

ANALYSIS AND COMPARISON OF R450A AS A REPLACEMENT OF R134a

A Dissertation submitted to the

Delhi Technological University

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the award of the degree of*

Master of Technology

(THERMAL ENGINEERING)

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CERTIFICATE

This is to certify that the work presented in this dissertation “ANALYSIS AND COMPARISON OF R450A AS A REPLACEMENT OF R134a” by **Bhushan Kumar** , Roll No. **2K15/THE/501** is a record of original research carried out by him under my supervision and guidance in partial fulfillment of the requirements for the degree of Master of Technology (Thermal Engineering). Neither this dissertation nor any part of it has been submitted earlier for any degree or diploma to any institute or university in India or abroad.

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For any errors or inadequacies that may remain in this work, of course, the responsibility is entirely my own.

BHUSHAN KUMAR

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NOMENCLATURE

VCRS	Vapor compression refrigeration cycle
COP _{sys}	Coefficient of performance of system
GWP	Global warming potential
m_{vcrs}	Mass flow rate of VCRS system
Q _{evap}	Heat of absorption in the evaporator
W _{turba}	Work output from turbine
m_{orc}	Mass flow rate of organic Rankine cycle
W _{pump}	Work input to the pump
Q _b	Heat is given to the boiler
η_{orc}	Efficiency of organic Rankine cycle
Q _c	Heat rejected from condenser
PR _c	Compressor pressure ratio
PR _t	Turbine pressure ratio
Ed	Total Exergy Equation

CHAPTER 1

INTRODUCTION

1.1 HISTORY OF REFRIGERATION

The use of mechanical procedures to produce cold is relatively new in 1748, Glasgow University's William Coolen created refrigeration by producing a partial vacuum over ethyl ether. However, his knowledge could not be put into practise. Perkin utilised a hand-operated machine to develop the machine in 1834.

The pace of advancement was modest when the steam engine was in use. Refrigeration applications grew as electric motors and compressors were introduced. Freon-free refrigerants have recently been developed due to the fact that it includes chlorine, which is responsible for the ozone layer in the higher atmosphere. Window air conditioners, split type air conditioners, and residential refrigerators are the most common refrigeration applications.

1.2 VAPOR COMPRESSION SYSTEM

In vapor compression cycle they consist of various equipment like compressor, condenser, evaporator and throttle valve they perform various function.

Compressor: It is the main part of vapor compressor system in which vapor compresses to a particular pressure and temperature by consuming power so it is also called as power consuming devices if its fails then all processes does not work .

Evaporator: It is a phase change process in which mixture of liquid and vapor came convert it into a vapor phase by its absorbing capacity .

Condenser: It is heat exchanger device worked at constant pressure changing its vapor phase to the liquid form by removing heat process .

Throttle Valve: It is a device which lower the pressure and temperature of refrigerant and convert into the liquid and vapor mixture form.

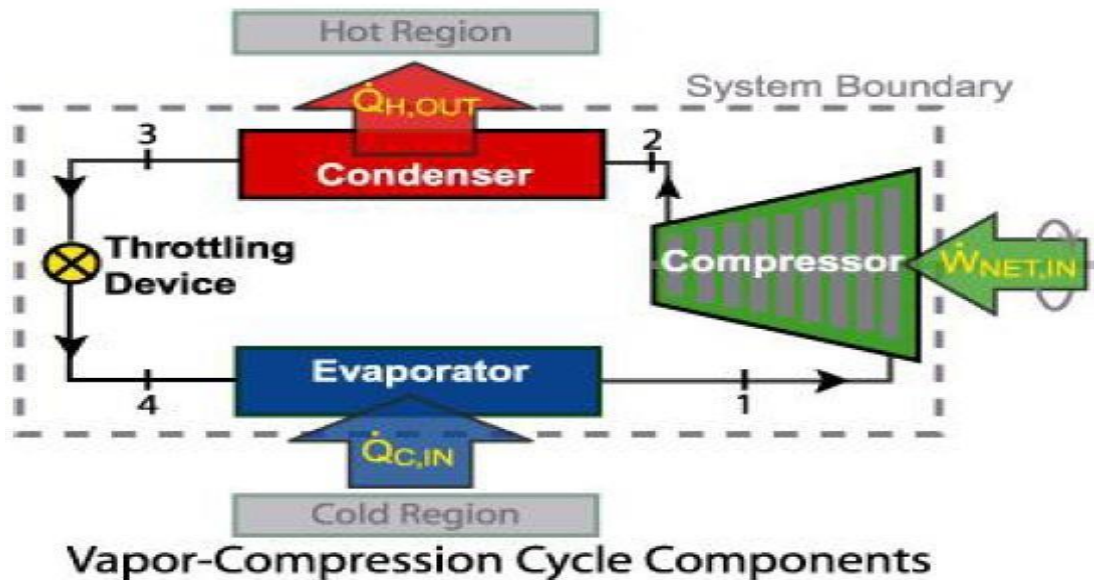


Figure 1.1: V a p o u r c o m p r e s s i o n c y c l e c o m p o n e n t s

This system goes through 4 processes

- Compression.
- Heat rejection.
- Throttling .
- Heat addition.

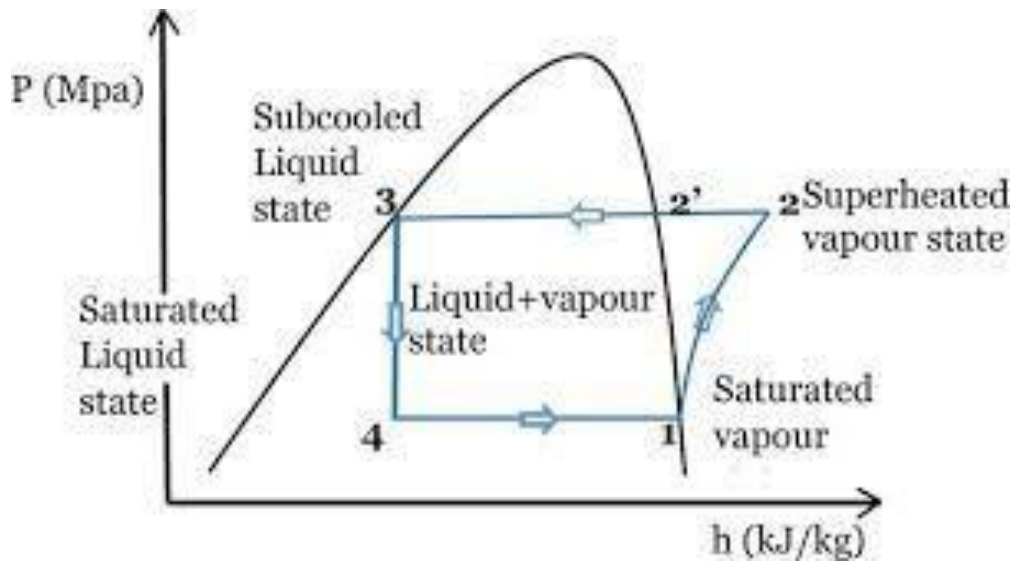


Figure 1.2 vapor compression cycle

In the vapour compression refrigeration cycle, liquid refrigerant is utilized as a medium to evacuate heat from the surrounding area and absorb heat from from where we want chilling effect . A typical single-stage compression refrigeration cycle is depicted . Saturated vapour refrigerant enters the compressor and circulates, then is compressed at a high pressure, leads to a higher temperature superheated vapour is a term for a hot compressed vapour. The high vapour is now sent through a condenser, where the flowing vapor rejects heat from the system to the environment via air. Now that the condensed liquid has reached saturation in the thermodynamic state, it is channeled to a capillary tube (expansion valve), where pressure and temperature drop abruptly, preserving the isenthalpic process. Now the fluid flows through an heat absorbing device , which absorbs heat from the enclosed chamber and cools it down before returning it to the atmosphere. After the refrigeration cycle is completed, the refrigerant vapor becomes saturated and returns to the compressor.

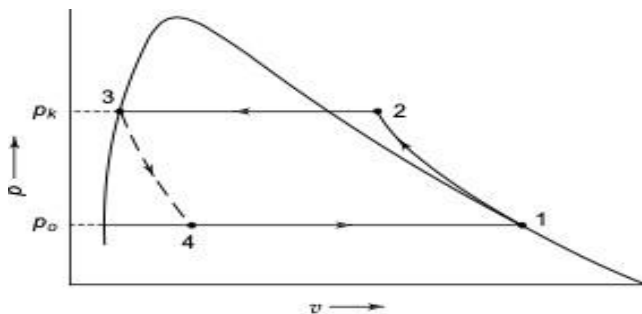


Figure 1.3 P-v diagram of vapor compression cycle

The RAC industry is heavily dependent on vapour compression refrigeration(VCR) system.The major applications where VCR System is used are listed below:

- 1 Refrigeration system used for domestic purpose(Refrigerator)
- 2 Food storage
- 3 Air conditioning in Hospitals
- 4 Hotels industries
- 5 Malls etc.

The refrigerants used in all above applications are mostly HFC or mixtures of HFC refrigerants.The HFC refrigerants are responsible for Global Warming.The refrigerant R134a is presently used in refrigeration system but has high GWP of 1430.Hence it needs to be replaced by such refrigerants which has low GWP value.The refrigerant R450a is a mixture of different HFC&HFO refrigerants i.e 58% of R134a & 42% of R1234ze.The GWP value of the R450a is 547 and it is alternative to R134a.

The scope of the present work is to analyse the performance of VCR Cycle using R450a which is a zeotropic refrigerant.

The project report comprises of the following chapters

1. Introduction
2. Literature survey
3. Thermodynamic analysis
4. Result & discussion
5. Scope for future work

CHAPTER 2

LITERATURE REVIEW

Makhnatch et al.2017 experimentally studies the performance R450A as drop in refrigerant for R134a in low capacity refrigeration system .there results showed that R450a gives nearly 10% lower cooling capacity than R134a . the COP IS ALSO 3% lower.

Gataric and Iorbek (2021) evaluated the experimental performance of R450A as the heat pump a drop-in replacement for R134a in household heat pump tumble dryers.the experimental result show that the energy requirement of dryers reduces by 3.7%. however the drying time increase by 4.2%.

Deani et.al(2022) experimentally investigated flow condensation of R450A,R515B and R1234ze(E) in a 0.7cm internal diameter micro-fin tube.

Molinaroli et.al(2022) examined the experimental performance of R450A and R513A as low-GAWP alternative to R134a in a water-to-water heat pump. They reported that R450A gives a cooling capacity which is 6.59%to15.02% lower than R134a.this COP varies -2.48% to +2.99% in comparison to R134a.

Yuan et.al(2024) experimentally investigated the performance of R450A and R134a in a micro channel tube.the result reported by them have predicted higher heat transfer co-efficient at higher heat fluxes in comparison to R134a.

Hussain et.al(2025) carried out simulation studies for energy evaluation of R450A,R1234yf,R513A,R516A,R152A and R1234ze as alternative to R134a in an air conditioner.they reported that R152A,R450Aand R516A promising alternative to their comparable performance with R134a.

Khan et.al(2025) investigated the effect of lubricant oil (PEC4) on condensation and thermostatically properties of refrigerant R450A .There result showed that the condensation process effectiveness is enhanced by using pack 4.it also enhanced heat transfer and help in reducing in energy consumption of refrigeration cycle.

The literature shows that R450A is good alternative to R134a

Gaps in literature Survey

The literature survey shows that the theoretical performance analysis of R450A as alternative to R134a is scant .

Objective of present studies

1. To analyse and compare the thermodynamic performance of refrigerants R450A and R134a in a vapour compression refrigeration system using key performance parameters such as coefficient of performance (COP), compressor work input, and heat removed by the evaporator.
2. To investigate the effect of operating parameters—namely evaporator temperature, condenser temperature, and refrigerant mass flow rate—on the performance of the system for both refrigerants under identical conditions.
3. To evaluate the suitability of R450A as a replacement for R134a, based on comparative energy performance and operational feasibility in low- and medium-temperature refrigeration applications.

Chapter 3

Thermodynamic analysis

The thermodynamic analysis is based on principle of mass and energy conservation. The various equation used is given below used in EES Software:

```
Qe_dot=m_dot*(h1-h4)
{te=-20}
tc=50
tr=2
h1=enthalpy(R134a,T=T1,x=x1)
t1=te
s1=entropy(R134a,T=T1,x=x1)
x1=1
s1=s2
Pc=p_sat(R134a,T=Tc)
h2=enthalpy(R134a,s=s2,P=P2)
p2=pc
h3=enthalpy(R134a,x=x3,P=P3)
p3=p2
x3=0
h3=h4
cop=(h1-h4)/(h2-h1)
Qe_dot=2*3.5167
```

Chapter 4

Result and Discussion

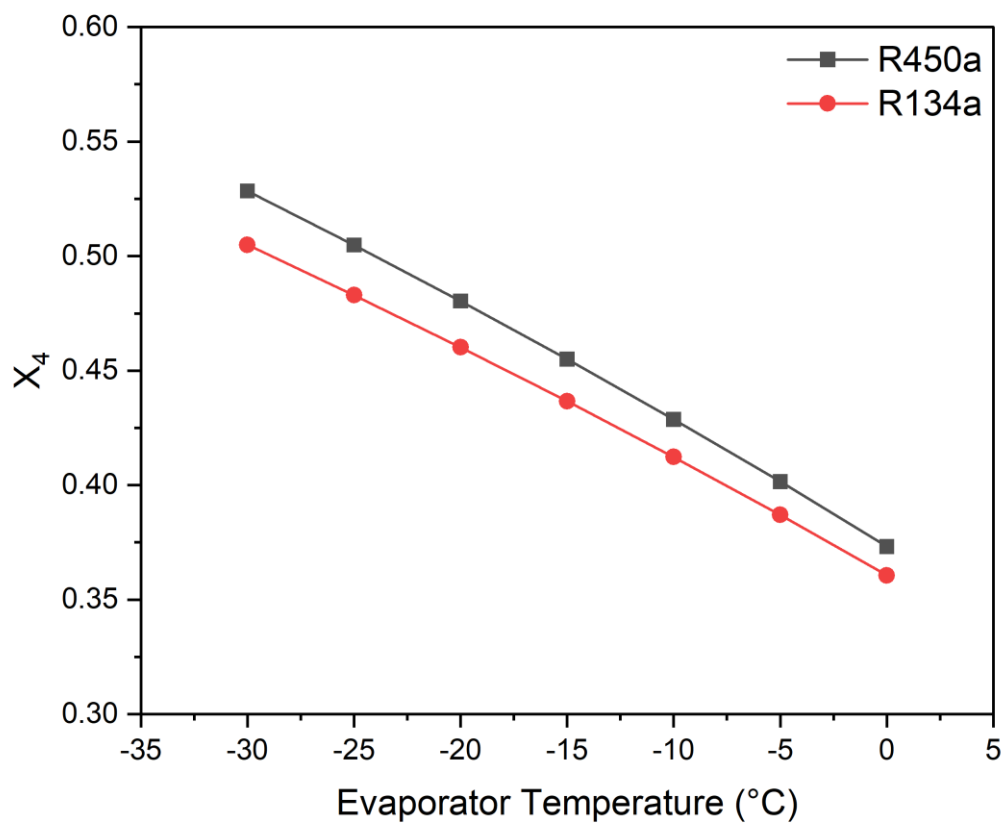


Fig 4.1 Effect of Evaporator Temp. On X_4

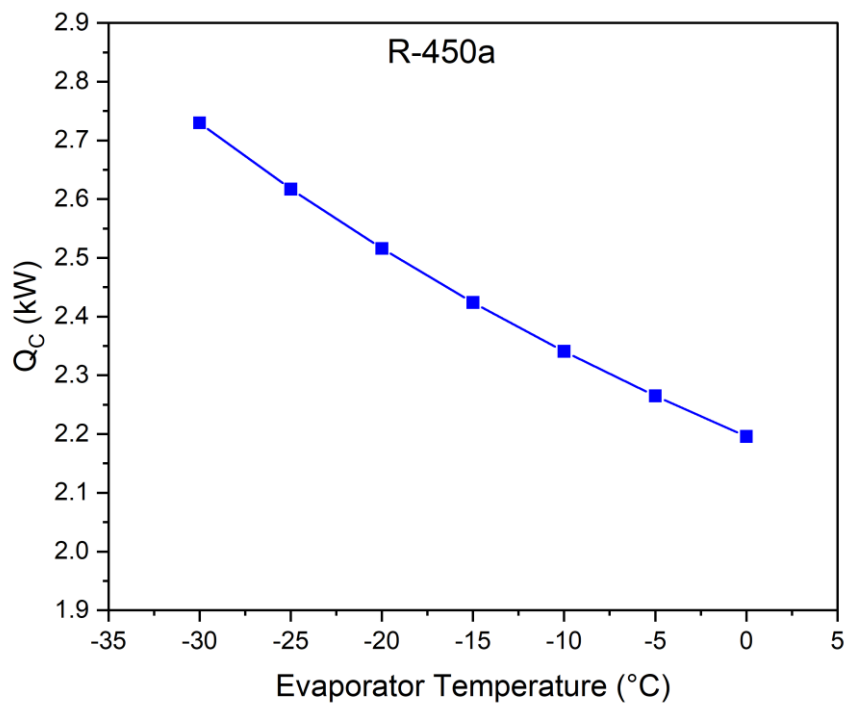


Fig 4.2 Effect of Evaporator Temp. On Q_c

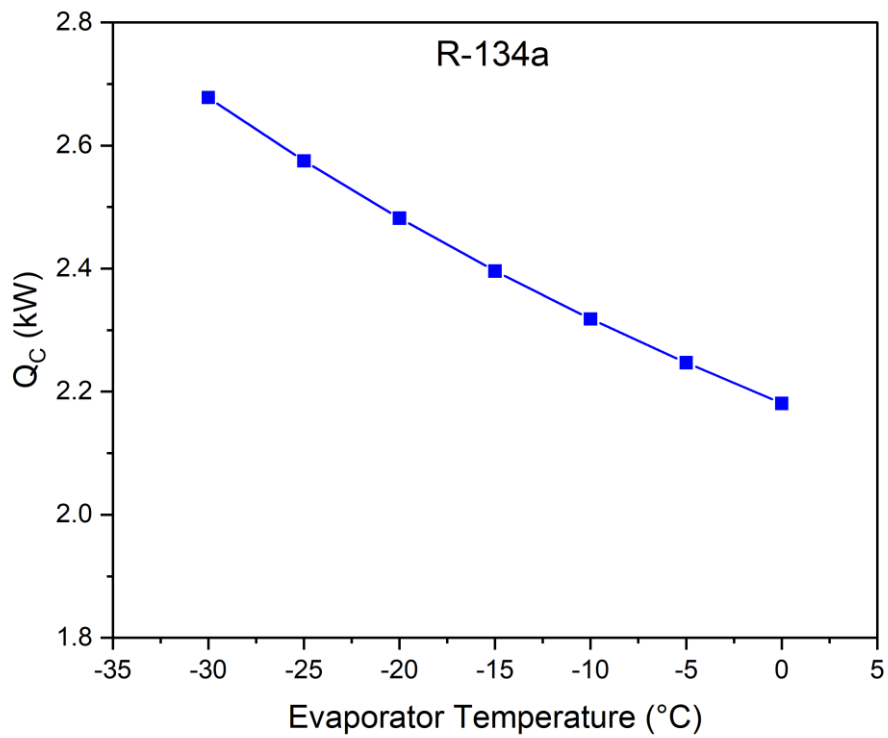


Fig 4.3 Effect of Evaporator Temp.on Q_c of R134a

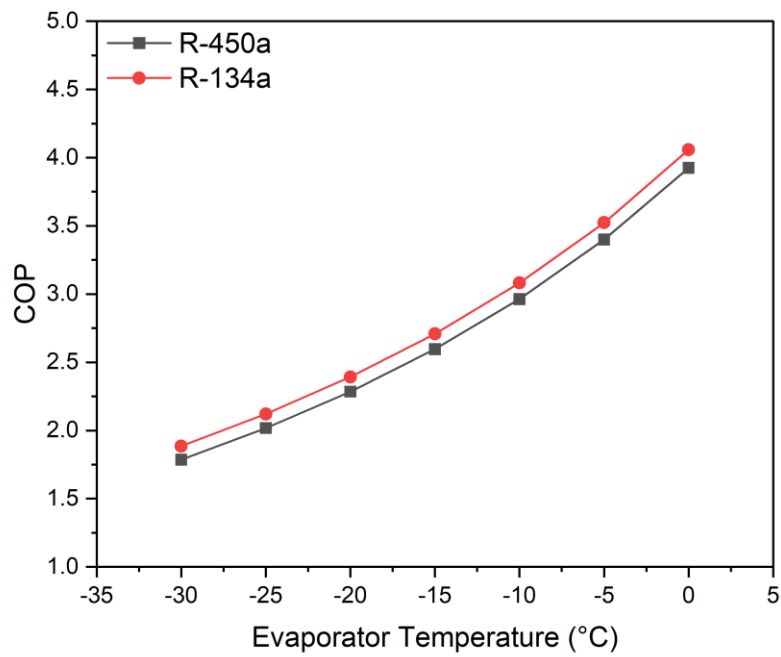


Fig 4.4 Effect of Evaporator Temp. On COP

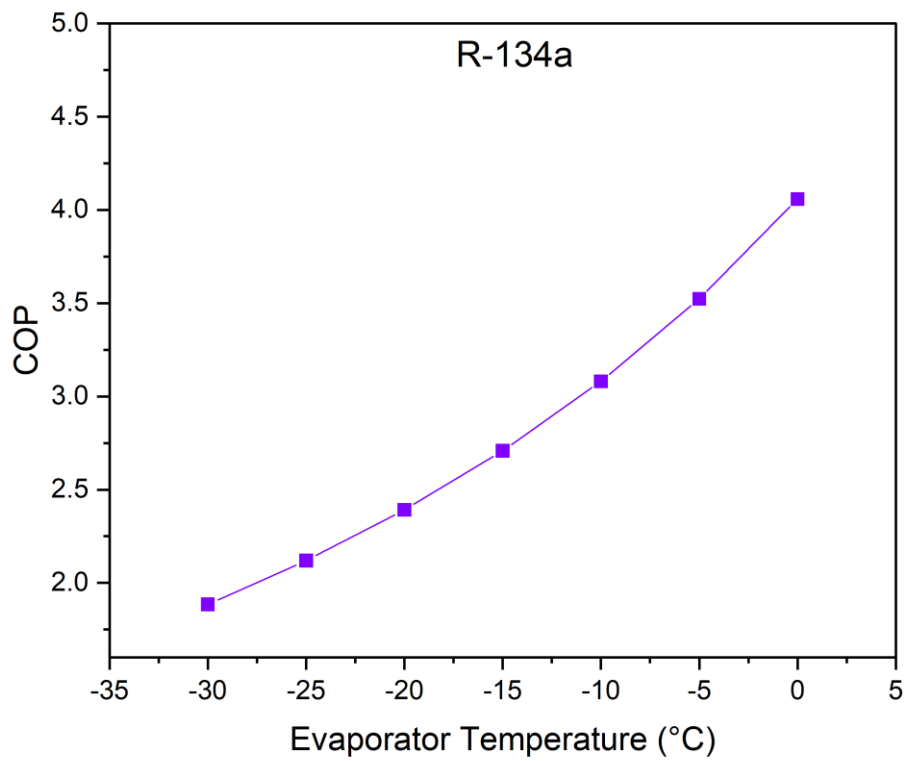


Fig 4.5 Effect of Evaporator Temp. On COP of 134a

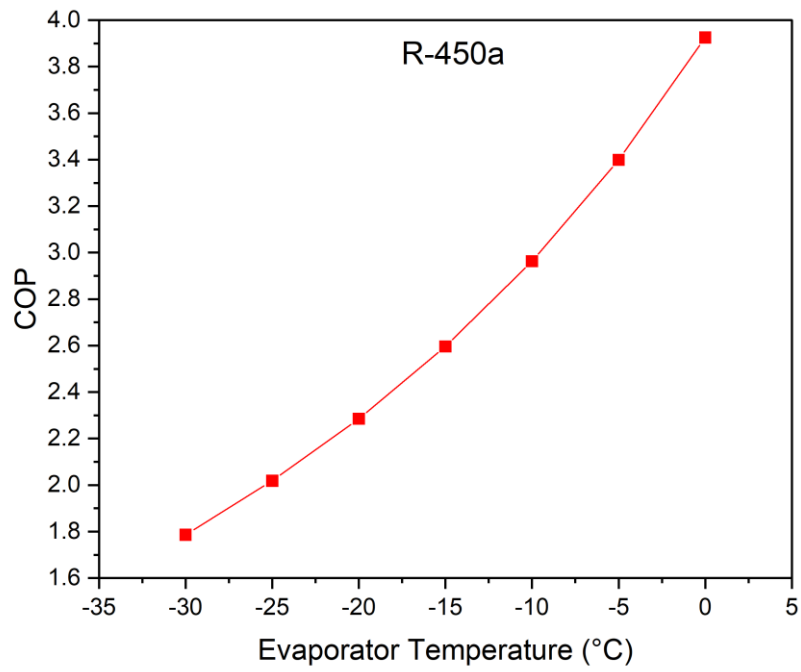


Fig 4.6 Effect of Evaporator Temp. On COP of 134a

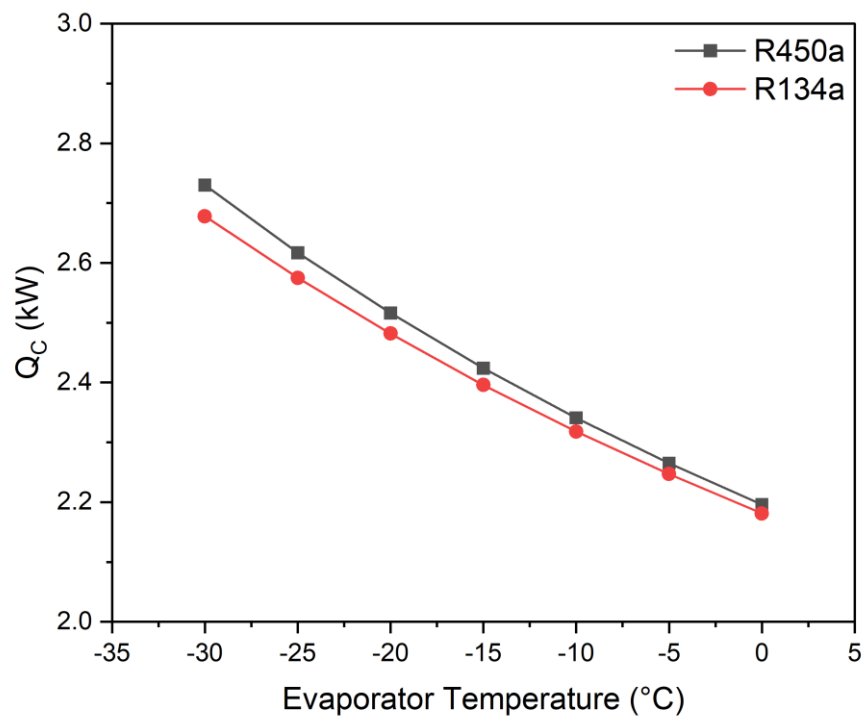


Fig 4.7 Effect of Evaporator Temp. On Q_c

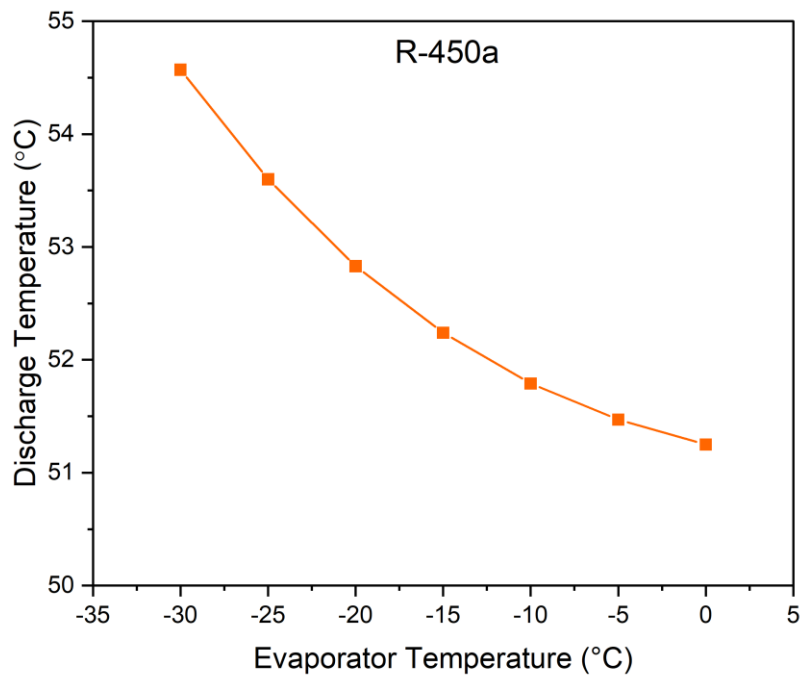


Fig 4.8 Effect of Evaporator Temp. On discharge Temp.

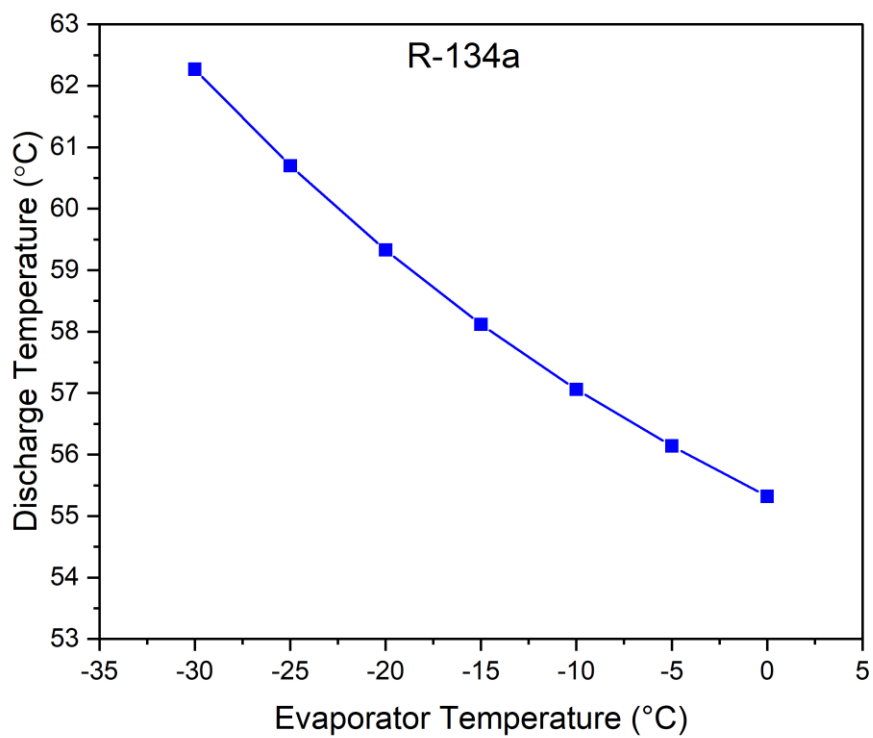


Fig 4.9 Effect of Evaporator Temp.

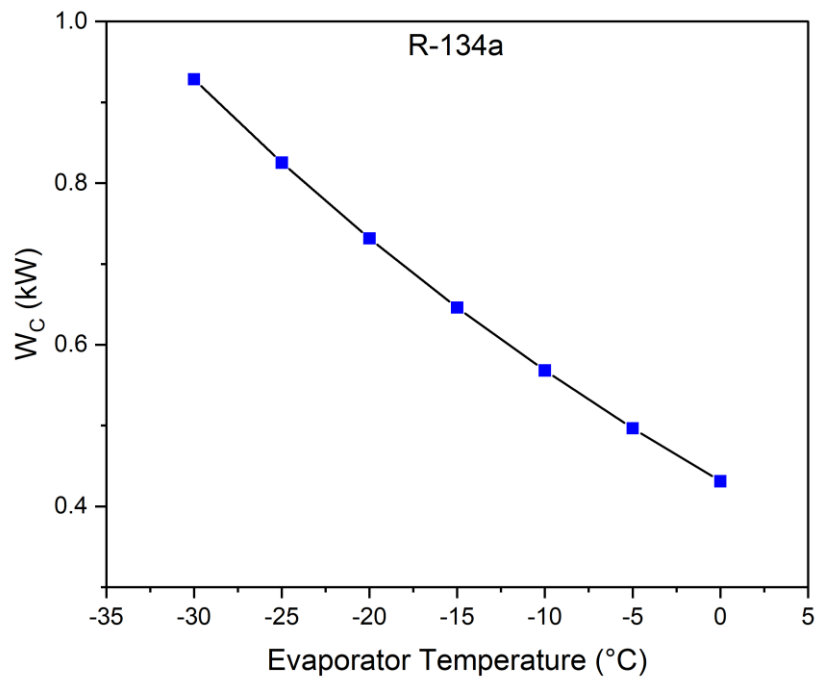


Fig 4.10 Effect of Evaporator Temp on W_c

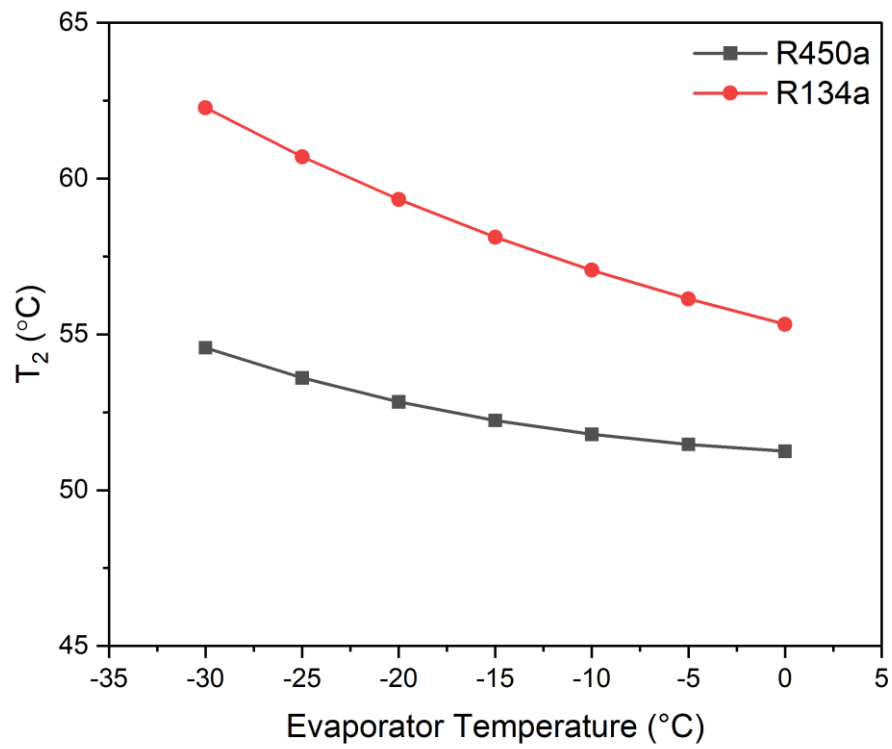


Fig 4.11 Effect of Evaporator Temp. on T_2

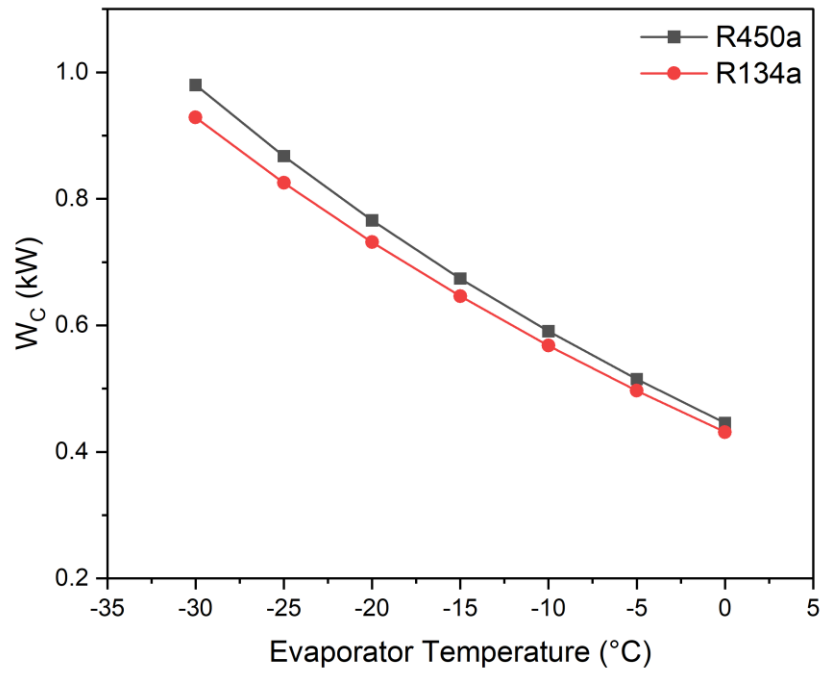


Fig 4.12 Effect of Evaporator Temp.ON Wc

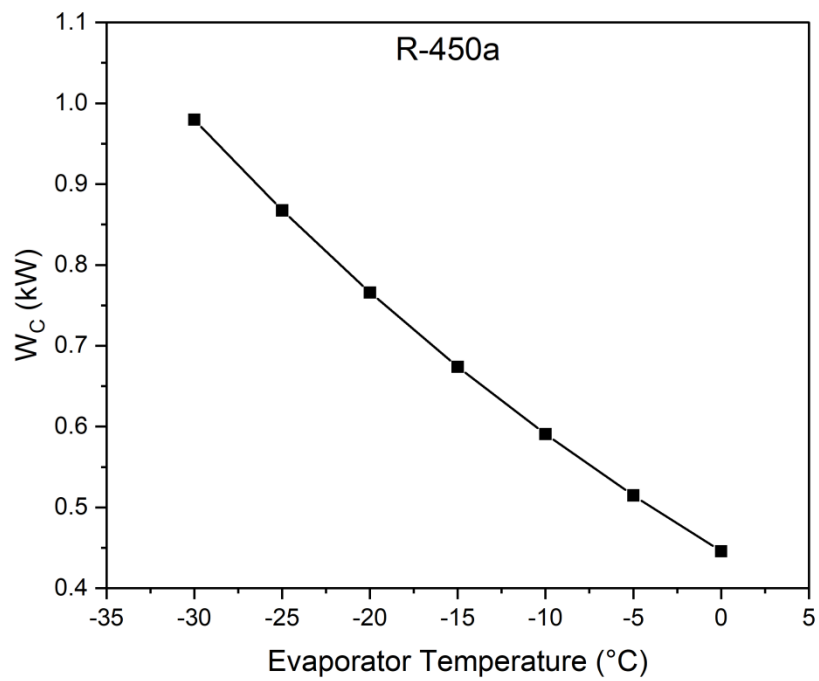


Fig 4.13 Effect of Evaporator Temp. On Wc

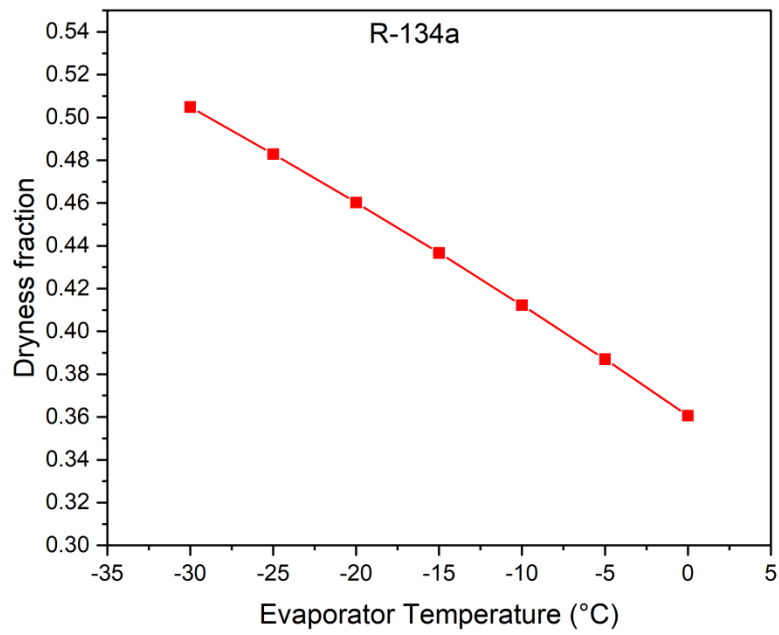


Fig 4.14 Effect of Evaporator Temp. On Dryness fraction of R134a

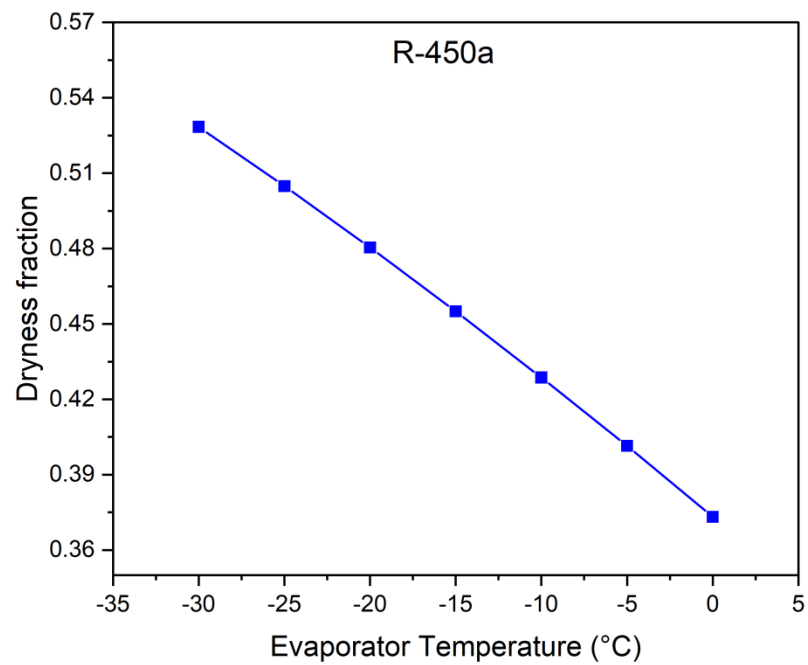


Fig 4.15 Effect of Evaporator Temp. On Dryness fraction of R450A

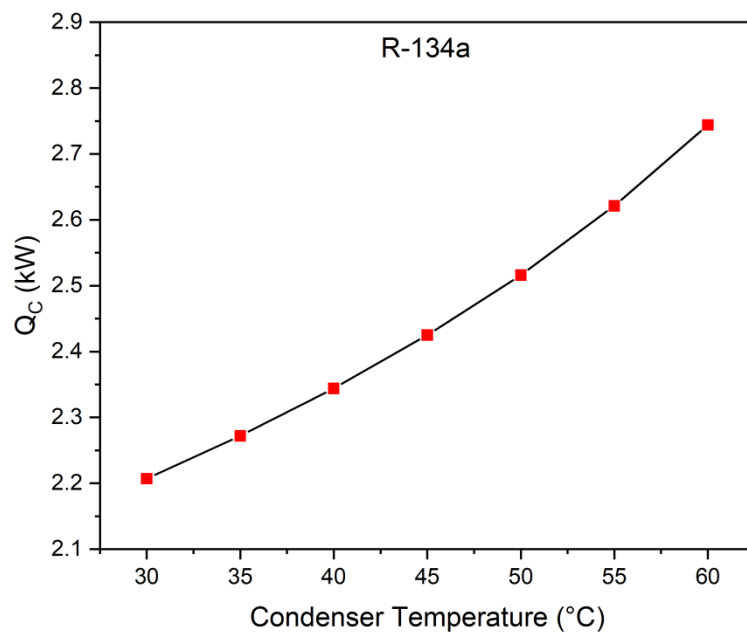


Fig 4.16 Effect of condenser Temp.on Q_c of R134a

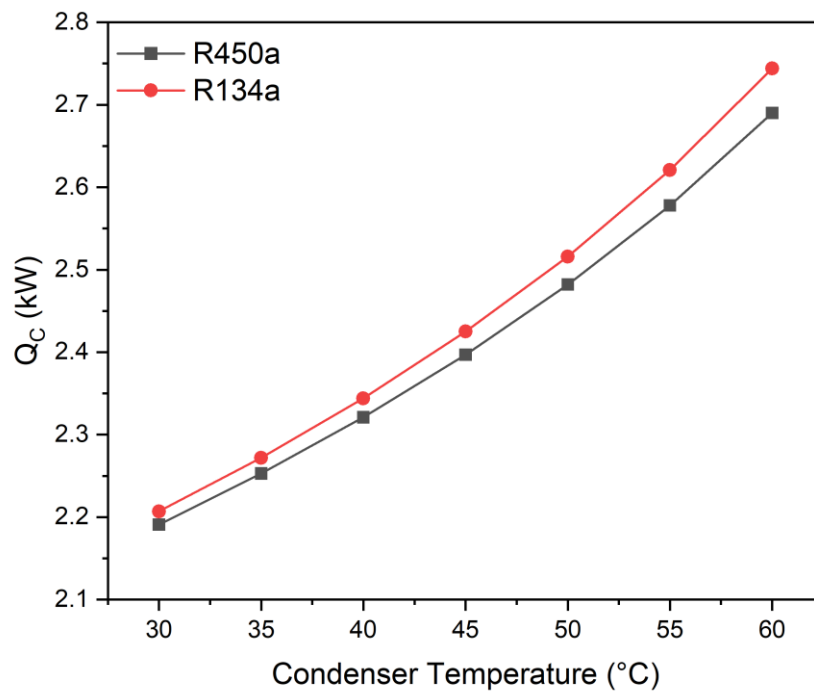


Fig 4.17 Effect of condenser Temp.on Q_c

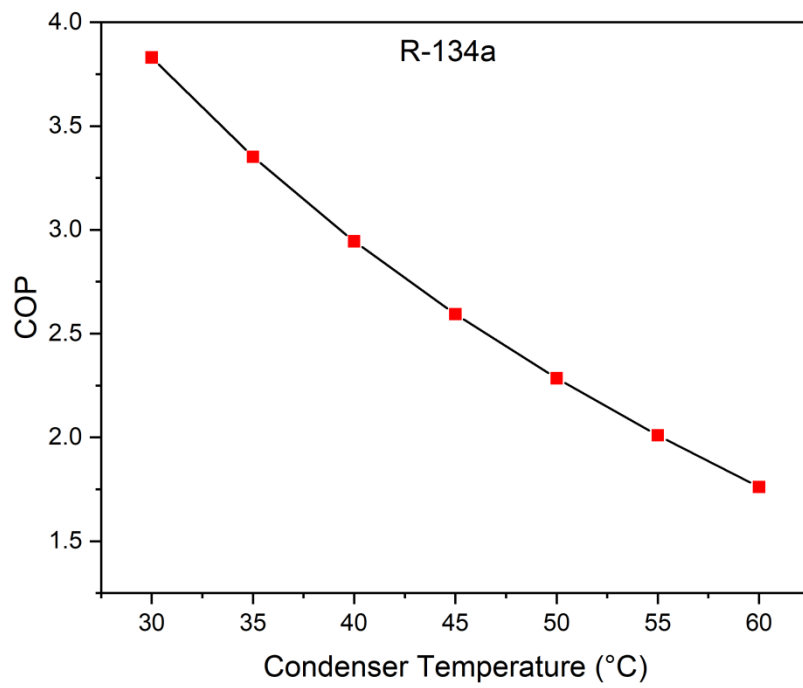


Fig 4.18 Effect of condenser Temp.on COP

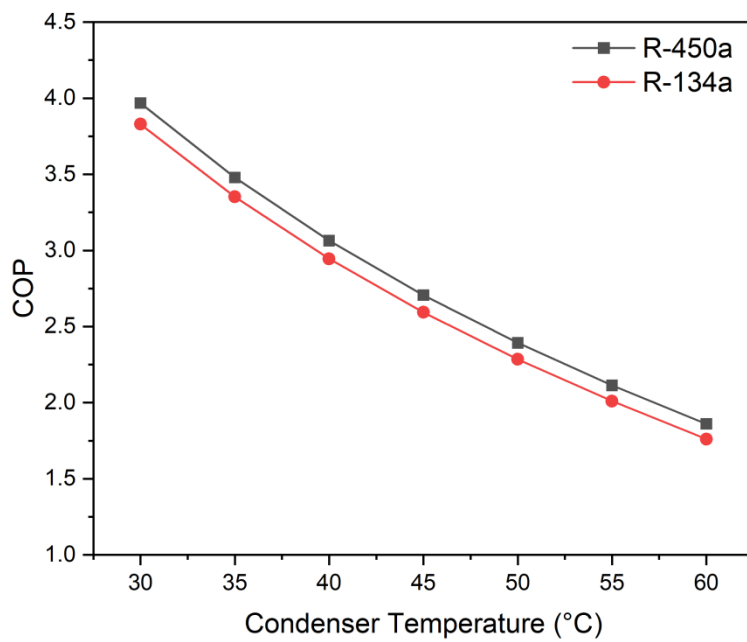


Fig 4.20 Effect of condenser Temp.on COP

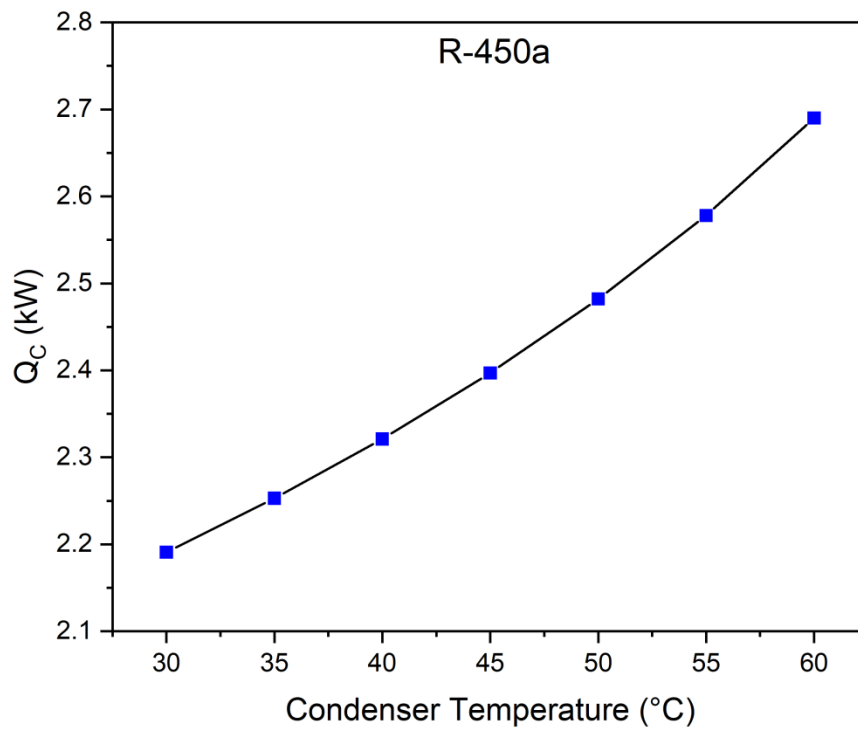


Fig 4.21 Effect of condenser Temp.on Q_c

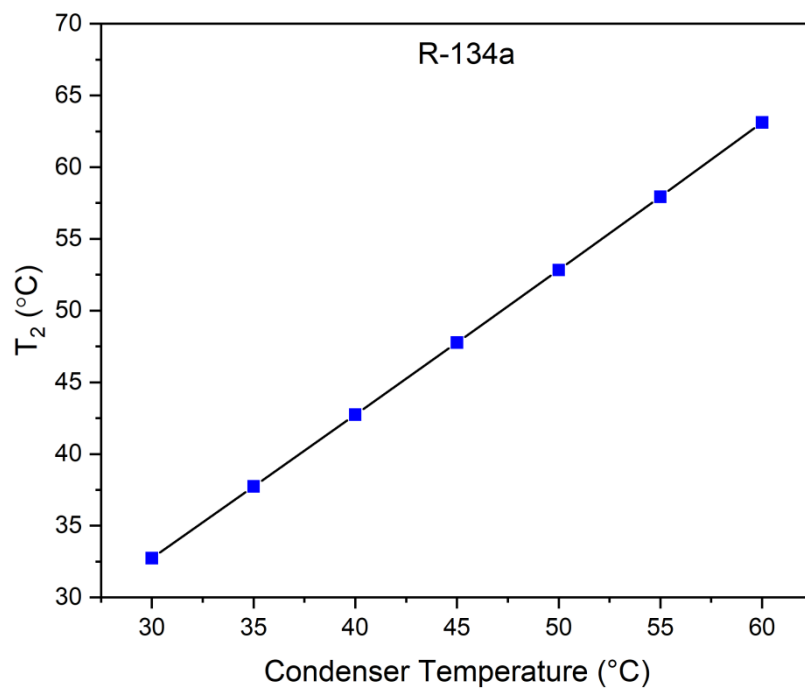


Fig 4.22 Effect of condenser Temp. On T_2

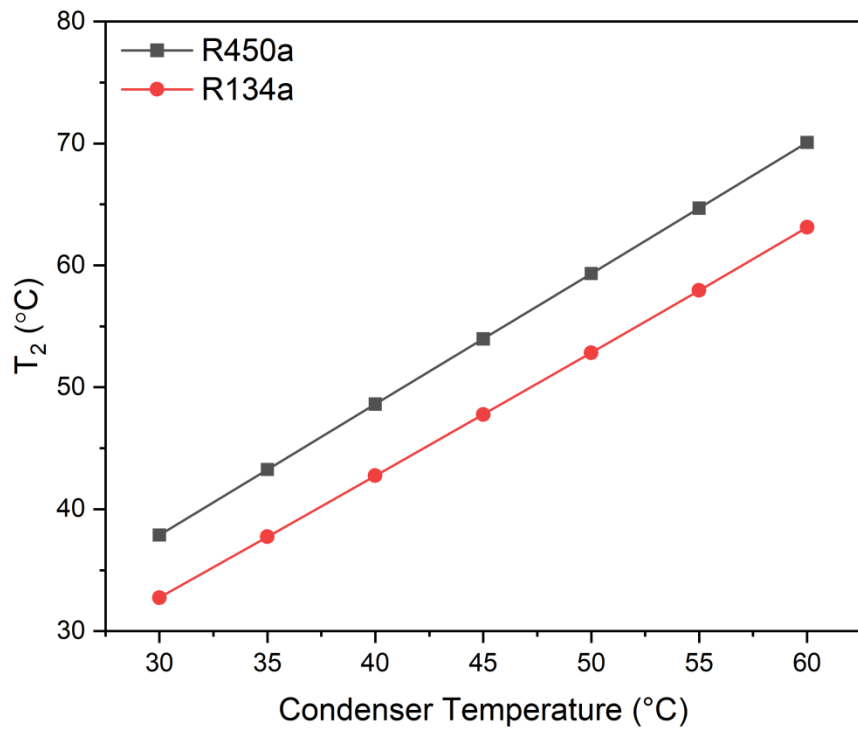


Fig 4.23 Effect of condenser Temp. On T₂

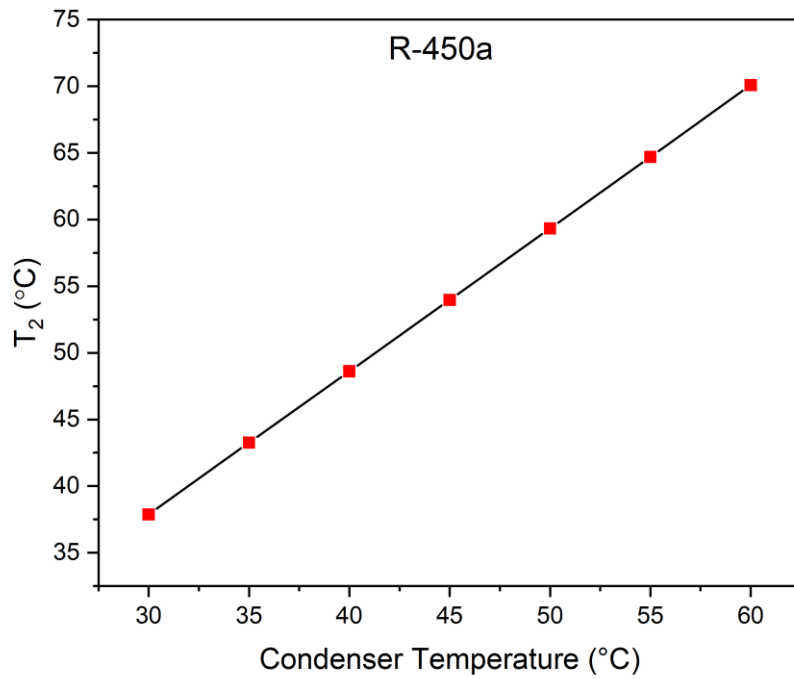


Fig 4.24 Effect of condenser Temp.on T₂

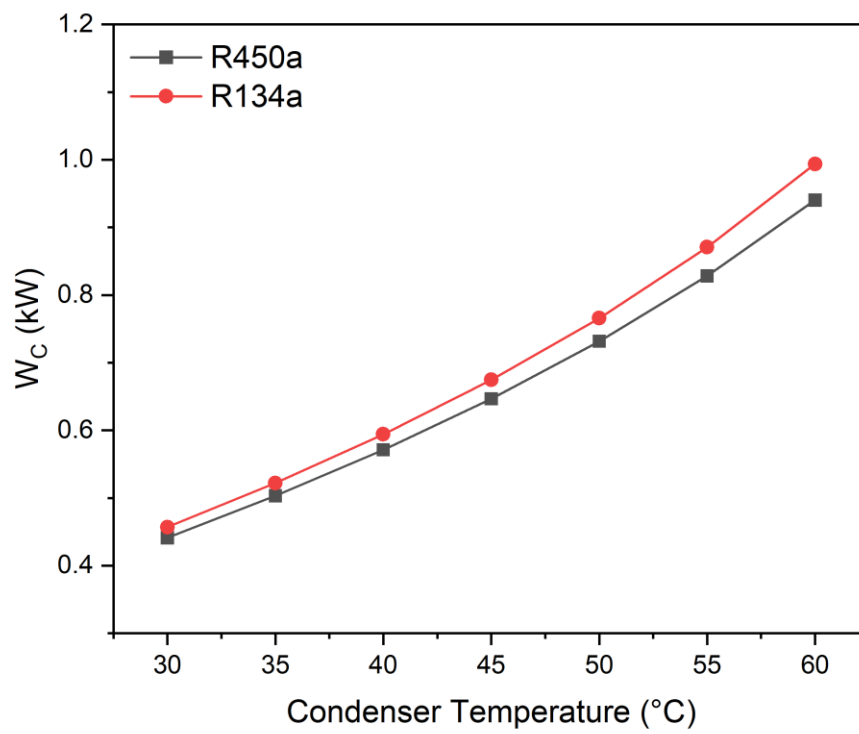


Fig 4.25 Effect of condenser Temp.on W_c

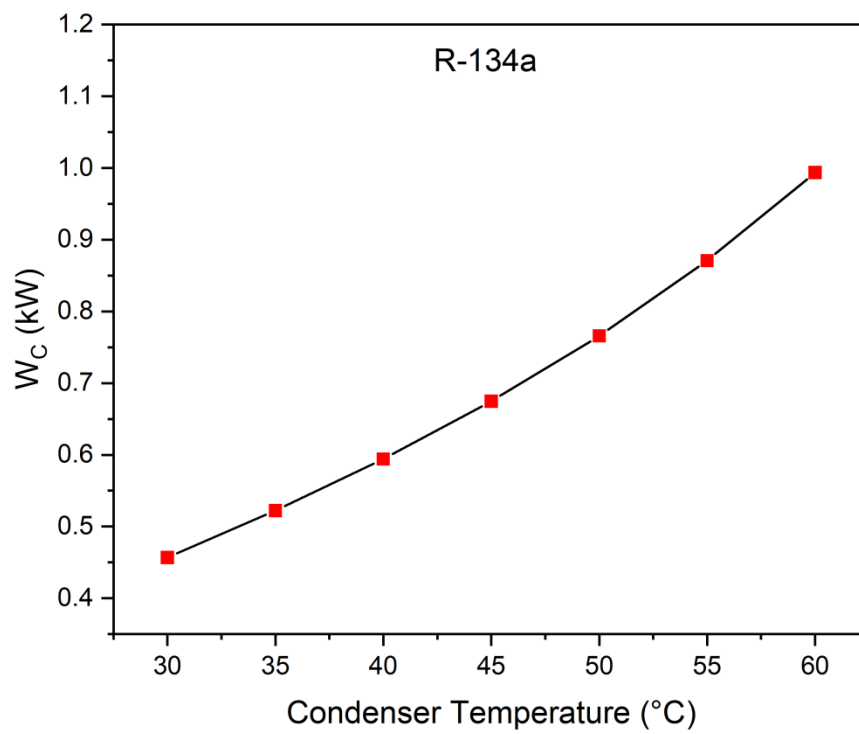


Fig 4.26 Effect of condenser Temp. On W_c

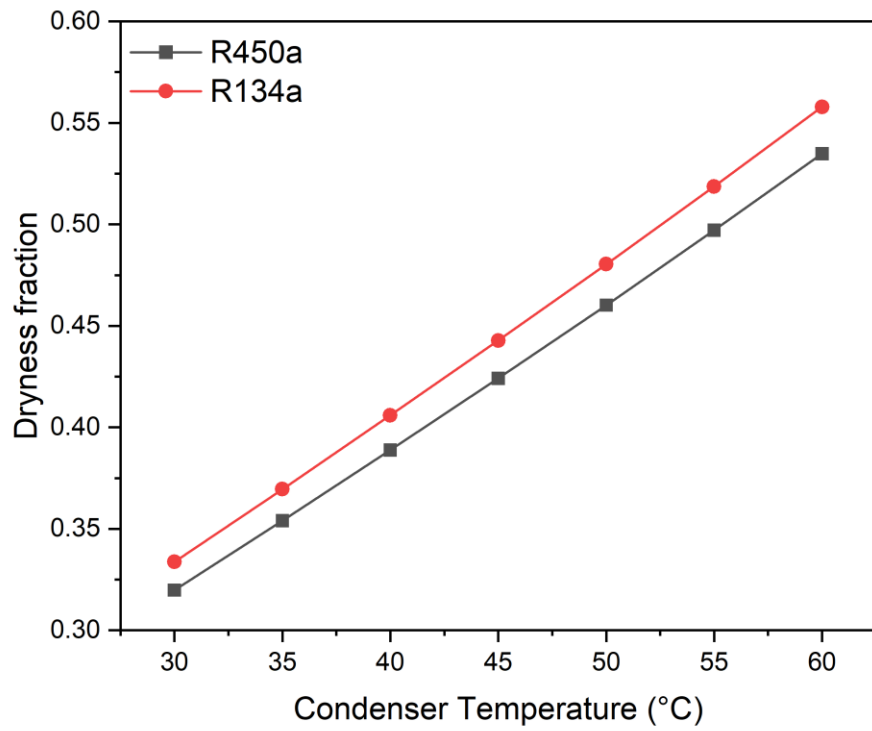


Fig 4.27 Effect of condenser Temp. On X4

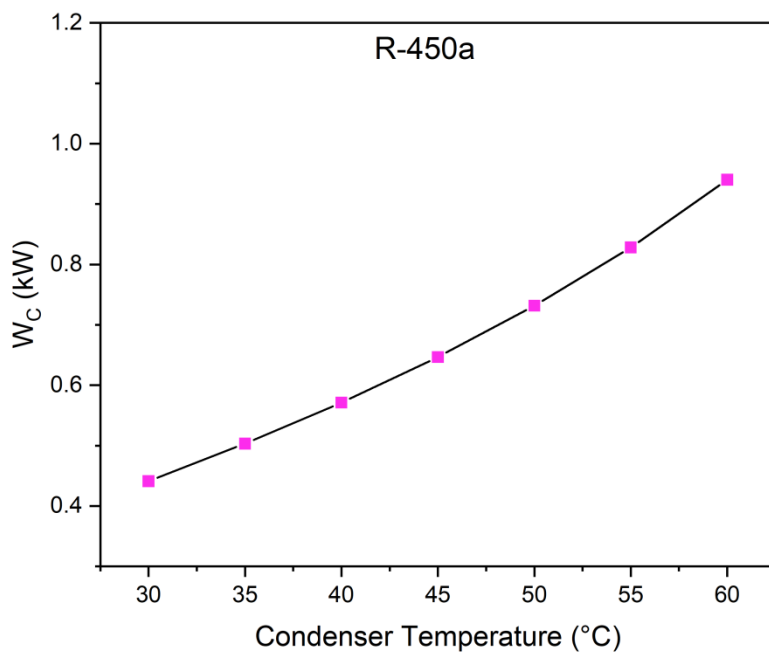


Fig 4.28 Effect of condenser Temp. On Wc

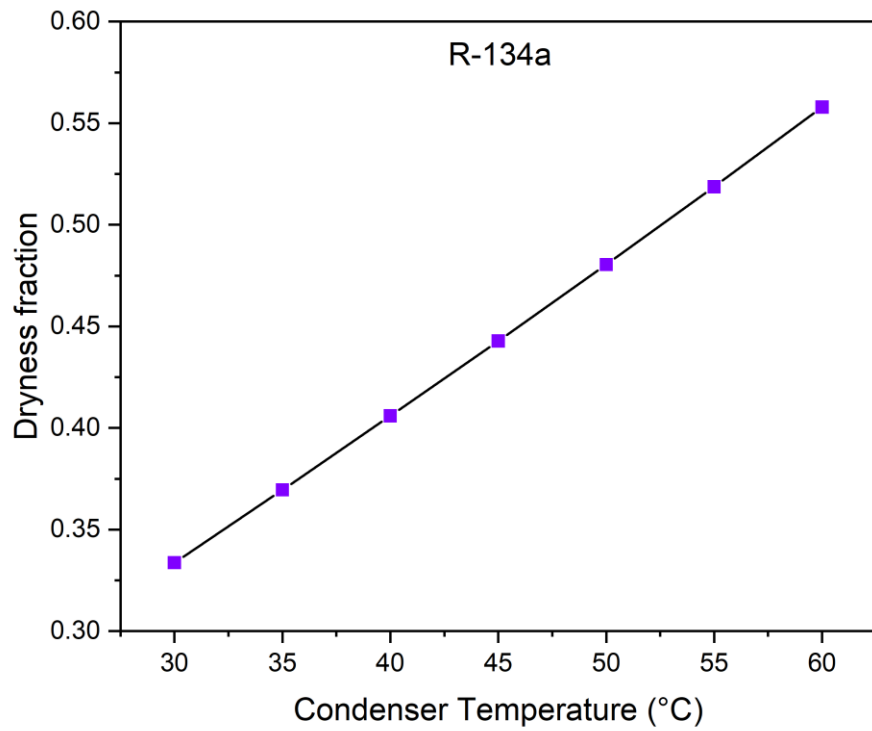


Fig 4.29 Effect of condenser Temp. On X4

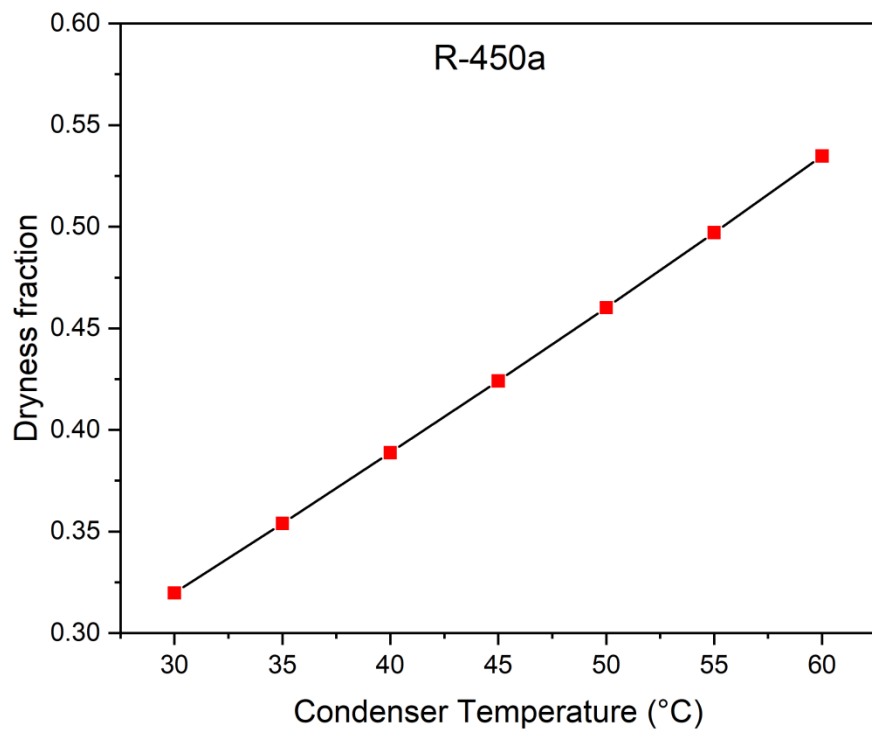


Fig 4.30 Effect of condenser Temp. On X4

CHAPTER 5

CONCLUSION AND SCOPE FOR FUTURE WORK

R450A is better refrigerant than R134a.

Scope for future work

1. Exergy analysis of the system can be carried out with these refrigerant can be performed.
2. Economy analysis of the system can be carried out with these refrigerant can be performed.

References

- [1] B.Drop-in analysis of R450A and R513A as low-GWP alternatives to R134a in a water-to-water heat pump environmental analysis of organic Rankine cycle based vapor compression refrigeration system, International Journal of Refrigeration, Volume 126, 2021, Pages 259-271, ISSN 0140-7007, <https://doi.org/10.1016/j.ijrefrig.2021.02.005>.
- [2] Youcai Liang, Andrew Mckeown, Zhibin Yu, Saif Fraih K. Alshammari, Experimental study on a heat driven refrigeration system based on combined and vapour compression cycles, Energy Conversion and Management, Volume 234, 2021, 113953, ISSN 0196-8904, <https://doi.org/10.1016/j.enconman.2021.113953>.
- [3] Xia Zhou, Yangyiming Rong, Song Fang, Kai Wang, Xiaoqin Zhi, Limin Qiu, Xuelin Chi, Thermodynamic analysis of an vapor compression cycle (ORVC) assisted air compression system for cryogenic air separation units, Applied Thermal Engineering, Volume 189, 2021, 116678, ISSN 1359-4311, <https://doi.org/10.1016/j.applthermaleng.2021.116678>.
- [4] Rania Zhar, Amine Allouhi, Mokhtar Ghodbane, Abdelmajid Jamil, Khadija Lahrech, Parametric analysis and multi-objective optimization of a combined Organic Rankine Cycle and Vapor Compression Cycle, Sustainable Energy Technologies and Assessments, Volume 47, 2021, 101401, ISSN 2213-1388, <https://doi.org/10.1016/j.seta.2021.101401>.
- [5] Junjiang Bao, Lei Zhang, Chunxiao Song, Ning Zhang, Xiaopeng Zhang, Gaohong He, Comparative study of combined organic Rankine cycle and vapor compression cycle for refrigeration: Single fluid or dual fluid?, Sustainable Energy Technologies and Assessments, Volume 37, 2020, 100595, ISSN 2213-1388, <https://doi.org/10.1016/j.seta.2019.100595>.
- [6] S. Aphornratana, T. Sriveerakul, Analysis of a combined Rankine-vapour compression refrigeration cycle, Energy Convers. Manage. 51 (2010) 2557–2564.
- [7] Alper Yılmaz, Trans-critical organic Rankine vapor compression refrigeration system for intercity bus air-conditioning using engine exhaust heat, Energy, Volume 82, 2015, Pages 1047-1056, ISSN 0360-5442, <https://doi.org/10.1016/j.energy.2015.02.004>.
- [8] Hailei Wang, Richard Peterson, Kevin Harada, Erik Miller, Robbie Ingram-Goble, Luke Fisher, James Yah, Chris Ward, Performance of a combined organic Rankine cycle and vapour.

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ANALYSIS AND COMPARISON OF R450A AS A REPLACEMENT OF R134a

A Dissertation submitted to the

Delhi Technological University

in partial fulfillment of the requirements of
the award of the degree of

Master of Technology

(THERMAL ENGINEERING)

By

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References

- [1] B.Drop-in analysis of R450A and R513A as low-GWP alternatives to R134a in a water-to-water heat pump environmental analysis of organic Rankine cycle based vapor compression refrigeration system, International Journal of Refrigeration, Volume 126, 2021, Pages 259-271, ISSN 0140-7007, <https://doi.org/10.1016/j.ijrefrig.2021.02.005>.
- [2] Youcai Liang, Andrew Mckeown, Zhibin Yu, Saif Fraih K. Alshammari, Experimental study on a heat driven refrigeration system based on combined and vapour compression cycles, Energy Conversion and Management, Volume 234, 2021, 113953, ISSN 0196-8904, <https://doi.org/10.1016/j.enconman.2021.113953>.
- [3] Xia Zhou, Yangyiming Rong, Song Fang, Kai Wang, Xiaoqin Zhi, Limin Qiu, Xuelin Chi, Thermodynamic analysis of an vapor compression cycle (ORVC) assisted air compression system for cryogenic air separation units, Applied Thermal Engineering, Volume 189, 2021, 116678, ISSN 1359-4311, <https://doi.org/10.1016/j.applthermaleng.2021.116678>.
- [4] Rania Zhar, Amine Allouhi, Mokhtar Ghodbane, Abdelmajid Jamil, Khadija Lahrech, Parametric analysis and multi-objective optimization of a combined Organic Rankine Cycle and Vapor Compression Cycle, Sustainable Energy Technologies and Assessments, Volume 47, 2021, 101401, ISSN 2213-1388, <https://doi.org/10.1016/j.seta.2021.101401>.
- [5] Junjiang Bao, Lei Zhang, Chunxiao Song, Ning Zhang, Xiaopeng Zhang, Gaohong He, Comparative study of combined organic Rankine cycle and vapor compression cycle for refrigeration: Single fluid or dual fluid?, Sustainable Energy Technologies and Assessments, Volume 37, 2020, 100595, ISSN 2213-1388, <https://doi.org/10.1016/j.seta.2019.100595>.
- [6] S. Aphornratana, T. Sriveerakul, Analysis of a combined Rankine-vapour compression refrigeration cycle, Energy Convers. Manage. 51 (2010) 2557–2564.
- [7] Alper Yılmaz, Trans-critical organic Rankine vapor compression refrigeration system for intercity bus air-conditioning using engine exhaust heat, Energy, Volume 82, 2015, Pages 1047-1056, ISSN 0360-5442, <https://doi.org/10.1016/j.energy.2015.02.004>.
- [8] Hailei Wang, Richard Peterson, Kevin Harada, Erik Miller, Robbie Ingram-

Goble, Luke

Fisher, James Yah, Chris Ward, Performance of a combined organic Rankine cycle and vapor

compression cycle for heat activated cooling, Energy, Volume 36, Issue 1, 2011, Pages 447-458,

ISSN 0360-5442, <https://doi.org/10.1016/j.energy.2010.10.020>.

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