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Experimental analysis of a new refrigerant mixture as drop-in replacement for CFC12 and HFC134a

K. Mani *, V. Selladurai

Department of Mechanical Engineering, Refrigeration and Air-conditioning Laboratory, Coimbatore Institute of Technology, Coimbatore 641 014, India

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Abstract

An experimental performance study on a vapour compression refrigeration system with the new R290/R600a refrigerant mixture as drop-in replacement was conducted and compared with CFC12 and HFC134a. The vapour compression refrigeration system was initially designed to operate with R12. Experimental results showed that the refrigerant R290/R600a had 19.9% to 50.1% higher refrigerating capacity than R12 and 28.6% to 87.2% than R134a.The refrigerant R134a showed slightly lower refrigerating capacity than R12. The mixture R290/R600a consumed 6.8% to 17.4% more energy than R12. The refrigerant R12 consumed slightly more energy than R134a at higher evaporating temperatures. The coefficient performance of R290/R600a mixture increases from 3.9% to 25.1% than R12 at lower evaporating temperatures and 11.8% to 17.6% at higher evaporating temperatures. The refrigerant R134a showed slightly lower coefficient of performance than R12. The discharge temperature and discharge pressure of the R290/R600a mixture was very close to R12. The R290/R600a (68/32 by wt%) mixture can be considered as a drop-in replacement refrigerant for CFC12 and HFC134a.The refrigeration efficiency of the system were also studied.

Keywords: Hydrocarbon mixture; Alternative refrigerants; ODP; Global warming; CFC

1. Introduction

The refrigerants chlorofluorocarbon (CFCs) and hydrochlorofluorocarbon (HCFCs) both have high ozone depleting potential (ODP) and global warming potential (GWP) and contributes to ozone layer depletion and global warming. Therefore these two refrigerants are required to be replaced with environmentally friendly refrigerants to protect the environment. The hydrofluorocarbon (HFC) refrigerants with zero ozone depletion potential have been recommended as alternatives. R134a is the long-term replacement refrigerant for R12 because of having favourable characteristics such as zero ODP, non-flammability, stability and similar vapour pressure as that of R12 [1–3]. The ODP of R134a is zero, but it has a relatively high global warming potential. Many studies are being carried out which are concentrating on the application of environmentally friendly refrigerants in refrigeration systems. The issues of ozone layer depletion and global warming have led to consideration of hydrocarbon refrigerants such as propane, isobutene, *n*-butane or hydrocarbon blends as working fluids in refrigeration and air-conditioning systems. Hydrocarbons are designated as A3 (highly flammable) refrigerants by ASHRAE standard 34, the industry standard for refrigerant classification. The hydrocarbon (HC) as refrigerant has several positive characteristics such as zero ozone depletion potential, very low global warming, non-toxicity, high miscibility with mineral oil, good compatibility with the materials usually employed in refrigerating systems. The main disadvantage of using hydrocarbons as refrigerant is their flammability [4,5]. If safety measures are taken to prevent refrigerant leakage from the system then a flammable refrigerant could be as safe as other refrigerants.

Fig. 1 shows the saturated vapour pressure versus temperature for R12, R134a and R290/R600a (68/32 by wt%) mixture. It was observed from Fig. 1 that the saturated vapour pressure for propane–isobutane mixture of propane concentration equal to 68% is very close to the vapour pressure curves of the refrigerant R12 and R134a and can be used as a potential retrofit refrigerant.

* Corresponding author.
E-mail address: maniakmani@yahoo.co.in (K. Mani).

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Nomenclature

CFC	chlorofluorocarbon	
CEC	compressor energy consumption	kW
COP	coefficient of performance	
GWP	global warming potential	
HCFC	hydrochlorofluorocarbon	
HFC	hydrofluorocarbon	
HC	hydrocarbon	
ODP	ozone depletion potential	
RC	refrigerating capacity	kW
RE	refrigeration efficiency	

Subscript

c	condensing/condenser

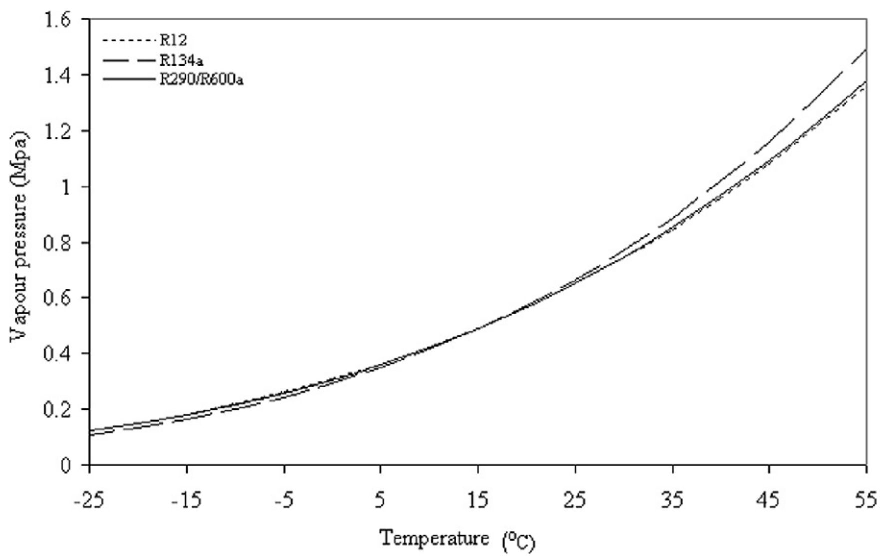

Fig. 1. Vapour pressure curves for R12, R134a and R290/R600a (68/32).

2. Literature review

Many studies have been concentrated on the research of substitutes for CFC12. The refrigerant propane/isobutane mixture is being sold under different brand names as substitutes for CFC12. But this R290/R600a (68/32 by wt%) mixture is a new HC blend composed of propane 68% and iso-butane 32% on mass basis and performed better than other propane/isobutane mixtures.

Richardson and Butterworth [6] investigated the performance of HC290/HC600a mixture in a vapour compression refrigeration system. It was shown that propane and propane/isobutane mixtures may be used in an unmodified R12 system and gave better COPs than R12 under the same operating conditions. Mixtures of around 50% propane and 50% isobutane have very similar saturation characteristics to R-12 but COP would seem to improve as the proportion of propane is increased. Dongsoo Jung et al. [7] tested the performance of R290/R600a mixture in the composition range of 0.2 to 0.6 mass fractions of R290 yields an increase in COP of 1.7% to 2.4% as compared to R12. R290/R600a mixture at 0.6 mass fraction of R290 showed a 3% to 4% increase in energy efficiency and a faster cooling rate as compared to R-12. Evelyn Baskin [8] studied different mixtures of HC600a/HC290 performance in residential refrigerator/freezers. The 60/40% and 70/30% (isobutane/propane) were the best overall mixtures. Kuijpers et al. [9] theoretically showed that 21/79 wt% propane/iso-butane mixture should be considered as a substitute to CFC-12. This composition has an evaporation pressure and volumetric refrigeration capacity comparable to CFC-12. Hammad and Alsaad [10] carried out experimental study with four ratios of propane, butane and isobutene as possible alternative to R12 in an unmodified R12 domestic refrigerator. The hydrocarbon mixture with 50% propane, 38.3% butane and 11.7% isobutene showed better performance among all other hydrocarbon mixtures investigated. Experimental results of Jung et al. [11] indicated that the mixture of propane and iso-butane with 60% mass fraction of propane has higher COP, faster cooling rate, shorter compressor on-time and lower compressor dome temperatures than R12. Akash and Said [12] conducted performance test with LPG (30% propane, 55% *n*-butane and 15% iso-butane by mass fraction) as a possible substitute for R12 in domestic refrigerator. The cooling capacity and COP were comparable to those of R12. Tashtoush et al. [13] conducted experimental study with butane/propane/R134a mixtures as alternative to R12. The results showed excellent performance with this new refrigerant mixture as an alternative to R12 in domestic refrigerators, without changing the compressor lubricating oil used with R12.