WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Thermodynamic Evaluation of R513A as a Replacement for R134a in Vapor Compression Refrigeration System

R. Siva Adithya [a], S. Ravi Teja [b], Y. Dhanunjaya [c], Sk. Mohommad Hasheer [d]

[a,b,c] Students, Department of Mechanical Engineering, R.V.R&J.C College of Engineering, Guntur.
[d] Associate Professor, Department of Mechanical Engineering, R.V.R&J.C College of Engineering, Guntur.

ABSTRACT-

This paper documents a comparative thermodynamic investigation of R513A and R134A within a vapor compression refrigeration system (VCRs) with special emphasis on the viability of substituting R513A as a low-GWP alternative. Experimental testing was conducted under controlled modes of evaporation and condenser temperature, which provides a steady cooling load close to 10kw. Key operating matrix - such as mass flow rate, energy input and system efficiency - measured and compared. Conclusions indicate that R513A can be an effective drop-in replacement for R134A, providing a stable performance with a moderate increase in compressor power and cold flow rates and a slight loss in energy efficiency. The research endorses the acceptability of R513A in climate-friendly refrigeration use.

Keywords: Alternative refrigerant, R513A, R134a, VCRS.

1.Introduction

A rising worldwide demand for air conditioning and refrigeration has prompted the extensive use of vapor compression refrigeration systems (VCRs), which utilize of the hydrophlorocarbons (HFC) refrigerant in most systems. Although such fluids have been efficient in the context of thermal performance and safety, their elevated global warming capacity (GWP) has caused significant environmental issues. The R134A, being one of the most widely applied HFCs, shows very good thermodynamic properties and zero ozone deficiency (ODP) but has an estimated GWP of 1300-leading to regulatory scrutiny and successive phase-down steps through the aerial environmental protocol.The global framework like the Kyoto Protocol and Kigali Amendment to the Montreal Protocol has established compulsory production and reduction in production and consumption of high-GWP compounds. In return, the refrigeration sector has started to identify low-GWP alternatives that can provide similar performances with minimal changes in current systems. An Azeotropic blend of R513A, R134A and R12344f has gained significant attention as a potential contender based on its low GWP (~ 573) and the comparable thermophic behavior.This research discusses the thermodynamic appropriateness of R513A as a direct alternative for R134A in an improbable VCRS. Experimental performance parameters like mass flow rate, compressor power consumption, condenser heat rejection and energy efficiency at different operating conditions, the aim of research is to determine if R513A can offer equal performance by mitigating environmental degradation.

2.Methodology

2.1 experimental objective:

The main goal of this research is to assess the thermodynamic performance of R513A as a direct, drop-in alternative for R134A in a standard vapor compression refrigeration system (VCRS). The experiment was carried out with the intention of running the system in identical hardware conditions for both refrigerants, which allows for an unbiased and isolated comparison of their performances.

2.2 Refrigerant Properties:

R134a (1,1,1,2-Tetrafluoroethane):

R134a is a saturated HFC refrigerant and non-toxic, non-flammable according to ASHRAE safety group A1. Its boiling point at atmospheric pressure is -26.3 °C and the molecular weight is 102.03 g/mol. Although having zero ozone depletion potential, due to its high GWP, it has been banned by international authorities in new refrigeration equipment..

Fig-1

R513A (R-134a/R-1234yf Blend):

R513A is a binary, near-azeotropic blend containing 56% R134a and 44% R1234yf by weight. It maintains ASHRAE A1 classification, having similar operating pressures and capacities as for R134a. With a GWP of about 573 and very small temperature glide (~0.3 °C), R513A is intended to be compatible with systems initially designed for R134a, such as using POE (polyolester) lubricants..

Fig-2

2.3 Lubricating Oil:

An EmkarateRL68H synthetic polyolester lubricant was employed throughout the experiment. The oil is specially designed for HFC and HFO refrigerant compatibility with ideal viscosity (≈68 cSt at 40 °C). Moisture levels were below 50 ppm to avoid hydrolysis and subsequent acid formation.

2.4 Experimental Setup:

Experimental equipment simulates a standard VCR cycle and consists of the following major components:

Compressor – Pressures and circulates the refrigerant vapor.

Condenser – Rejects heat to the environment and liquefies the refrigerant.

Capillary Tube – Serves as the expansion component, lowering pressure and temperature.

Evaporator – Pumps heat and changes refrigerant from liquid to vapor.

Temperature and pressure sensors were placed at critical points, and energy utilization was monitored with a calibrated digital power meter.

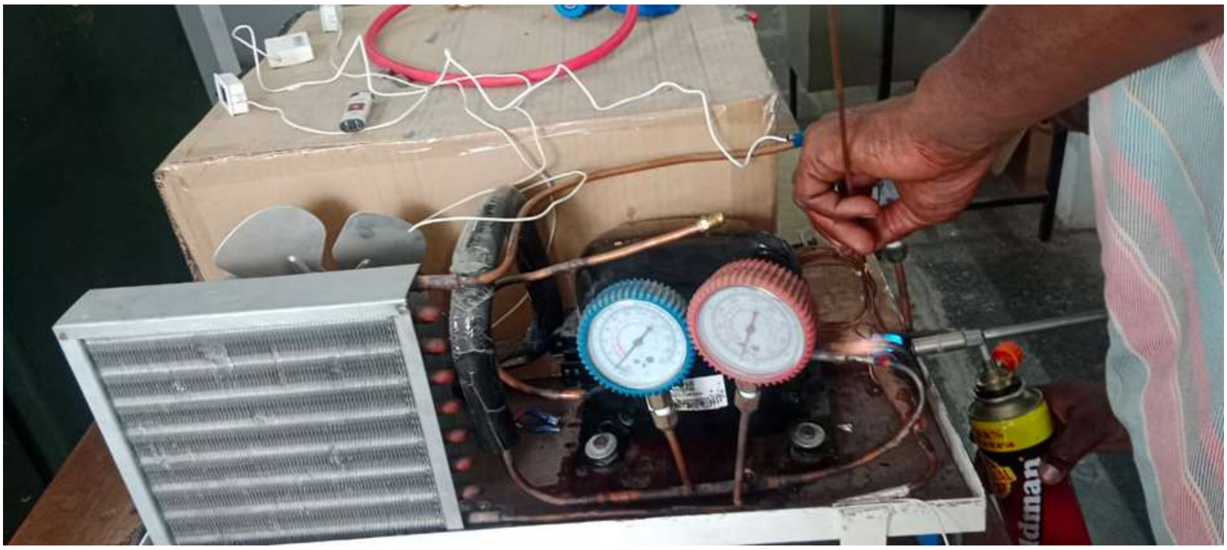

Fig-3

2.5 Testing Procedure

1. The system was evacuated and filled with either R134a or R513A.

2. The compressor was started and left to stabilize.

3. Steady-state readings were taken for pressures, temperatures, and energy input.

4. The most important thermodynamic parameters, including mass flow rate, Energy Efficiency Ratio (EER), and coefficient of performance (COP), were calculated.

Tests were carried out at three evaporator temperatures (-5 °C, 0 °C, and 5 °C) and three condenser temperatures (40 °C, 45 °C, and 50 °C), with the cooling load kept close to 10 kW under all experiments.

3.Results:

Experiment analysis was also performed under the same system setup using R134A and R513A as a working fluid. Measurements were obtained in a 3x3 matrix of evaporation temperatures (° C, 0 ° C, and 5 ° C) and condenser temperatures (40 ° C, 45 ° C, and 50 ° C) while having a cooling capacity of approximately 10kw.The key performance parameters measured are mass flow rate, compressor power input, condenser heat rejection and energy efficiency ratio (EER). Average was performed across a number of tests to achieve repetition of data sets for every refrigerant and minimize experimental deviations.

3.1 mass flow rate:

Close to all test conditions, the R513A system necessitates high mass flow rate than the R134A on a continuous basis. It is accountable for less latent heat of evaporation at similar pressures of R513A. On average, R513A proved to have an increase of 18.08% in mass flow rate over R134A in order to provide equivalent cooling performance.

3.2 Compressor Power Consumption:

R513A showed an increment in demand for compressor power by an increase of 6.19% over R134A for the same thermal load. It is associated with high volumetric flow rate and mild elevated suction pressure observed in increase tests.

3.3 Condenser heat rejection:

The condenser outlet heat rejection capacity was also slightly greater for the R513A, averaging 1.95% higher. This is due to high mass flow rates and compressor operations with inputs, which helps in raising the baggage discharge on the condenser side.

3.4 Energy efficiency ratio:

Even though the operation of the system with R513A was stable, the EER value was slightly reduced in comparison to the R134A. On average, EER had a reduction by 5.84%.

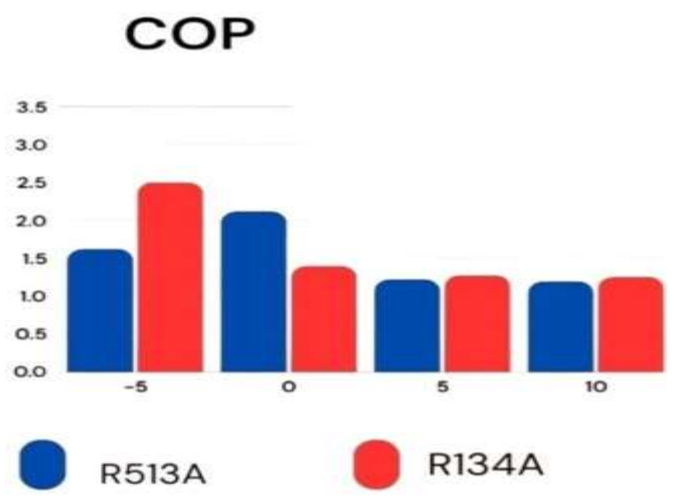

Fig-4

4.Conclusions:

1. The paper gives a comparative thermodynamic analysis of R513A and R134A in a vapor compress refrigeration system under consistent experimental conditions. Conclusions imply that R513A can be used as a viable and environmentally superior substitute for R134A without any changes in the existing system hardware.
2. Even though the R513A partially shows high mass flow demands and compressor power inputs, these alterations are counteracted with its operational stability and compatibility with existing system components. The lack in the Energy Efficiency (EER) is mild and acceptable, particularly when a substantial reduction in global warming potential (GWP) -from approximately 1300 to 573 to 573 for R134A for R513A.
3. The findings validate that the R513A system is a promising low-GWP cold alternative for use in developing environmental regulations by maintaining performance. Future Research Life Cycle Climate (LCCP) can increase this task to further confirm the deployment of R513A into the refrigeration network to assessment, dynamic load modeling, and long -term reliability studies.

References:

[1] UNEP, Montreal Protocol on Substances that Deplete the Ozone Layer. Final Act. United Nations, New York, 1987.

[2] Regulation (EU) No. 517/2014 of the European Parliament and the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No. 842/2006. Official Journal of the European Union, 2014.

[3] Global Environmental Change Report GCRP. A Brief Analysis Kyoto Protocol, vol. IX, p. 24, 1997

[4] United Nations Environment Programme (UNEP). Twenty-eighth meeting of the parties to the Montreal Protocol on substances that deplete the ozone layer. Decision XXVIII/Further Amendment of the Montreal Protocol 2016:1-9.

[5] Intergovernmental Panel on Climate Change (IPCC), 5th Assessment Report (AR5): Chapter 8, Access date: April 3, 2023, https://www.ipcc.ch.

[6] Bolaji B.O., Huan Z. Performance investigation of some hydrofluorocarbon refrigerants with low global warming as substitutes for R134a in refrigeration systems. Journal of Engineering Thermophysics. 2014;23:148-157.

[7]Yang M., Zhamg H., Meng Z., Qin Y.Experimental study on R1234yf/R134A mixture (R513A) as R134a replacement in a domestic refrigerator. Applied Thermal Engineering. 2019;146:540-547.