mixture is up to 15.8% higher than that of HCFC22. From the view point of energy efficiency, R32/R152a mixture is excellent as compared to HCFC22. Compressor discharge temperatures of R32/R152a mixture are increased up to 15.4 °C as compared to those of HCFC22. The amount of charge for R32/R152a mixture is decreased up to 27% as compared to that of HCFC22. Overall, R32/R152a mixture is an excellent long term solution to replace HCFC22 in water source heat pumps under the similar evaporator and condenser temperatures. The flammability study shows that the mixture is virtually not flammable at the ‘drop-in’ composition of 36%R32/64%R152a.

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1. Introduction

Chlorofluorocarbons (CFCs) have been used as refrigerants for various refrigeration and air-conditioning applications for more than a half century since they were first introduced in 1930s due to their excellent thermodynamic and chemical properties. But these useful fluids have been regulated and completely phased out by the Montreal protocol of 1987 [1] due to a finding that chlorine atoms in them destroy the stratospheric ozone layer. In 1997, Kyoto protocol was proposed for the reduction of the greenhouse warming [2], which calls for the energy efficiency improvement in all energy conversion devices including refrigeration and air-conditioning and power generation devices.

R22, a hydrochlorofluorocarbon (HCFC), has been used predominantly in residential and commercial air-conditioners and heat pumps. Even though the Montreal protocol requires the complete phase out of R22 by 2020, all European countries have already stopped using R22 and from 2010 the United States will not use R22 in new equipment. Therefore, R22, an ozone depleting substance, has to be replaced by environmentally safe refrigerants. Unlike CFC11 and CFC12, however, no pure ‘drop-in’ refrigerant has been identified to substitute for R22.

For the past decade, a refrigerant mixture of R410A (50%R32/50% R125) has been identified as a promising candidate for R22 and many products charged with this alternative fluid have been on the market these days. R410A, hydrofluorocarbon (HFC) mixture, is a near-azeotropic mixture whose gliding temperature difference (GTD) is less than 0.2 °C. Its vapor pressure is about 50% higher than that of R22 and hence its volumetric capacity is significantly increased. Due to the high pressure, compressors and heat exchangers are to be redesigned completely for the optimization necessary to accommodate the lower volumetric flow rate associated with the use of R410A. A simple thermodynamic cycle analysis shows that the thermodynamic efficiency of R410A is somewhat lower than that of R22. The actual energy efficiency of R410A, however, is found to be higher than that of R22 due to the improved compressor efficiency and reduced energy losses in some components of the refrigeration system [3].

Even though R410A is used quite extensively these days, there is a great concern for the high global warming potential (GWP) of R410A. The 100 year GWP of R410A is 2068 as compared to that of carbon dioxide (CO₂), which is even higher than that of R22 whose GWP is 1790. In fact, the Kyoto protocol has in itself a control measure for greenhouse gases including HFCs. Consequently, HFC134a was identified as one of the controlled greenhouse gases. The global warming potential (GWP) of HFC134a, one of the major refrigerants used in refrigeration and air-conditioning field, is 1430

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Nomenclature

CFC	Chlorofluorocarbon
COP	Coefficient of performance
GTD	Gliding temperature difference (°C)
GWP	Global warming potential
HFC	Hydrofluorocarbon
HCFC	Hydrochlorofluorocarbon
HTF	Heat transfer fluid
$\dot{m}$	Mass flow rate [kg/s]
ODP	Ozone depletion potential
P	Pressure (kPa)
Q	Capacity [W]
rpm	revolutions per minute
T	Temperature (°C)

Subscripts

c	condenser
dis	discharge
e	evaporator
w	water

as compared to that of CO₂. In fact, European Union's F-Gases Regulation bans the use of HFC134a from 2011 in automobile air-conditioners of newly manufactured vehicles for environmental protection [4]. The same regulation specifically prohibits the use of fluorinated greenhouse gases whose GWP is greater than 150. From the view point of this development for the ban of HFCs with high GWPs, the fate of R410A is not certain at this time since its GWP is even higher than that of HFC134a. Therefore, many people and organizations try to develop alternative refrigerants with low GWPs for R410A these days.

In order to comply with strict environmental regulations of the European Union, alternative refrigerants for HCFC22 and R410A with no ozone depletion potential (ODP), low GWP, and high energy efficiency have to be developed. Recently, reflecting this trend, major refrigerant suppliers have developed alternatives with GWP of less than 500, which is about 25% of R410A.

At this time, many countries are concentrating their efforts for the development of water source heat pumps in the field of geothermal energy and unutilized and waste energies according to the mandate set by the global environmental protection and energy conservation. For many countries' green projects, a variety of ground source or ground coupled heat pumps have been developed and used for diverse applications all over the world [5–9]. Ground source heat pumps extract and discharge the energy needed for the heating and air-conditioning operation via ground and hence they are basically stable and sustainable energy conversion devices. US Environmental Protection Agency (EPA) has shown that ground source heat pumps are environmentally friendly and cost effective solution providing the highest energy efficiency among the all existing space heating and air-conditioning devices [10]. Developed countries have expended much efforts for the widespread use of ground source humps since they offer about 40% reduction in energy use resulting in the reduction of indirect global warming. Most of the ground source heat pumps exchange the energy to and from the brine loop installed underground and hence have the basic structure similar to that of conventional water source heat pumps [8–10].

On the other hand, there has been a constant effort for the mobilization of various unutilized energy sources including waste water from residential, commercial, and industrial complexes and

open waters such as lake, river, and sea [9,10]. For example, the heat pump system can utilize waste energy from a sewage disposal and treatment plant connected to a large residential complex of up to a few thousand apartments or an industrial complex and supply both hot water and heating water. By the installation of water source heat pumps, the temperature of the sewage can be reduced for environmental protection and also the hot water can be supplied to the needed facilities. Water source heat pumps extracting energy from the river and lake have become popular in many parts of the world since they offer sustainable energy without pollution all year round.

At present, alternative refrigerants with no ODP, low GWP, and high energy efficiency are needed for water source heat pumps all over the world. One way of developing alternative refrigerants is to use non-azeotropic refrigerant mixtures (NARMs). By selecting good pure fluids with differing pressures and characteristics, certain NARMs can be used as 'drop-in' fluids providing an environmentally friendly solution with energy efficiency improvement and good material compatibility [11].

Due to these advantages, NARMs have been identified as a way of increasing energy efficiency in refrigeration and air-conditioning fields and for the past few decades and many researchers have taken efforts to examine the characteristics of NARMs in many applications [12–14]. Unlike pure refrigerants, the temperature of NARMs increases during evaporation at constant pressure while that decreases during condensation. This phenomenon is called a 'temperature glide' and the difference between the beginning and ending temperatures during evaporation is termed a 'gliding temperature difference' (GTD). Fig. 1 shows the temperature and composition diagram of a NARM composed of R32 and R152a. One can easily see that the GTD of the mixture is a strong function of composition. The ideal cycle utilizing NARMs is called a Lorenz cycle. In Lorenz cycle, thermodynamic irreversibilities caused by the temperature difference between the refrigerant and heat transfer fluid (HTF) in evaporator and condenser can be reduced as compare to a Carnot cycle using pure refrigerants by temperature matching between the refrigerant and HTF. Hence, for well designed NARMs, a significant increase in COP was reported [12].

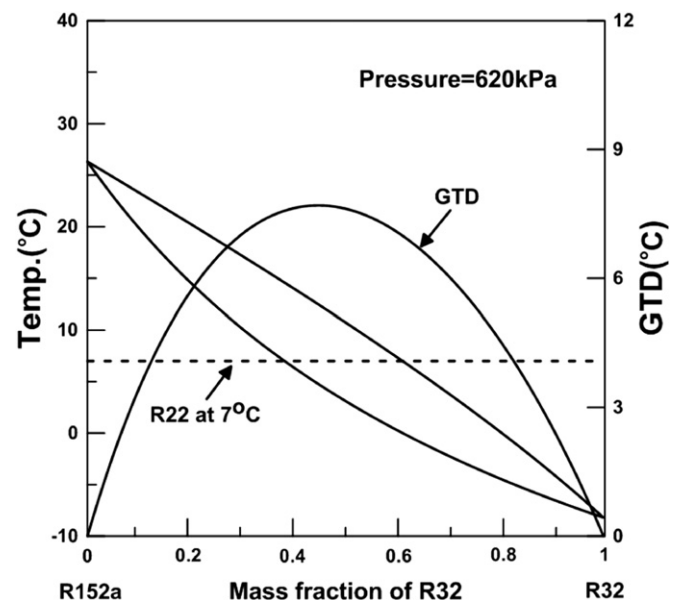


Fig. 1. Temperature-composition diagram of non-azeotropic refrigerant mixture of R32/R152a with gliding temperature difference.

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