INTERNATIONAL JOURNAL OF REFRIGERATION 63 (2016) 125–132

Available online at www.sciencedirect.com

ScienceDirect

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

Experimental comparison of the energy parameters of HFCs used as alternatives to HCFC-22 in split type air conditioners

*Vedat Oruç, Atilla G. Devecioğlu *, Uğur Berk, İbrahim Vural*

Department of Mechanical Engineering, Dicle University, 21280 Diyarbakır, Turkey

ARTICLE INFO

Article history:
Received 8 July 2015
Received in revised form 2 November 2015
Accepted 3 November 2015
Available online 10 November 2015

Keywords:
Drop-in
R22
Alternative refrigerants
COP

ABSTRACT

The R22 refrigerant widely used in refrigerating and air conditioning devices is invariably released to the atmosphere due to reasons such as breakdown and/or translocation. As the sales of new devices operating with R22 are decreasing gradually, refrigerants of such available devices should be changed with the ones that are not depleting the ozone layer. In this paper, the amount of consumed energy, cooling capacity and COP values of R417A, R422A, R422D and R424A, which can be used as alternatives to R22, were determined experimentally for a split type air conditioning device at the ambient temperatures of 35, 38 and 41 °C. Basically, COP values of all HFC refrigerants were found to be smaller than that of R22. It was noted that the most suitable refrigerating fluid was R424A, which can be used instead of R22, since the COP of R424A was smaller than that of R22 by 2.5% only at an ambient temperature of 41 °C.

Comparaison expérimentale des paramètres énergétiques des HFC utilisés comme alternatives au HCFC-22 dans les conditionneurs d'air de type split

Mots clés : Baisse ; R22 ; Frigorigènes alternatifs ; COP

1. Introduction

Since R22 causes ozone layer depletion, its use will be gradually eliminated until 2030 by Montreal Protocol. In developing countries, it is allowed to sell the new air conditioners utilizing R22 refrigerant, which is currently present in millions of devices. R22 refrigerating fluid is widely used in air-conditioners. According to EU regulation, such available devices should be used until the beginning of 2015, and after this date, they have to be replaced with the refrigerants that do not lead to ozone depletion (Llopis et al., 2012).

* *Corresponding author.* Department of Mechanical Engineering, Dicle University, 21280 Diyarbakır, Turkey. Tel.: +904122488217/3604; Fax +904122488218.
E-mail address: atillad@dicle.edu.tr (A.G. Devecioğlu).

http://dx.doi.org/10.1016/j.ijrefrig.2015.11.004

Nomenclature

COP	coefficient of performance [–]
Q_E	cooling capacity [kW]
$\dot{W}_{el}$	electric consumption [kW]
$\dot{m}$	mass flow rate [kg s^{-1}]
T	temperature [°C]
h	enthalpy [kJ kg^{-1}]
P	pressure [kPa]

Subscripts

a	ambient
C	condenser
d	discharge
E	evaporator
i	inlet
o	outlet
HP	high pressure
LP	low pressure

The halogenated refrigerants have serious emission through air conditioning and similar refrigeration based industries. The substantial environmental impacts may be due to the emission of fluorine and chlorine atoms, which exist in the halogenated refrigerants. Starting from the 1990's, the development and usage of ozone-friendly HFC (hydro fluorocarbon) refrigerants, which can be preferred as alternatives to HCFC refrigerants, are continuing. The initial samples are the domestic type refrigerators in which R134a was present as a refrigerating fluid instead of R12. Then, R407C and R410A were started being used in place of R22 for air conditioners. Obviously, gas leakages may occur in devices with R22 refrigerant because of translocation or failure. Hence, R22, which has a global warming potential (GWP) and ozone depletion potential (ODP) of 1600 and 0.055, respectively should be replaced with gases having ODP of zero. The replacement process may be achieved by the complete system change; however, the refrigerating systems can continue to operate more economically using an alternative refrigerant simply. This can be accomplished either by replacing some elements (e.g., oil, expansion device, etc.) or changing only the refrigerating fluid without making any modification on the system (Llopis et al., 2012).

The typical applications of alternative refrigerants for R22 (e.g., R417A, R424A, R422A, R422D) can be given as split type air conditioners, cold storage rooms, refrigerated transport, cold cabinets and dairy chillers (Aprea et al., 2004). Moreover, the mineral oil, which is present in the systems operating with R22 can be used directly as the compressor oil (without making any component change on the device) for the mentioned refrigerating fluids.

In the available literature, there are studies on operating refrigeration systems with alternative refrigerants. The related investigations are currently continuing due to the engineering significance of the topic (Aprea et al., 2014; Oruç and Devecioğlu, 2015; Rocca and Panno, 2011; Yang and Wu, 2013). The studies on air conditioners in which ozone-friendly refrigerants were used are still updated as it was specified in these papers that alternative refrigerants should be preferred as a substitute HCFC-22 (Devotta et al., 2001; Kapadia et al., 2009; Padalkar et al., 2014; Padmanabhan and Palanisamy, 2013; Park et al., 2007, 2008; Suzuki et al., 1998).

Literature survey points out that use of the alternative refrigerants in the refrigerating and air conditioning systems is possible by means of two different methods. In the first, called drop-in, the refrigerant that aimed to be investigated is only changed without performing any other modifications on the available device (Cabello et al., 2013; Farraj et al., 2012; Llopis et al., 2011; Mani and Selladurai, 2008; Park et al., 2009; Zhao et al., 1999). The second method known as retrofitting (adaptation) is related to the replacement of compressor oil and/or requirement for modifying some system parts (Aprea et al., 2014; Chinnaraj et al., 2011; Devotta et al., 2005; Vijayan and Srinivasan, 2009; Wu et al., 2012; Yang and Wu, 2013; Yu and Teng, 2014).

The drop-in application is the subject in this study, namely R422A, R422D, R417A and R4242A are the refrigerants that could be directly used instead of R22 without making any modifications in the facility (especially, oil change for the compressor is not necessary). These alternative refrigerants were also preferred since they have proper evaporation temperature (high and medium) values. Additionally, ODP values of the considered alternative gases are zero. Although the air conditioners of small capacities are widely used, the effects of different refrigerants on the energy parameters of these devices are not exactly known. Therefore, the energy parameters of R422A, R422D, R417A and R424A refrigerants are experimentally investigated in this study for a split type air conditioner with a cooling capacity of 2.05 kW.

2. Methods and materials

The experimental setup was designed to determine the energy consumed by the device during actual operating conditions. A split type air conditioner operating with R22 refrigerant and a cooling capacity of 2.05 kW was used as the experimental system. The rotary type compressor and capillary tube expansion device existing in the air conditioner consisted of both an inside and outside unit. As shown in Fig. 1, the inside unit was installed in a cold storage room (i.e., control volume) where the temperature and heat loads could be adjusted. The control volume was composed of polyurethane foam filling material. Electrical heaters were also placed inside the control volume.

The condenser was placed inside an isolated channel to simulate the fixed outside ambient operating conditions. The temperature of air flowing over the condenser could be kept constant through resistive heaters fixed to the air inlet side of the channel. There were four resistive heaters, each having a load of 1000 W at the channel entry. The capacity could be increased by progressively turning on these electrical heaters. The heating energy was yielded from the resistive heaters; hence, the temperature could be varied so that the ambient temperature was kept constant. The experimental investigation was conducted at three different ambient temperatures: 35, 38, and 41 °C. The indoor unit temperature of the device was adjusted to 18°C to prevent on/off operation, which causes an undesirable start/stop activity of the device and hinders