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Performance Analysis of Heat Pump and Air Conditioning System Using R-32 Refrigerant & Theoretical Comparison With R-290 Refrigerant

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Abstract

An extensive performance analysis of a heat pump air conditioning system for both cooling and heating applications is included in this research. The purpose of the research is to assess the system's overall performance, energy consumption, and efficiency under various operating scenarios. The research incorporates a range of experimental techniques. An overview of the heat pump air conditioning system's parts and operation is given at the outset of the examination. Key factors like the outside temperature, the flow rate of refrigerant, the power consumption of the compressor, and the differences in temperature between the inside and outside are monitored in the experimental setup. Both the heating and cooling modes are taken into account while collecting these measurements throughout a range of operational circumstances. For HVAC engineers, researchers, and policymakers, the heat pump air conditioning system performance study provided in this paper is an invaluable resource. The knowledge gathered from this research helps with continuous attempts to enhance the functionality and design of heat pump systems for use in heating and cooling, promoting energy efficiency and sustainability in the built environment. This article explores the performance of heat pump and air conditioning systems using R-32 refrigerant, providing a theoretical comparison with R-290 refrigerant. R-32, a hydrofluorocarbon (HFC) with a relatively low global warming potential (GWP), demonstrates excellent energy efficiency and stability across varying ambient temperatures, making it suitable for diverse climates. In contrast, R-290, a natural refrigerant with an even lower GWP, offers high cooling capacity but poses safety challenges due to its flammability. The analysis highlights R-32's advantages in terms of energy consumption, system design compatibility, and regulatory compliance, while discussing the trade-offs associated with R-290's performance and safety considerations.

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Keywords: Heat Pump, HVAC System, Dual Mode heat pump, Heating and Cooling

INTRODUCTION

The HVAC (Heating, Ventilation, and Air Conditioning) industry's growing concentration on energy efficiency and sustainability in the environment has sparked a lot of interest in how distinct refrigerants act.

Among these, R-32 and R-290 have emerged as prominent candidates due to their distinct properties and potential environmental benefits. This project delves into the performance analysis of heat pump and air conditioning systems using R-32 refrigerant, providing a theoretical comparison with R-290 refrigerant to highlight their respective advantages and limitations [1].

The performance analysis of heat pump and air conditioning systems using R-32 refrigerant involves a detailed evaluation of its thermodynamic properties, efficiency metrics, environmental impact, and operational characteristics in comparison to R-290 refrigerant. R-32 (Difluoromethane) is a hydro fluorocarbon (HFC) that boasts a lower global warming potential (GWP) of 675 compared to traditional refrigerants like R-410A, making it a more environmentally friendly option.

R-290 (propane) is a hydrocarbon refrigerant known for its excellent thermodynamic properties and very low GWP of 3. Unlike HFCs, R-290 does not contribute to ozone depletion and has negligible global warming potential, making it one of the most environmentally benign refrigerants available [2].

Commercial Buildings: Commercial buildings, such as office spaces, retail stores, and hotels, can benefit from heat pump systems that offer simultaneous heating and cooling.

Educational Institutions: Heat pump systems for simultaneous heating and cooling are applicable in educational institutions, including schools and universities

Healthcare Facilities: To maintain clean facilities surroundings and guarantee patient comfort, hospitals, clinics, and other hospitals need to precisely regulate the temperatures inside. The demand for energy-efficient cooling and heating solutions has led to the exploration of various refrigerants. R-32 and R-290 are two refrigerants gaining traction due to their distinct properties and environmental impacts. This article presents a performance analysis of heat pumps and air conditioning systems utilizing R-32 refrigerant, alongside a theoretical comparison with R-290 refrigerant [3].

Frolov et al [1] performance evaluation of R-32 and R-290 refrigerants in air conditioning systems. Lee [2] experimental study on the performance of R-32 and R-290 refrigerants in heat pumps. HVAC system requirements in constructing energy regulations, Pérez et al. [3].

Energy and buildings. Dr. Claire [4] BC Campus thermodynamic testbook. Refrigerator and Heat Pump. Bhatia [5] heat pumps for heating and cooling. CED engineering.

Despite progress, several research gaps persist in the study of R-32 and R-290 refrigerants:

1. *Long-Term Performance:* There is a lack of extensive data on the long-term performance of these refrigerants under varied conditions.
2. *Safety Analysis:* More research is needed to develop standardized safety protocols for both R-32 and R-290, particularly regarding leak and fire risks.
3. *Climate-Specific Evaluations:* There is limited research on how these refrigerants perform in extreme or variable climates.
4. *Economic Impact:* Detailed cost-benefit analyses of the economic implications, including installation, maintenance, and overall cost of ownership, are needed.
5. *Integration with Emerging Technologies:* The interaction of R-32 and R-290 with new HVAC technologies like smart controls and renewable energy systems requires further study.

Determine the R32 refrigerant's coefficient of performance for both cooling and heating applications.

A theoretical comparison of system design, safety measures and temperature conditions between R290 (propane) and R32 (difluoromethane) refrigerants.

Experimentation

This cycle works with following stages:

- *Stage 1:* As seen in the illustration (Figure 1), refrigerant enters the evaporator as a cold, low-pressure liquid and vapor mixed. The liquid refrigerant boils as a result of heat transferring from the heated interior air to the compressor.
- *Stage 2:* The compressor elevates the pressure (and thus the temperature) of the refrigerant vapor as it enters via the reservoir.

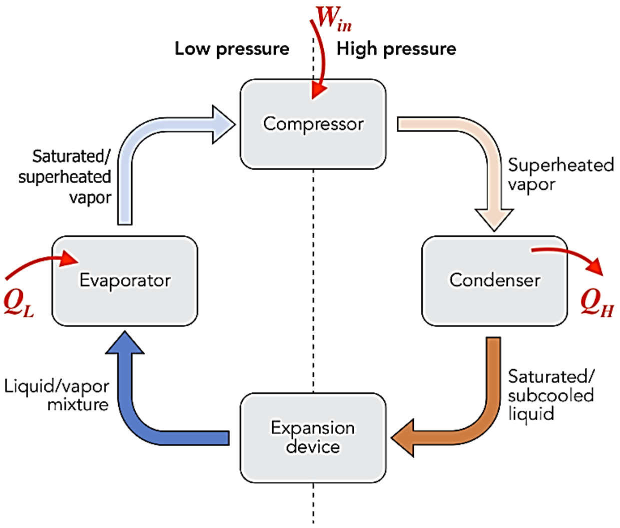

Figure 1. Heat Pump Refrigeration Cycle [4].

- *Stage 3:* The hot, high-pressure locations refrigerant vapor that arises enters the condenser, where it transmits warmth to either water or the surrounding air. The refrigerant condenses into a liquid inside a condenser.
- *Stage 4:* The expansion device accepts this high-pressure liquid refrigerant from the condenser, which lowers its pressure. A small amount of the refrigerant boils (or flashes) at this low pressure, lowering the remaining liquid refrigerant down to the appropriate converter temperature [4].

Operation of a Heat Pump in Cooling Mode

- *Heat Absorption (Evaporator):* In cooling mode, the condenser's and evaporator play opposed roles. Now located inside the building itself, the evaporator coil takes in heat from its own air (Figure 2).

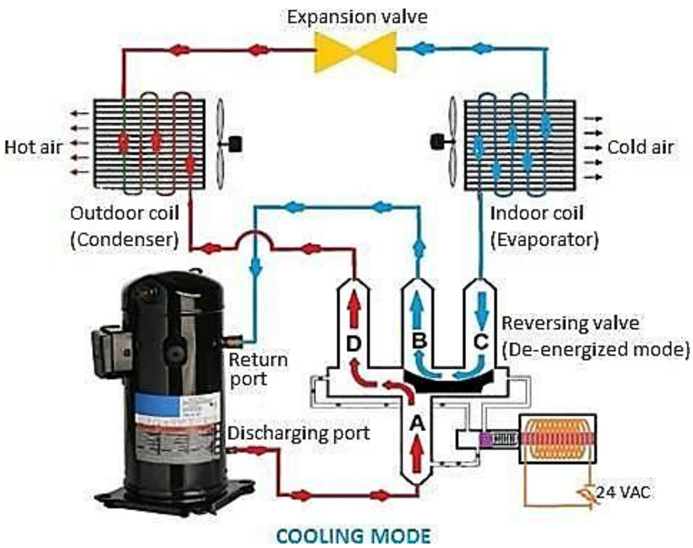

Figure 2. Cooling Mode [5].

- *Compression (Compressor):* The compressor eventually compresses the low-pressure gas, raising its pressure as well as its temperature.
- *Heat Release (Condenser):* Here, the refrigerant collapses back into a liquid by dissipating the heat it has absorbed into the external air.

Pressure Reduction (Expansion Valve): After passing through an expanding valve, the high-pressure liquid ammonia lowers its temperature and pressure before coming to the evaporator [5].

Operation of a Heat Pump in Heating Mode:

- *Heat Absorption (Evaporator):* By absorbing heat from the area around me air, the refrigerant in the evaporator coil evaporates and transformed into a low-pressure gas.
- *Compression (Compressor):* The compressor itself then draws in the low-pressure gas, enhancing the refrigerant gas's pressure and temperature as well. The refrigerant's capacity to release heat is improved by this means.
- *Heat Release (Condenser):* The refrigerant expands back into a high-pressure liquid by discharging the heat it has absorbed into its interior air (Figure 3).

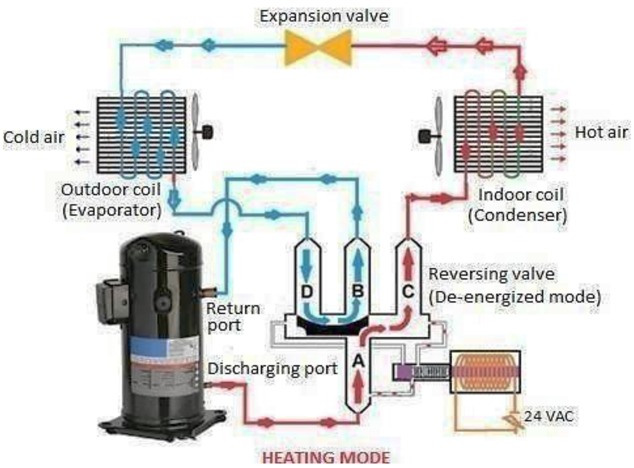

Figure 3. Heating Mode [5].

Pressure Reduction (Expansion Valve): Before returning the evaporator, the expansion valve lower the temperature and pressure of the very high-pressure refrigerant [5].

RESULTS AND DISCUSSIONS

COP in Heating Mode:

The COP in heating mode represents the ratio of the heat output to the power input of the heat pump when it is operating in heating mode. The formula for calculating COP in heating mode is: COP (Heating Mode) = Heat Output / Compressor Power [6-8]

The heat output is the amount of heat energy provided by the heat pump, and the compressor power represents the electrical power consumed by the heat pump's compressor. To calculate the theoretical (COP) heat pump = (COP) refrigeration + 1

Example 1

For the heating mode:

(COP) heat pump = 4.5+1

=5.5

Example 2

For the heating mode:
(COP) heat pump = 1.73+1
=2.7

COP in Cooling Mode:

The COP in cooling mode represents the ratio of the cooling capacity to the power input of the heat pump when it is operating in cooling mode. The formula for calculating COP in cooling mode is: COP (Cooling Mode) = Cooling Capacity / Compressor Power [9,10].

The cooling capacity is the amount of cooling provided by the heat pump, and the compressor power represents the electrical power consumed by the heat pump's compressor. To calculate the Theoretical (COP) refrigeration, divide the h1-h4/h2-h1

: COP = h1-h4/h2-h1 kJ/kg

Example 1

For the cooling mode:
COP = (440-270) / (460-440)
= 8.5

Example 2

For the cooling mode:
COP = (505-260)/(560-505)
= 4.45

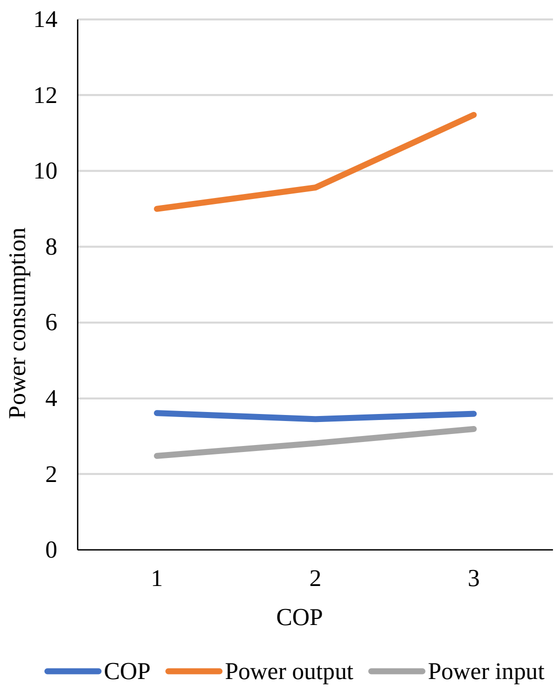

Figure 4. COP in Heating Mod.

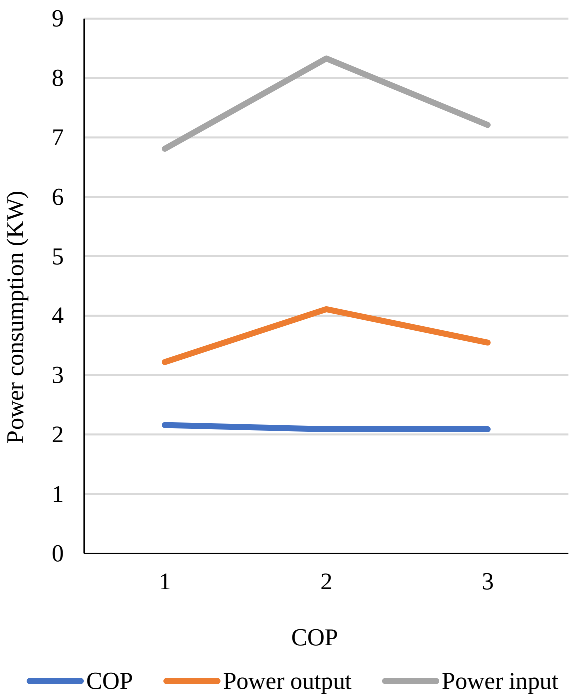

Figure 5. COP in Cooling Mode.

The Figure 4 shows that as the COP (efficiency) increases, the power output also increases at a faster rate than the power input.

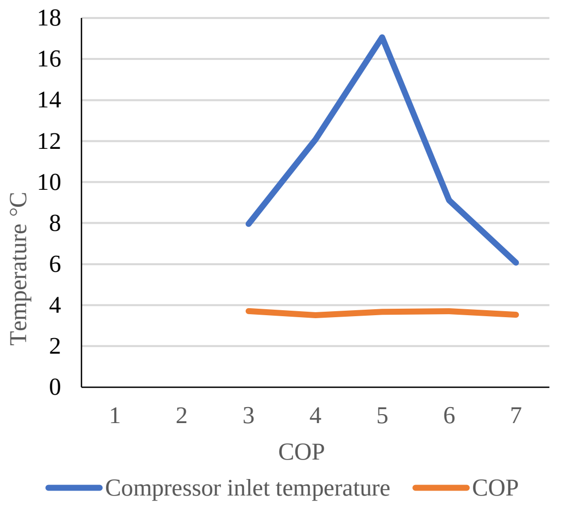

Figure 6. Compressor Inlet Temp vs COP.

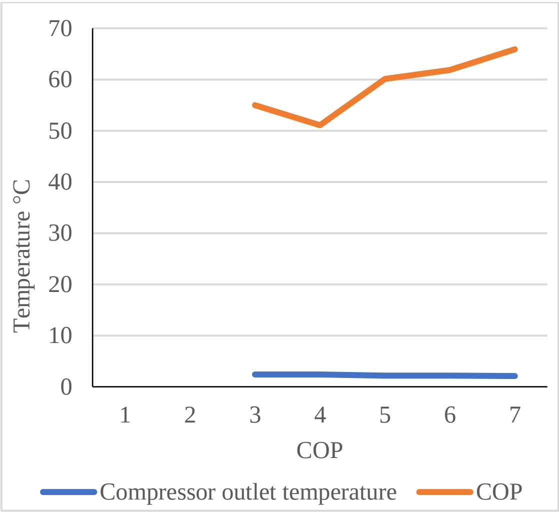

Figure 7. Compressor Outlet Temp vs COP.

The Figure 5 shows he increase in COP itself is relatively small, indicating that the system might have limitations in improving its efficiency beyond a certain point.

The Figure 6 shows compressor inlet temperature experiences a significant increase followed by a decrease, while the COP remains largely unaffected.

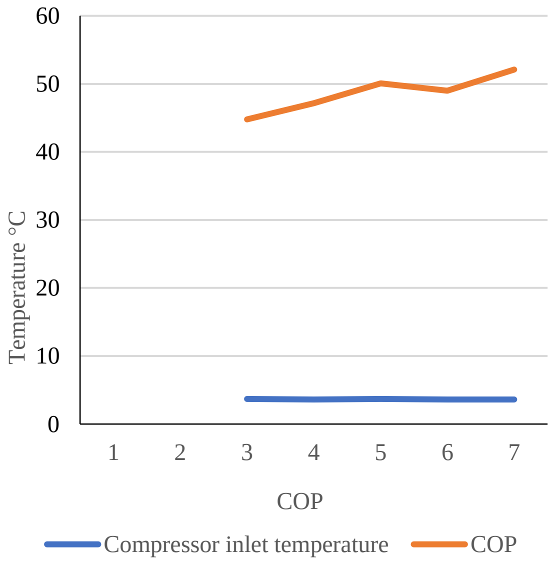

Figure 8. Condenser Inlet Temp vs COP

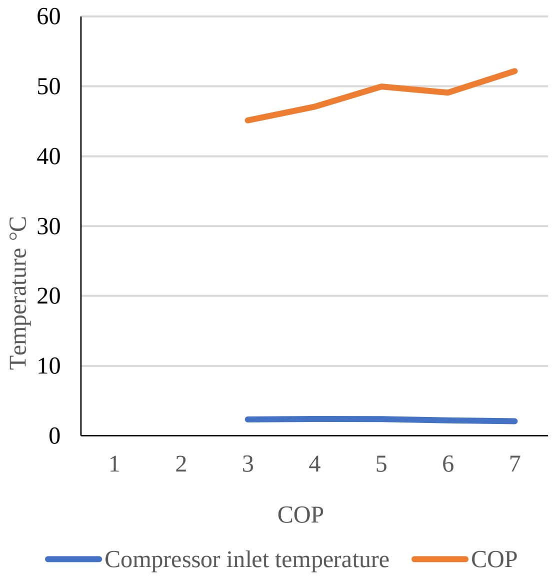

Figure 9. Condenser Outlet Temp vs COP

The Figure 7 shows compressor outlet temperature initially decreases slightly and then increases steadily, while the COP remains largely unaffected.

The condenser inlet temperature experiences a slight increase initially, then stabilizes or decreases slightly, while the COP remains largely unaffected (Figure 8).

The condenser outlet temperature experiences a slight increase initially, then stabilizes or decreases slightly, while the COP remains largely unaffected (Figure 9).

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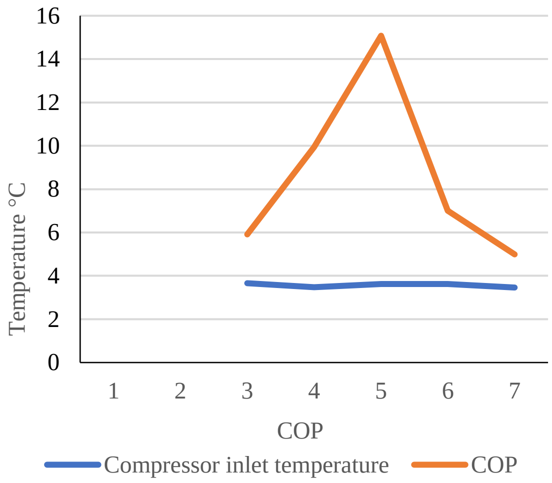

Figure 10. Evaporator Inlet Temp vs COP

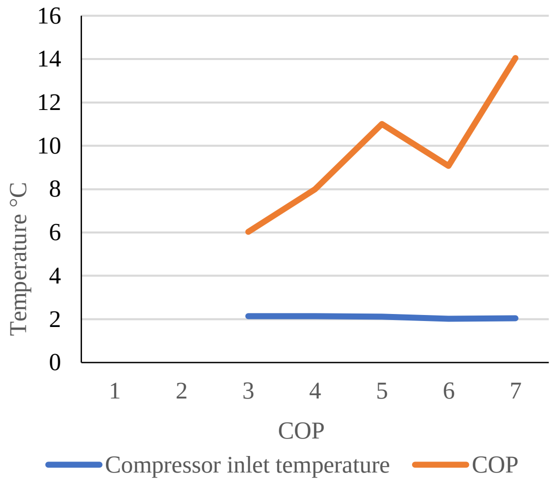

Figure 11. Evaporator Outlet Temp vs COP.

The Evaporator Inlet Temperature experiences a significant increase followed by a decrease, while the COP remains largely unaffected (Figure 10).

The Evaporator Outlet Temperature experiences a significant increase followed by a decrease, while the COP remains largely unaffected (Figure 11).

CONCLUSION

In summary, considerations such as system design, safety measures, and temperature conditions influence the choice between R32 and R290 refrigerants for heating and cooling applications. R290 is preferred because of its greater heating capacity and ability to perform well in low-temperature heating scenarios (T1 to T3), but because of its flammability, it need careful system design and strict safety precautions. Conversely, R32 is frequently utilized for cooling purposes, particularly in high-temperature environments (T4 to T7), albeit the precise operating parameters depend on the needs of the system and the load. Because both refrigerants are combustible, safety must be the first priority, and regulatory compliance is essential.

The future scope for heat pump systems designed for simultaneous heating and cooling purposes is promising. There are a number of possible areas for growth and improvement as technology develops and energy efficiency gains importance. Conversely, while R-290 presents exceptional cooling capacity and a lower global warming potential, its flammability introduces safety challenges that can complicate its use, particularly in commercial settings. These factors necessitate additional precautions, which may not be feasible for all applications.

Ultimately, the choice between R-32 and R-290 will depend on specific operational needs, safety considerations, and environmental goals. As the HVAC industry continues to evolve toward more sustainable practices, R-32 is poised to play a crucial role in the development of energy-efficient and environmentally friendly heating and cooling solutions.

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