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# Performance Comparison of Vapor Compression Refrigeration System Using Various Refrigerants

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**ABSTRACT:** The sustainable development of domestic economies is reliant on energy conservation and environmental protection. This paper aims to conduct a comparative performance analysis of VCR systems by the use of different refrigerants. Both theoretical and experimental studies were reviewed in this particular field of research. The results indicate that R600a yields a better coefficient of performance (COP) and refrigeration effect compared to other refrigerants. Additionally, Nano-refrigerants have been shown to have better thermo-physical properties than regular refrigerants, making it a relatively fresh idea to combine them with conventional refrigerants in vapour compression cycles. The performance of vapour compression refrigeration systems can be improved by combining nanoparticles with refrigerants. In conclusion, the refrigerant R600a appears to be a suitable alternative to replace R134a as a novel refrigerant in VCR systems in the near future due to its environmentally acceptable properties and favourable refrigeration performances. With further advancements in research and technology, nano-refrigerants may prove to be the best alternative in the future.

**KEYWORDS:** VCRS, Refrigerants, Nanoparticles, COP, R134a, R600a.

## I. INTRODUCTION

Vapor Compression Refrigeration System is a thermodynamic cycle that produces cooling effects primarily by using an expansion valve, compressor, condenser and evaporator. The working fluid in this process absorbs heat from the surrounding atmosphere at a comparatively lower temperature and rejects heat at a higher temperature. Compounds known as refrigerants are frequently encountered in either a liquid or vapour form. It can quickly absorb heat from the environment and can produce refrigeration or air conditioning effect, when it is combined with other components like compressors and evaporators. CFC and HCFC refrigerants, along with HFC refrigerants, are subject to significant regulations because of their harmful environmental effects such as toxicity, flammability, and contribution to ozone depletion and climate change. Automobile air conditioning systems and the refrigerant pipes in industrial refrigeration systems both use HFC R-134a. It possesses exceptional chemical and thermal stability, with low toxicity and non-flammability, in addition to exhibiting excellent compatibility with a wide range of materials.[7]

Natural sources are supplied to the R-600 series refrigerant, which has a negligible chance of contributing to global warming and zero ODP. To prevent fire problems, it must be designed with the highest level of accuracy. Furthermore, it needs to be used with caution.

A nanofluid is a liquid that contains nanoparticles, or particles that are smaller than one nanometer. By adding nanoparticles into a basic fluid, these fluids are created. Metals, oxides, carbides, or carbon nanotubes are commonly used to constitute the nanoparticles found in nanofluids. Water, ethylene glycol, and oil are a few examples of typical base fluids employed in this context. Many researchers have investigated the feasibility of incorporating nanoparticles into refrigerants in order to develop a new class of nano fluids referred to as "Nano refrigerants."

With the swift advancement of nanotechnology, it is now possible to produce metal, oxide, and carbide nanoparticles (1 to 100 nm) that can improve heat transfer in refrigeration systems and hence raise their efficiency. A brand-new category of heat transfer fluids known as nanofluids has been created as a result of the extraordinary thermal conductivity of tiny nanoparticles contained in conventional heat transfer fluids.

The following traits distinguish nano fluids from typical liquid solid mixtures.



- A) Greater transfer of heat between the fluid and particles as a result of the articles' high surface areas.
- B) Greater stability of dispersion.
- C) Dampens the accumulation of particles.
- D) Uses less pumping force than base fluid to achieve equal heat transfer.

## II. RELATED WORKS

**S.Umaet al.(20180)** [1]. Utilized COP criteria as a novel approach to compare and evaluate various refrigerants, including R12, R134a, and R600a, with the aim of examining the VCR simple cycle and system components.

**Nagarajuet al.(2018)** [2]. Analyzed the variation in performance by using nanoparticles; The use of nanoparticles has made compressors more efficient by improving heat transfer and reducing power consumption.

**Pawaleet al.(2017)** [3], reviewed the addition of nanoparticles to traditional refrigerants and concluded that adding Al<sub>2</sub>O<sub>3</sub> nanoparticles to the base refrigerant can improve the overall efficiency of the system more than using just the unadulterated refrigerant.

**Dhivakar Raviramet al.(2020)** [4] analyzed various refrigerants and provided that R22 has a greater COP but a very negative environmental effect. Since R290 uses less electricity while providing a superior environment, it is suitable for VCRS based Air Conditioners.

**Babarindeet al.(2019)**[5], investigated the enhancement of VCR system using various refrigerants and capacitors to minimize the consumption of power and concluded that isobutene is a better alternative for Tetra fluoro ethane and adding capacitor to the electric circuit will increase performance.

**Raghunathaet al.(2018)** [6], concluded that increase in the volume of nanoparticles is directly proportional to the rise in viscosity, whereas when temperature increases the viscosity decreases. The concentration of nanoparticles is directly proportional to the enhancement in the efficiency of heat transfer of the system.

**Dalkilicet al.(2010)** [8], showed the results of a theoretical performance study on a conventional vapour-compression refrigeration system using mixtures of HFC134a, HFC152a, HFC32, HC290, HC1270, HC600, and HC600a were compared with those of CFC12, CFC22, and HFC134a as potential substitutes.

**Satsangiet al.(2018)** [9]. provided a detailed study about the R134a refrigerant and its usage in the current refrigeration system.

**Baskaran et al.(2012)** [10],analyzed regarding potential substitutes for R134a in refrigeration applications, the refrigerant blend R435A [RE170 (80%), R152a (20%)] has emerged as the most favorable choice. Evaluations demonstrate that the coefficient of performance (COP) of the system rises as the evaporating temperature increases, assuming a consistent condensing temperature.

**S.K. Kalla1et al.(2018)** [11] reviewed the most suitable replacement option for the current refrigerant R22, while requiring minimal or no modifications to the air conditioning system. The suggestion put forth in this paper is to opt for HFC and HC mixtures with the lowest Total Equivalent Warming Impact (TEWI) index, until the safety concerns associated with using hydrocarbon refrigerants in quantities exceeding 500 grams are resolved.

B.B. Arora et al.(2018) [12], The aim of this paper was to evaluate how well refrigerants R22, R407C, R432A, R438A, and NM1 (R32/R125/R600a) perform in order to find a suitable replacement for HCFC 22. The results indicate that when considering the energetic efficiency, exergetic efficiency, TEWI, and flammability at the same time, R438A proves to be the better option for substituting R22.

III. TEST SETUP & METHODOLOGY

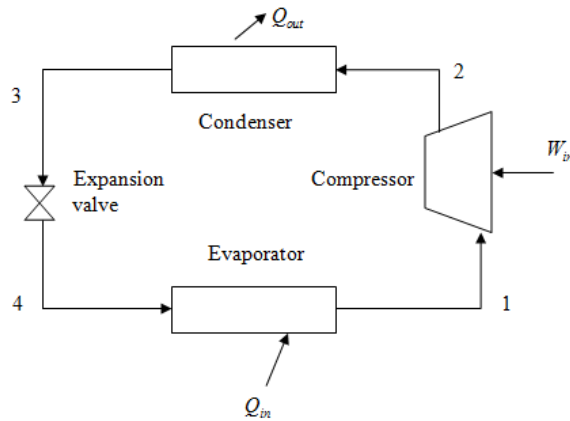


Fig.III.1: Simple Vapour Compression Cycle

III.1 Vapour Compression Refrigeration System Elements comprises of

**1.Compressor** - Refrigerants having low temperature and high pressure flows from evaporator to condenser through suction or inlet valve and is then compressed isentropically which in turn increases the temperature and pressure and is released into the condenser with the help of the discharge valve.

**2.Condenser** - The condenser is constructed using slender copper pipe coils, where high temperature and pressure refrigerant is condensed and cooled. It is basically a heat exchanger where refrigerant releases its heat to the surroundings.

**3.Receiver** - The receiver vessel stores the mixture of condensed liquid and vapor at elevated pressure and temperature. It then provides a supply of condensed refrigerant to the expansion valve, enhancing control and achieving improved throttling efficiency.

**4.Expansion Valve** - The purpose of this valve is the smooth and controlled flow of liquid refrigerant, which has been subjected to temperature and pressure reduction, at elevated temperatures and pressures. During its passage through the expansion valve, a fraction of the liquid refrigerant undergoes evaporation, while the majority of it vaporizes within the evaporator at low pressure and temperature.

**5.Evaporator** - Evaporator is a type of heat exchanger in which the refrigerant gains heat from the surrounding in the form of latent heat to evaporate and enter into the compressor in vapour form resulting in cooling of the surrounding.

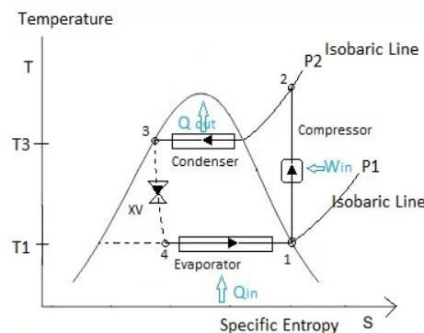


Fig. III.2: T-s Diagram Of VCRS Cycle



### III.2 Methodology

Initially, the compressor in this experimental setup is powered by conventional electrical power. To compare the performance parameters of the refrigerator, tests are conducted at the same condenser and evaporator temperatures for all refrigerants. During the experimentation process, various instruments, such as pressure gauges, thermocouples, voltmeters, and ammeters, are used to measure pressure, temperature, voltage, and current, respectively. The temperature at various points in the vapor compression refrigeration system is directly measured using a thermocouple sensor.

To generate base data, the VCR system is first charged with a refrigerant and tests are conducted at various operating conditions. Subsequently, the VCR system is charged with other refrigerants, and similar tests are conducted while recording experimental data. By analyzing the experimental results, the performance of the vapor compression refrigeration system will be assessed. This experiment is specifically designed to find the system's coefficient of performance (COP).

### III.3 Measurement of System's Efficiency

A refrigeration system's COP can be used to calculate its efficiency. This is specified as:

$$\text{COP} = \text{Desired Effect} / \text{Required input} = Q_L / W_{\text{net,in}} \quad (1)$$

Equation (1) can also be written as follows:

$$\text{COP} = [Q_L / (Q_H - Q_L)] = 1 / [(Q_H / Q_L) - 1] \quad (2)$$

where  $Q_L$  and  $Q_H$  represent, respectively, the heat accepted from the lower temperature source and the heat released to the higher temperature reservoir.

The COP can also be calculated by using the absolute temperature ratio in place of heat transfer ratio:

$$\text{COP} = 1 / [(T_H / T_L) - 1] \quad (3)$$

## IV. EXPERIMENTAL RESULTS

### 1. COMPARISON OF COEFFICIENT OF PERFORMANCE OF VCR SYSTEM BY USING REFRIGERANTS R134A AND R600A (ISOBUTENE).

The experimental results indicate that both COP and refrigeration effect of the R600(Isobutene) refrigerant is higher than the R134a.



Refrigeration Effects vs. Refrigerants

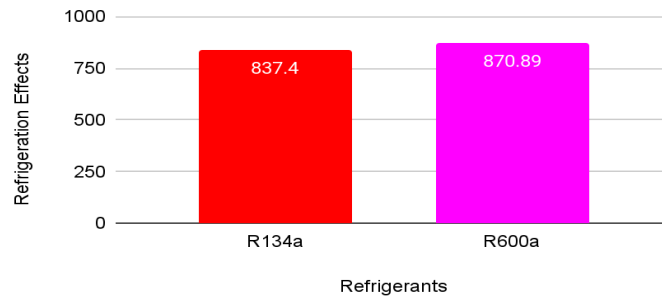


Fig. IV.1: Refrigeration Effect vs. Refrigerants

COP vs. Refrigerants

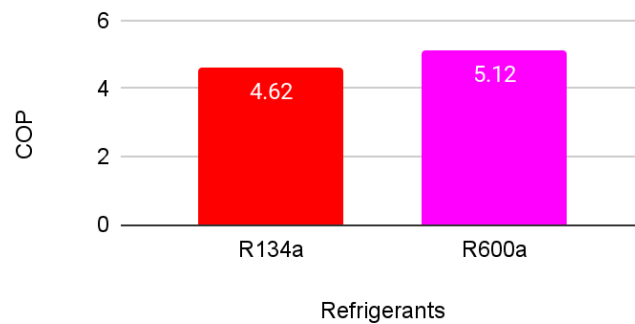


Fig. IV.2: COP vs. Refrigerants

**2. Performance analysis of R134a blended With Mineral Oil and (CuO) Nanoparticle.**

CuO nanoparticles can enhance the efficiency of refrigeration systems when used in conjunction with R134a refrigerant. The optimal concentration of CuO nanoparticles in R134a refrigeration equipment was found to be 0.8% of CuO mixed with 175 grams of R134a. This resulted in a significant modification in the coefficient of performance (COP), leading to higher cooling loads with less power consumption and energy consumption. Experimental investigation has shown that the usage of CuO nanoparticles with R134a refrigerant results in higher performance characteristics of the refrigeration system.

| Refrigerants   | T <sub>1</sub> (°C) | T <sub>2</sub> (°C) | T <sub>3</sub> (°C) | T <sub>4</sub> (°C) | P <sub>1</sub> | P <sub>2</sub> |
|--|---------------------|---------------------|---------------------|---------------------|----------------|----------------|
| R134 <sub>a</sub>                                    | 25                  | 25.3                | 11.2                | 5.11                | 0.357          | 7.215          |
| R134 <sub>a</sub><br>+CuO(0.8%)<br>Concentrati<br>on | 30                  | 26.4                | 10                  | 3.3                 | 4.017          | 1.013          |

Table1: Temperature and pressure against refrigerants



| Refrigerants  | h <sub>1</sub> | h <sub>2</sub> | h <sub>3</sub> | h <sub>4</sub> |
|---|----------------|----------------|----------------|----------------|
| R134 <sub>a</sub>                                     | 370.23         | 440.23         | 240            | 240.23         |
| R134 <sub>a</sub><br>+ CuO(0.8%)<br>Concentrati<br>on | 410.74         | 440.74         | 260            | 240.74         |

Table 2: Enthalpy at all points

### COP vs. Refrigerants

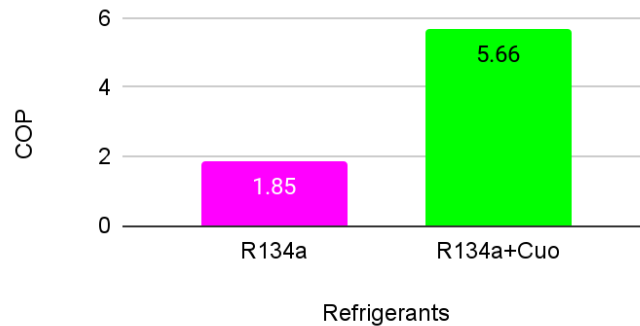


Fig. IV.3: COP vs. Refrigerants

### 3. Performance Analysis of VCRS with Nano-Refrigerant Al<sub>2</sub>O<sub>3</sub> with R134a

The inclusion of 0.5% Al<sub>2</sub>O<sub>3</sub> nanoparticles in the base refrigerant can enhance the overall performance of the VCRS compared to using only the unadulterated base refrigerant. Nonetheless, if nanoparticle concentration is further increased, it will cause a decline in the system's performance.

| Refrigerants                                   | T <sub>1</sub> (°C) | T <sub>2</sub> (°C) | P <sub>1</sub> (Bar) | P <sub>2</sub> (Bar) |
|--|---------------------|---------------------|----------------------|----------------------|
| R134a  | 52                  | 84                  | 3.8                  | 17.5                 |
| R134a + 0.5%<br>Al <sub>2</sub> O <sub>3</sub> | 40                  | 86.35               | 2.7                  | 17.58                |
| R134a + 1%<br>Al <sub>2</sub> O <sub>3</sub>   | 37                  | 86.98               | 3.1                  | 18.9                 |

Table 3: : Temperature and pressure against refrigerants

## COP vs Refrigerants

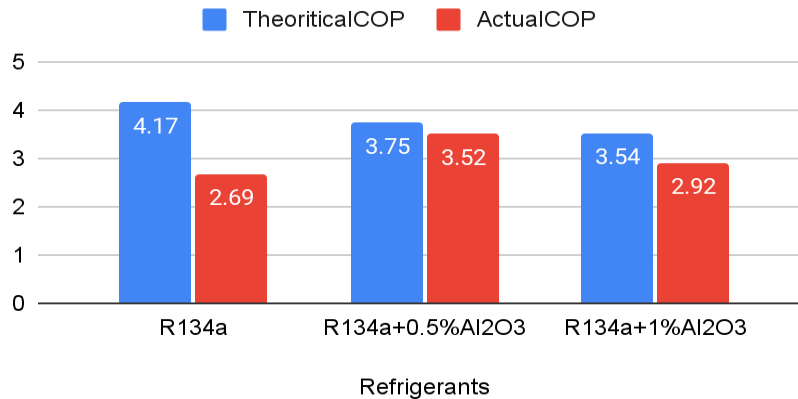


Fig. IV.4: COP vs. Refrigerants

## v. CONCLUSION AND FUTURE SCOPE

The Vapour Compression Refrigeration (VCR) system test results have demonstrated that R600a refrigerant has significantly higher COP and refrigeration effect than other refrigerants tested. R600a refrigerant is a naturally founded ingredient that has zero ozone depletion potential (ODP) and almost negligible global warming potential (GWP). However, the fact that it is a flammable refrigerant contributes to environmental issues and climate change. Despite this drawback, R600a refrigerant is environmentally friendly, and its use can help reduce global warming potential while protecting the ozone layer. Additionally, the vapor pressure characteristics of R134a and R600a are very similar to R12. Therefore, R600a refrigerant could be considered as a new alternative for the VCR system. Furthermore, according to experimental results, there is a significant reduction in the pumping power and work done in the compressor when using R134a with CuO or Al<sub>2</sub>O<sub>3</sub> compared to using only R134a. By adding 0.8% volume concentration of CuO and 0.5% of Al<sub>2</sub>O<sub>3</sub> nanoparticles, the heat transfer properties are improved and power consumption and compressor work done are reduced. However, it should be noted that as the percentage of nanoparticles in the refrigerant increases, the performance of the system will decrease. Therefore, there is a need to develop new refrigeration systems that incorporate low-nano refrigerants. Refrigeration systems that utilize nano refrigerants as working fluids have higher coefficient of performance than conventional refrigeration systems.

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