
*Research Article***Performance Evaluation of Vapour Compression Refrigeration System in Heating and Cooling mode assisted with IoT Technology****Shubham Mehra¹, Chetan², Daksh Gandotra³, Nitin Yadav⁴, Md Taufique Umar⁵, Keshav Nandan⁶, Keshav J^{7,*} and Vaibhav Jain⁸**¹⁻⁷Student, Department of Mechanical Engineering, Maharaja Agrasen Institute of Technology(MAIT), New Delhi, 110086, India.⁸Associate Professor, Department of Mechanical Engineering, Maharaja Agrasen Institute of Technology(MAIT), New Delhi, 110086, India.*Corresponding Author: Keshav J. Email: jkeshav541123@gmail.com

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Abstract: The Heating and Cooling strategy for the vapour compression refrigeration cycle has been characterized by temperature and pressure limits. The theoretical model was established to analyze the performance indicators viz. Coefficient of Performance (COP), exergy loss, exergy analysis, Second Law efficiencies, also catering to different sets of refrigerants present in the market these days. Also, with advancement in the field of science and research, the search for the better is the growth, so talking about all the different refrigerants and comparing based on performance indicators too. The Internet of Things has been incorporated to make the controls easier and user-friendly.

Keywords: Vapour Compression Refrigeration Cycle, IoT, 4-WAY Reverse Valve, Refrigerants, UV radiation.

1. Introduction

Over the past hundred years, global energy usage has increased significantly and is projected to keep expanding in the years to come. Considering the impact of population, economy, living standards and other aspects, it is expected that the world's energy use will increase by 56% in the next 30 years (International Energy Agency). Power and climate change: special report on the global energy outlook (International Energy Agency, 2015) [1]. Indian households and markets are filled with machines that serve specific functions and play vital roles in daily life and market operations. appliances like refrigerators, air conditioners, microwaves, and heat pumps cannot be ignored. An integrated system has been developed to cater to the cooling and heating needs, combining the functions of an air conditioner and a heat pump. This system operates on the Vapour Compression Refrigeration System (VCRS), which is widely used for air conditioning in buildings, vehicles, refrigerators, warehouses, and other industrial facilities. In the past, chlorine and fluorine-based refrigerants such as CFCs and HCFCs were widely used but contributed to ozone layer depletion. These substances, when released, would reach the stratosphere where they break down due to UV radiation, releasing chlorine free radicals that catalyze ozone depletion. This led to severe damage to the ozone layer, resulting in increased rates of skin cancer and other harmful effects. However, newer refrigerants like HCFCs and HFCs with reduced Ozone Depletion Potential (ODP) have replaced most CFCs [2]. HFCs may not damage the ozone layer, but they possess significant potential to contribute to global warming. HFCs are used in domestic and commercial refrigeration systems because of their good thermodynamic qualities, but the Kyoto Protocol classified them as global warming gases due to their higher GWP value (1300). Finding HFC replacement refrigerants is crucial for



meeting both global norms and environmental requirements [3].

2. System Descriptions

Figure 1 shows the components of the system, it includes an evaporator, a compressor, a condenser, a thermal expansion valve, and most importantly a 4-way reversing valve. The operating fluid is the refrigerant. The compressor operates in cooling mode, Where it begins as saturated vapour and is subsequently compressed to achieve a higher temperature and after passing through the condenser, where heat is released into the surrounding air. The method of heat removal in a condenser is contingent upon its type, utilizing either air or water for this purpose [4-6].

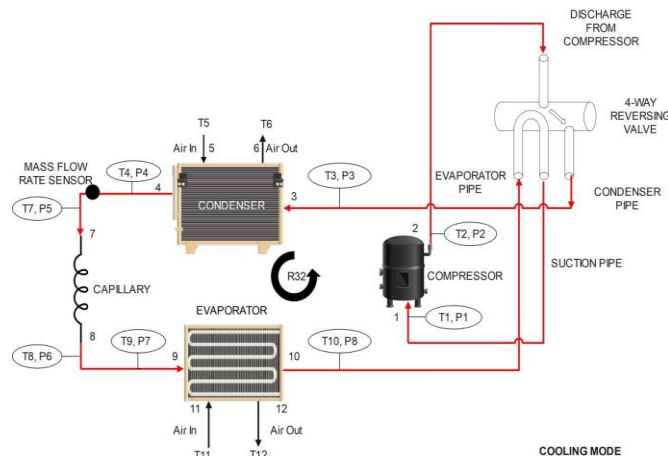


Figure 1: Showing the components and the Gauges placement in Cooling mode

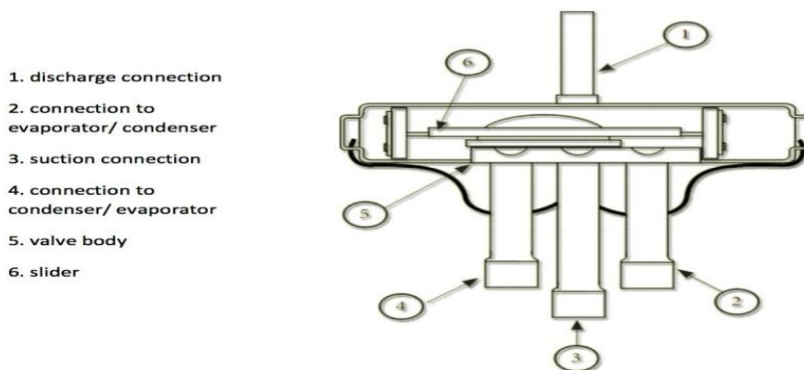


Figure 2: 4-way Reversing valve

Figure 2 shows technological device that helps to shift from cooling to heating mode and vice-versa. It internally changes the valve position between evaporator and condenser and thus, the whole operation that is taking place. The element also plays an important role in the automatic switch between heating mode and cooling mode depending upon the ambient.

The only change in the heating mode is that there is a change in the working of condenser and evaporator, they interchange their workings due to changes in the inlet and outlet pipelines, condenser plays role of evaporator and evaporator as condenser (Fig 3) [7-10].

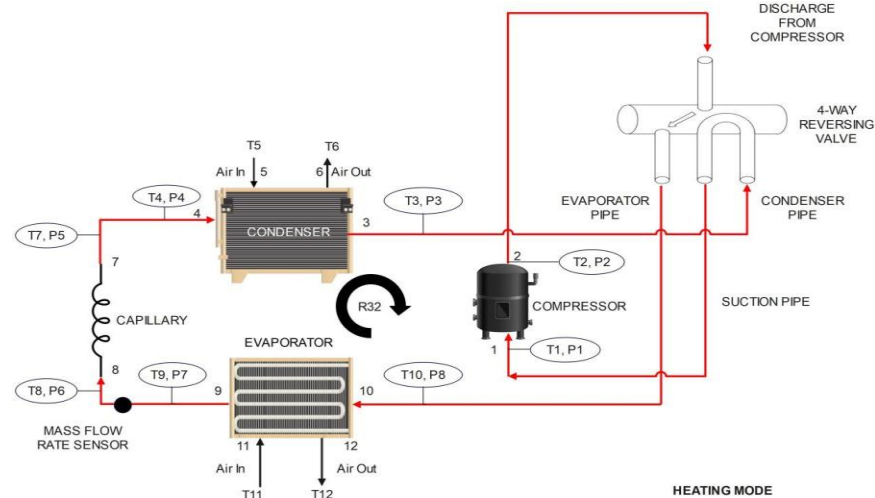


Figure 3: Showing the Components of Gauges and valves in Heating mode

3. Mathematical Modeling

In the study, the following assumptions are made [11-12]:

1. Steady state conditions are assumed in all the components (To be easy to apply Steady State Energy Equations i.e., SFEE).
2. Pressure losses in the pipeline are neglected (If they would have been included then the coefficient of discharge and all come into equations and hamper the calculations).
3. Saturated state exists at evaporator and condenser.
4. Kinetic energy and Potential energy losses are not considered.
5. Compression process is assumed to be isentropic.
6. Throttling process is assumed to be isenthalpic.

3.1 Thermodynamic Modelling

Refrigerant mass conservation equations under steady state condition for a control volume can be written as follows:

$$\dot{m}_3 = \dot{m}_{10}$$

For calculating the performance parameters, first $COP = W/Q_e$ and $W = m(h_2 - h_1)$, $Q_e = m(h_{10} - h_9)$.

The formulations of energy interaction and irreversibility across the various components of our system [13-15]. Irreversibility is governed by the Guoy-Stodola theorem, i.e., $I = T\Delta S$. The following are the formulations (Table 1):

Table 1: Formulations

System	Energy interaction across the system (E)	Irreversibility (I)
Compressor	$W_{input} = h_2 - h_1$	$I = \int T ds$
Condenser	$Q_{rej} = h_2 - h_3$	$I = \int T ds$
Throttling Device	No energy interactions	$I = mRT \ln V_2/V_1$

4. Results and Discussions

In respect to Figure 4, with the increase in condenser temperature, the COP of the system is decreasing, and compressor work is increasing. This happens because the refrigeration capacity decreases, and the compressor power increases with an increase in the condensing temperature.

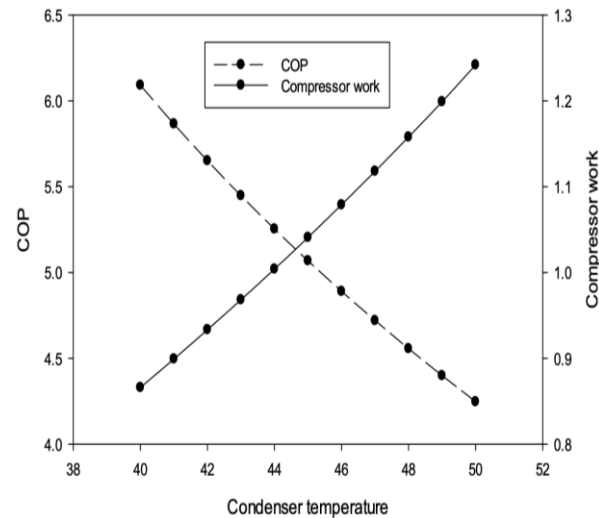


Figure 4: Condenser characteristics in terms of COP and Second Law Efficiency

Also, It can be clearly seen that increasing condenser temperature lowers the Second Law efficiency, as increasing temperature causes more entropy (randomness) among the particles; as according to Guoy-Stodala theorem, Irreversibility is product of change in entropy and absolute temperature, as change in entropy is positive this increases in irreversibility, which in turn lowers the Second Law efficiency of the system.

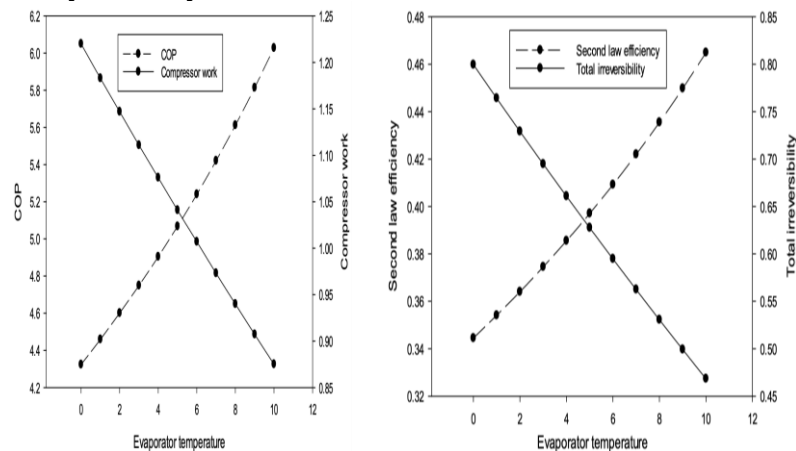


Figure 5: Evaporator characteristics in terms of COP and Second Law efficiency

With reference to figure 5, with the increase in evaporator temperature, there is an increase in COP and a decrease in compression work, as can be seen from graph 5; as the temperature of the evaporator's capacity rises, the system pressure also increases, resulting in reduced compressor work. Consequently, the rise in evaporator temperature leads to a diminished temperature differential across the evaporator, in turn decreasing the amount of heat addition and therefore increasing the cop of the system. There is a decrease in entropy of the system as $\Delta S \Delta Q/T$, and a change in heat interaction decreases, which in turn decreases the entropy. As entropy (randomness) decreases, irreversibility decreases, and thus, there is an increase in the Second Law efficiency of the system.

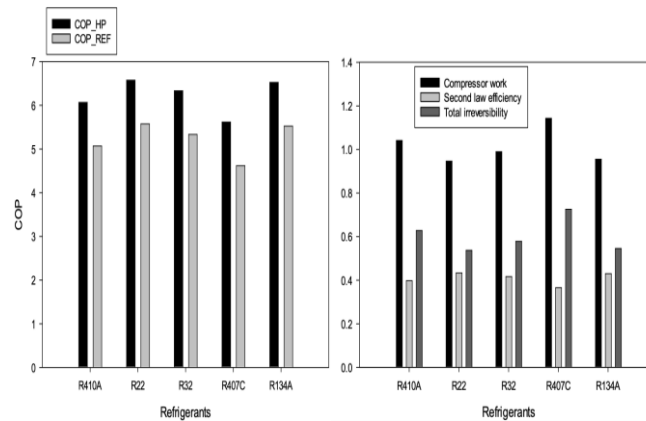


Figure 6: Comparison of different Refrigerants, viz. R410A, R22, R32, R407C, R134A

Figure 6 shows the trend across the various refrigerants in reference to COP as a Heat pump and a Refrigerator, i.e., Heating and Cooling mode, respectively, and the trend of various refrigerants on various factors such as compressor work, Second Law efficiency, and total irreversibility.

5. Conclusion

This paper presented a system that can work both as a heat pump or an air conditioner. The main goal of this integrated system is to create a single system with multiple functionalities, i.e., heating and cooling, and to find the best temperature ranges to get better cop and performance. This paper also helps in finding the best refrigerant among R32, R22, R134a, R410a and R407c by studying their behavior on parameters like condenser and evaporator temperature. Second Law efficiency, total irreversibility and compressor work is also considered while finding the suitable refrigerant for the system.

Nomenclature

COP	Coefficient of Performance
GWP	Global Warming Potential
CFCs	Chlorofluorocarbons
HCFCs	Hydro-chlorofluorocarbons
VCRS	Vapour Compression Refrigeration System
HFCs	Hydro-fluorocarbons
W	Work, kW
Q_e	Heat Interaction, kW
T	Temperature, K
S	Entropy
H	Enthalpy, kJ
h	Specific enthalpy

C	Specific heat, kJ/kg K
R	Characteristic gas constant, kJ/kg K
V	Volume, m ³
HP	Heat Pump
REF	Refrigerator
P	Pressure
S	Specific entropy

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