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Performance Investigation of Natural Refrigerant R290 as a Substitute to R22 in Refrigeration Systems

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Abstract

Use of natural refrigerant R290 can play a vital role in fulfilling the objectives of the international protocols like Montreal and Kyoto. Because of environmental problems such as ozone depletion and global warming, R22 needs to be phased out on urgent basis. This paper analyzes the possibilities of R290 as a potential substitute to R22.Thermodynamic performance analysis of refrigerants R290 and R22 was carried out using standard vapour compression cycle, with evaporating temperature range of -25°C to 10°C for the condensing temperature of 45°C, based on analytical calculations. Refrigerant properties were obtained from REFPROP 9.0.Performance parameters like, discharge temperature, volumetric refrigerating capacity and required mass flow of refrigerant were found to be lower with R290 when compared to R22.Coefficient of performance with R290 is slightly lower than that of with R22.However, higher COP can be expected by especially designed system pertaining to the properties of R290.Overall, R290 can be a better substitute to R22 in real applications because of its excellent environmental and thermo-physical properties.

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*Keywords:*COP, natural refrigerant; refrigeration system; R22; R290.

1. Introduction

Refrigeration technology has forever played an important role in improving the human standard of living. Inventions such as the refrigerator and air-conditioner have become a necessity for comfort living. However, right from its inception, the refrigeration industry has been constantly tackling the issues of safety and environmental impact of refrigerants. Despite the constant effort from the researchers, the industry has still been a major contributor towards environmental degradation.

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After an early struggle with natural refrigerants and issues like their flammability, the industry received a major catapult with the discovery of CFCs and HCFCs. Since their introduction in 1930, CFCs and HCFCs have been widely used. This success can be attributed to their excellent thermo-physical properties and security. However, in 1974, it had been observed that CFCs and HCFCs are responsible for ozone layer depletion. Ozone layer is a protective shield, the depletion of which leads the harmful ultra violet (UV) rays to enter the earth's atmosphere. Taking this effect into account, decisions were made regarding the phasing out of CFCs and HCFCs at the Montreal Protocol in 1987. While manufacturers were still in the process of replacing CFCs with HCFCs and subsequently HCFCs with HFCs, another environmental issue, that is, global warming came into light. Climate change and rise in average temperature of earth's atmosphere are the serious consequences of the global warming. Though HFCs and many other substances had a lower value of ozone depletion potential (ODP) they were discovered to have higher global warming potential (GWP) value. This created the need for new environment friendly yet energy efficient refrigerants. The search for such a refrigerant seems to have taken researchers back to the natural hydrocarbon such as Propane (R290)[1-3].

For the past few decades, flammable hydrocarbon refrigerants have been prohibited in normal refrigeration and air-conditioning applications due to a safety concern. Infact, hydrocarbon R290 was identified as an odorless, colorless safe refrigerant possessing excellent thermo-physical properties in the year 1920. However, after the development of CFCs and HCFCs in 1928, it was neglected because of its flammability. With the current change in scenario and technological developments, the industry now seems more receptive towards R290 as a potential replacement for R22 [10-14].

Various studies have been carried out with Propane and its mixture [4-7]. Devotta et al.[4]studied R290 refrigerant as an alternative to R22 in window air conditioners. Their results demonstrated that the cooling capacity and energy consumption of R290 were lower than those of R22 by 6.6 to 9.7% and 12.4 to 13.5%, respectively. The COP ofR290 was higher than that of R22 by 2.8 to 7.9%.Purkayastha and Bansal [5] analyzed R22 in a 15 kW heat pump with R290 and showed that R290 has higher COP than R22 by 18%. However, R290 had a lower refrigeration capacity than R22, by 16%. Chang et al.[6]investigated R290, R1270, R600, R600a and mixtures of R290/R600a and R290/R600 as R22 alternatives in a heat pump. They reported that the cooling and heating capacities of R290 were smaller and COP was slightly higher than that of R22. Zhou et al.[7]compared the system performances of a split type air conditioner with R22 and R290 with various operating conditions. Their results indicate that the refrigerant charge and mass flow rate of R290 were only 44% and 47% of R22, and R290 had 4.7- 6.7% lower cooling capacity and 12.1- 12.3% lower input power than R22. The energy efficiency ratio (EER) of R290 was 8.5% higher than that of R22.

Present work demonstrates the applicability of refrigerant R290 as a substitute to R22, with the comparative analysis of properties of R22 and R290 with its thermodynamic performance for different applications.

Nomenclature

CFCs	choloroflurocarbons	h	enthalpy in kJ/kg
HCHCs	hydrochloroflurocarbons	P	pressure in MPa
HFCs	hydroflurocarbons	RE	refrigerating effect in kJ/Kg

2. Properties of Refrigerants R22 and R290

Selection of a refrigerant is a complex process involving detailed analysis of environmental, thermo physical and safety properties.

2.1. Environmental properties

Ozone depletion potential (ODP) and global warming potential (GWP) and atmospheric life are the significant factors demonstrating environmental impact of refrigerant when released to the surroundings. ODP is a normalized