

Methods of Improving Thermal Performance of Vapour Compression Based Refrigeration System Through Eco Friendly Refrigerants to Reduce Their Environmental Impact

R.S. Mishra, Ansh Agarwal, Jayant Dixit, Samruddhi Kadam

Abstract: Tetrafluoroethane (CF_3CH_2F), an HFC refrigerant, is also known as R134a. It is safe for normal handling because it is neither poisonous, flammable, nor corrosive. After it was discovered recently that R-134a contributes to global warming, the European Union forbade its use in brand-new automobiles starting in 2011. Worked on a vapour compression-based refrigeration system, utilised hydrocarbon (HC) refrigerants which were examined for their energetic and exergetic performance. In this investigation, pure Tetrafluoroethane (CF_3CH_2F) from the R134a family of HFCs was used for a theoretical analysis, along with other refrigerants which were eco-friendly and had a lower environmental impact (low Global Warming Potential and Ozone Depletion Potential): *trans*-1,3,3,3-Tetrafluoroprop-1-ene (R1234ze (Z)), R1234ze (E), (Z)-1-Chloro-2,3,3,3-Tetrafluoropropane (R1224YD (Z)), Fluoroethene (R1141), 3,3,3-Trifluoroprop-1-ene (R1243 ZF). The thermodynamic equations of the refrigerants were solved for analysis using the Engineering equation solver application. It was concluded that R1234ZE (Z) is the most effective refrigerant.

Key Words: Thermal Performance analysis, Refrigeration System, Refrigerants, Eco-friendly.

I. INTRODUCTION

An upgraded version of the air refrigeration cycle used in general refrigeration and commercial applications is the vapour compression cycle. It involves four operations: compression, condensation, expansion, and vaporisation. The thermodynamic cycle is a process in which a liquid refrigerant is condensed into a saturated liquid and stored in the liquid receiver.

The low-pressure refrigerant vapour expands before entering the evaporator or refrigerator, where it absorbs heat and creates refrigeration. At point 5 the cold and partially vaporised refrigerant moves towards point 1 passing from the evaporator coils/tubes. Warm air is introduced through the coil or tubes by a fan. The generated refrigerant vapour then flows back to point 1, the compressor inlet. The vapour compression cycle, which involves compression, condensation, throttling, and evaporation, has been the focus of scientists' attention. EES is a commercial software package used to solve systems of simultaneous nonlinear equations, storing thermodynamic properties and performing iterative problem solving. Code can be input in any order.

II. LITERATURE REVIEW

R.S. Mishra et al. (2013) [1] Employed several evaporators, compressors, expansion valves, intercoolers, and flash chambers to enhance the vapour compression refrigeration system's thermal efficiency. Results revealed a 22% improvement in first- and second-law effectiveness.

R.S. Mishra et al. (2020) [2] found that raising evaporator load or decreasing high grade energy can both increase the thermal performance (COP) of a Vapour compression based refrigeration system utilizing eco-friendly refrigerants.

S C Kaushik et al. (2008) [3] performed a conceptual study of a vapour compression based refrigeration system using R502, R600, R404A, and R507A [4]. R507A was concluded to be a better replacement of R502 than R404A, with minor issues of the liquid vapour heat exchanger efficiency and minor condenser issues.

Akhilesh Arora and SC Kaushik et al. (2008) conducted a study to identify the appropriate interstage pressure and temperature of a Refrigeration system with two stages utilising HCFC22, R410A, and R717 refrigerants.

Conclusion: R717 is a better HCFC22 replacement refrigerant than R410A.

S K Tyagi et al. (2012) [5] found that the system's overall exergy destruction is highest at 100% charge and lowest at 25% charge.

Kapil Chopra, V. Sahni et al. (2015) [6] compared the refrigerants used in two-stage vapour compression refrigeration systems. At -50°C for evaporation and 45°C for condensation, R134a had 8.97% and 5.38% less energy and exergy efficiency than R152a and R600.

Manuscript received on 10 May 2023 | Revised Manuscript received on 05 May 2023 | Manuscript Accepted on 15 April 2024 | Manuscript published on 30 May 2024.

*Correspondence Author(s)

R.S. Mishra, Professor, Department of Mechanical Engineering, Delhi Technological University, New Delhi, India. E-mail: rsmishradtu@gmail.com

Ansh Agarwal, Student, Department of Mechanical Engineering, Delhi Technological University, New Delhi, India. E-mail: anshagarwal_2k19ae010@dtu.ac.in

Jayant Dixit*, Student, Department of Mechanical Engineering, Delhi Technological University, New Delhi, India. E-mail: jayantdixit08@gmail.com

Samruddhi Kadam, Student, Department of Mechanical Engineering, Delhi Technological University, New Delhi, India. E-mail: samruddhikadam_2k19ae052@dtu.ac.in

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC-BY-NC-ND license <http://creativecommons.org/licenses/by-nc-nd/4.0/>

Methods of Improving Thermal Performance of Vapour Compression Based Refrigeration System Through Eco Friendly Refrigerants to Reduce Their Environmental Impact

Vaibhav Jain et al. (2011) conducted a performance comparison research of R22, R134a, R410A, R407C, and M20-based vapour compression refrigeration systems.

R407C can be a viable HFC refrigerant replacement with the least expense and work.

Huang et al. (2017) [7] studied the energetic and exergetic performance of a mini air cooled heat exchanger.

Naushad Ahmad Ansari, Akhilesh Arora, Samsher and K. Manjunath et al (2019) investigated the functioning of a Vapour Compression based Refrigeration System with customized Mechanical Subcooling and the Effect of Green Refrigerants. It was found that R1233zd(E), a low GWP refrigerant, performed better than R134a in terms of COP and energy efficiency.

Jeyaraj Thavamani & Ramalingam Senthil et al. (2020) had conducted a study on the effectiveness of retrofitting hydrocarbon-based household vapour compression refrigeration systems [8][9]. Separate tests using HC mix and R134a refrigerants were conducted under no-load conditions. Because of the high latent heat, it was found that the temperature of the HC mix is 3C lower.

Bolaji, B.O. et al. (2011) [10] chose environmentally friendly refrigerants from methane derivatives and ethane derivatives based on flammability, toxicity, chemical stability, and atmospheric lifespan.

Neeraj Agrawal, Shrikanesh Patil, Prasant Nanda et al. (2017) [11] used R290/R600a Zeotropic Blends to determine the ideal charge for a residential refrigerator, with a 60 g charge and -3.5°C as the lowest temperature.

Piyanut Saengsikhiao, Juntakan Taweekun, Somchai Saeng, Thanasak et al. (2020) [12] conducted research to create an energy-efficient and ecologically friendly

refrigerant for medium temperature refrigeration systems. The end product is a nontoxic refrigerant with low GWP, 0% ODP, high capacity, and low operating pressure.

Kazım Kumaş, Ali Akyüz et al. (2020) [13] conducted a performance investigation of the R450A refrigerant in a vapour compression cooling system. The energy characteristics of R450A and R134a refrigerants were theoretically and ecologically examined. It was determined that R450A has a larger mass flow rate than R134a due to cooling more slowly. R134a has a greater COP.

Alptug Yataganbaba, Ali Kilicarslan, Irfan Kurtbas et al. (2015) [14] found that R1234yf and R1234ze are good alternatives to R134a in terms of their environmental friendliness.

Mr. Sandip P. Chavhan, Prof. S. D. Mahajan et al. (2015) [15] conducted a study on the experimental performance assessment of R152a as a potential R134a replacement. R152a has an average refrigerating effect that is 57% higher than R134a's. It is the most energy-efficient refrigerant since it uses the least amount of electricity per tonne of refrigeration of the two refrigerants under study and has the lowest GWP (Global Warming Potential (120)) and ODP (Ozone Depleting Potential (0)) values.

Lalit Mishra, Asst. Prof. Sunil Kumar, Prof. Abhishek Bhandari et al (2019) [16] analysed performance of an ice plant using R-134a eco-friendly refrigerant. Three refrigerants,

R32, R152a, and R245a, were combined in a certain ratio to replace R134a. The global warming potential of all three refrigerants was lower than that of R134a. Based on their

thermal performance in the given conditions and environmental impact the refrigerant mixes were evaluated. A L Tarish, J Al Douri, and V Apostol et al. (2020) [17] examined effectiveness and efficiency for a vapour compression based refrigeration system (VCRS) employing R1234ze and R1234yf, two ecologically friendly refrigerants. studied how performance and energy destruction were affected by subcooling temperature in all VCRS components. The thermodynamic properties of the refrigerant were obtained using the Engineering Equation Solver (EES) software programme. The findings showed that R1234yf demonstrated the biggest COP gain (16.7%) as a result of subcooling, followed by R1234ze (14%), and R134a (12.8%).

Uma Shankar Prasad, R.S Mishra, R.K Das et al. (2020) [18] investigated the thermal performance of a vapour compression based refrigeration system utilising R134a refrigerant with nanofluids and an Al₂O₃ base. They concluded that nanoparticles with R134a refrigerant can improve heat transfer qualities.

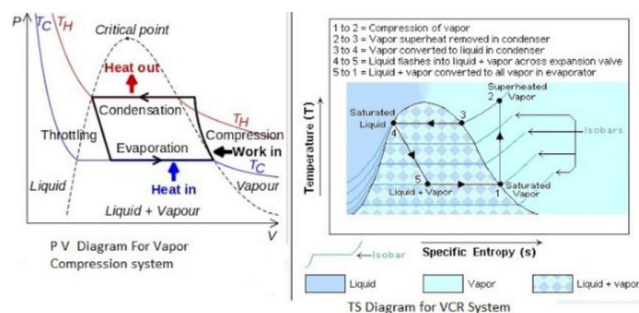


Figure 1: PV And TS Diagram for Vapour Compression System

III. ADVANTAGES AND DISADVANTAGES

Benefits of a vapour compression system include its smaller size and cheaper running costs for a given refrigeration capacity. It may be used in a wide variety of temperatures. The vapour compression system offers the following benefits: It is smaller in size for the same refrigeration capacity, and it costs less to operate. Disadvantages of Vapour Compression System: The system's primary difficulty is controlling refrigerant leakage, and the initial cost is rather high. Moving Parts cause more wear and tear and noise. Liquid droplets in the suction line could be harmed.

A. System description

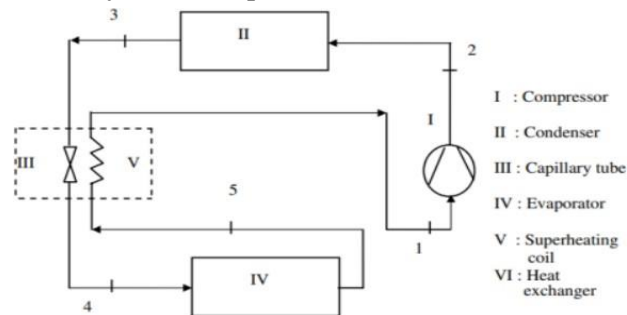


Figure 2: System Description

I: Compressor: In order to maintain a constant flow of refrigerant throughout the system, compressors pull refrigerant vapour from the evaporator and increase its temperature and pressure so that it condenses.

II: Condenser: It is a heat exchanger device used for condensation which employs a cooling medium to transfer heat from the refrigerant [19]. The cooling system of the apparatus generally utilises atmospheric air or water as the medium which receives the system's rejected heat. The cooling medium ultimately ejects the heat to the universe or the outside atmosphere. The heat rejected in the condenser is the sum total of heat equivalent to the compressor work and absorbed evaporator heat. Due to heat transfer, the refrigerant going through the condenser is first desuperheated, then condensed, and occasionally somewhat sub-cooled.

III: Capillary Tube: Because the capillary tube is not adjustable and cannot alter the flow of the refrigerant, it is built for certain environmental circumstances. However, if correctly chosen, it can perform pretty effectively under a variety of scenarios [20]. Because of the capillary's short diameter, the pressure of the refrigerant decreases.

IV: Evaporator: The evaporator also acts as a heat exchanger in a typical refrigeration circuit apart from the condenser, it functions at the "business end" of the refrigeration cycle. The evaporator's fins absorb heat from the air as it is forced past them, cooling the air by collecting heat from space. Since it transfers heat from the objects in the cold room to the refrigerant, it is the main part of the refrigeration system.

V SuperHeating : The process of turning saturated or wet steam into superheated or dry steam, which is subsequently used in steam turbines, steam engines, and procedures like steam reforming, is known as a superheater coil. Before the liquid reaches the evaporator coil, it evaporates, absorbing heat that is then released as superheated vapour. The operational superheat controls how much of the evaporator is used.

VI: Heat Exchanger: Heat is transferred using heat exchangers from one flowing substance to another that is flowing and has a lower initial temperature. Heat exchangers are employed as evaporators and condensers in refrigeration engineering, where the refrigerant goes through a phase shift. As a counter-flow heat exchanger, the capillary tube and suction line move refrigerant vapour from the evaporator to the condenser and maintain its condensed state throughout the process. Throughout the procedure, which uses a non-adiabatic throttling technique, heat is transferred from the capillary tube to the suction line, keeping it apart from the evaporator. The thermal performance of this system is boosted due to heat transfer [22][23].

IV. MATERIALS AND METHODS

These mentioned numerical values were employed for the numerical calculation to verify the thermal model: Reference temperature (T_0) = 298.15 Kelvin

Reference pressure (P_0) = 110 kilo Pascal Refrigeration

capacity (Q_{evap}) = 10 kilo Watt

Evaporator temperature range (T_{evap}) = 250–273.15 Kelvin
Condenser temperature range ($T_{\text{condenser}}$) = 313–333.15 Kelvin

Subcooling temperature (DT_{SC}) = 0 Kelvin Superheating temperature (DT_{SH}) = 3 Kelvin Compressor isentropic efficiency = 80% Electric motor efficiency = 90%

Mass flow rate range of refrigerants:

R134a = 0.06905 kg s⁻¹ R600 = 0.0042 kg s⁻¹ R600a = 0.0050 kg s⁻¹

A. Energy and Exergy Analysis

For the simple vapour compression refrigeration cycle, energy and exergy analyses require some mathematical formulations. The compressor receives external energy (power), and the evaporator adds heat to the system while the condenser rejects heat. The energy efficiency of the refrigerants changes as a result of changes in heat rejection and heat addition for various refrigerants [21]. The different parts of the system's components experience different exergy losses. T_0 and P_0 represent the surrounding ambient temperature and pressure. Exergy is consumed or destroyed as a result of the entropy generated by the associated processes.

Second law efficiency (Exergy):

$$\Psi = (h - h_0) - T_0 (s - s_0) \text{ ----- [1]}$$

For Evaporator: Heat addition in evaporator $Q_{\text{ev}} = m (h_1 - h_4) \text{ ----- [2]}$

Exergetic losses:

$$I_{\text{ev}} = m (\psi_4 - \psi_1) + Q_{\text{ev}} (1 - T_0 / T_{\text{evap}}) \\ = m [(h_4 - h_1) - T_0 (s_4 - s_1)] + Q (1 - T_0 / T_{\text{evap}}) \text{ ----- [3]}$$

For Vapour Compressor:

Exergetic losses:

$$I_{\text{compressor}} = m (\psi_1 - \psi_2) + W_{\text{el}} \\ = m [(h_1 - h_2) - T_0 (s_1 - s_2)] + W_{\text{el}} \text{ ----- [4]}$$

For Condenser:

$$Q_{\text{condenser}} = m (h_2 - h_3) \text{ ----- [5]}$$

Exergetic losses:

$$I_{\text{condenser}} = m (\psi_2 - \psi_3) - Q_{\text{condenser}} (1 - T_0 / T_{\text{condenser}}) \\ = m [(h_2 - h_3) - T_0 (s_2 - s_3)] - Q_{\text{condenser}} (1 - T_0 / T_{\text{condenser}}) \text{ ----- [6]}$$

For Expanding through valve: cooling the condensed refrigerant

Exergetic destruction:

$$I_{\text{exp}} = m (\psi_4 - \psi_3) \\ = m (s_4 - s_3) \text{ ----- [7]}$$

[Throttling, $h_4 = h_3$] ----- [7]

For thermal efficiency: coeff of performance $COP = Q_{\text{ev}} / W_{\text{el}} \text{ ----- [8]}$

aggregate system destruction:

$$\text{total} = I_{\text{condenser}} + I_{\text{exp}} + I_{\text{compressor}} + I_{\text{ev}} \text{ ----- [9]}$$

Exergetic efficiency (2nd law efficiency):

$$\eta_x = (\Psi_1 - \Psi_4) / W_{\text{el}}$$

Methods of Improving Thermal Performance of Vapour Compression Based Refrigeration System Through Eco Friendly Refrigerants to Reduce Their Environmental Impact

B. EES:

Unit Settings: SI C kPa kJ mass deg

COP_m = 1.562

Ex_Q_{evap} = 14.18 [kJ/kg]

F\$ = 'R134a'

Click on this line to see the array variables in the Arrays Table Window

No unit problems were detected.

EES suggested units (shown in purple) for COP_{en} Ex_Q_{evap} h₁ h₂ h₃

Calculation time 0.02 sec.

Figure 3: Settings of EES Code

V. RESULTS AND DISCUSSIONS

A. R134a:

Table 1(a): Variation of Evaporating Temperature with Thermal Performance for R134a

Temp Evap (deg C)	-20	-15	-10	-5	0
COP	2.10	2.36	2.68	3.06	3.54
Efficiency	0.3	0.29	0.27	0.26	0.23
Q(cond)	14.66	14.46	14.28	14.12	13.96
W(comp)	4.25	3.8	3.38	2.97	2.58
Exergy Product	1.85	1.65	1.45	1.25	1.04
Q(evap)	10.41	10.66	10.9	11.14	11.37
EDR(sys)	2.28	2.4	2.57	2.83	3.2

Table 1(b): Variation of Condensing Temperature with Thermal Performance for R134a

Temp Cond (deg C)	60	55	50	45	40
COP	1.89	2.16	2.46	2.81	3.22
Efficiency	0.16	0.18	0.21	0.24	0.28
Q(cond)	12.85	13.24	13.61	13.96	14.28
W(comp)	7.44	4.19	3.93	3.66	3.38
Exergy Product	1.12	1.2	1.29	1.37	1.45
Q(evap)	8.41	9.05	9.68	10.3	10.9
EDR(sys)	5.18	4.41	3.73	3.13	2.57

B. R1234ze (Z):

Table 2(a): Variation of Evaporating Temperature with Thermal Performance for R1234ze(Z)

Temp Evap (deg C)	-20	-15	-10	-5	0
COP	2.61	3.01	3.32	3.72	4.33
Efficiency	0.29	0.27	0.26	0.24	0.24
Q(cond)	12.82	13.14	13.57	13.84	14.55
W(comp)	4.12	3.84	3.67	3.39	2.99
Exergy Product	1.91	1.83	1.8	1.7	1.62
Q(evap)	10.77	11.57	12.2	12.61	12.93
EDR(sys)	2.34	2.48	2.6	2.94	3.31

Table 2(b): Variation of Condensing Temperature with Thermal Performance for R1234ze(Z)

Temp Cond (deg C)	60	55	50	45	40
COP	1.99	2.26	2.67	2.92	3.34
Efficiency	0.26	0.28	0.31	0.34	0.38
Q(cond)	12.98	13.41	13.82	13.96	14.32
W(comp)	7.74	4.28	3.93	3.56	3.23
Exergy Product	1.42	1.61	1.7	1.47	1.58
Q(evap)	8.61	9.15	9.88	10.45	10.92
EDR(sys)	5.38	4.81	3.48	3.22	2.87

C. R1234ze (E):

Table 3(a): Variation of Evaporating Temperature with Thermal Performance for R1234ze(E)

Temp Evap (deg C)	-20	-15	-10	-5	0
COP	2.42	2.872	3.325	3.67	4.322
Efficiency	0.311	0.28	0.27	0.2611	0.23
Q(cond)	14.86	14.61	14.2	14.13	14
W(comp)	4.29	3.884	3.31	2.88	2.56
Exergy Product	1.9	1.711	1.46	1.23	1.11
Q(evap)	10.38	11.15	11.01	10.61	11.08
EDR(sys)	2.25	2.42	2.6	2.84	3.211

Table 3(b): Variation of Condensing Temperature with Thermal Performance for R1234ze(E)

Temp Cond(deg C)	60	55	50	45	40
COP	1.887	2.17	2.47	2.82	3.23
Efficiency	0.1623	0.187	0.2112	0.2431	0.2981
Q(cond)	12.82	13.31	13.65	13.98	14.35
W(comp)	7.5	4.13	3.97	3.65	3.33
Exergy Product	1.18	1.2	1.27	1.34	1.52
Q(evap)	8.4	9.05	9.633	10.32	10.8
EDR(sys)	5.232	4.41	3.78	3.445	2.456

D. R1224YD (Z):

Table 4(a): Variation of Evaporating Temperature with Thermal Performance for R1224YD

Temp Evap (deg C)	-20	-15	-10	-5	0
COP	2.41	2.85	3.34	3.69	4.29
Efficiency	0.3	0.29	0.28	0.27	0.23
Q(cond)	14.81	14.59	14.23	14.05	13.91
W(comp)	4.22	3.88	3.31	2.8	2.59
Exergy Product	1.91	1.76	1.76	1.72	1.7
Q(evap)	10.17	11.05	11.08	10.32	11.1
EDR(sys)	2.23	2.44	2.53	2.85	3.12

Table 4(b): Variation of Condensing Temperature with Thermal Performance for R1224YD

Temp Cond (deg C)	60	55	50	45	40
COP	1.86	2.14	2.56	2.9	3.25
Efficiency	0.16	0.19	0.21	0.24	0.3
Q(cond)	12.86	13.57	13.79	13.98	14.56
W(comp)	7.46	4.13	3.96	3.64	3.33
Exergy Product	1.14	1.23	1.28	1.38	1.67
Q(evap)	8.45	9.08	9.69	10.56	10.78
EDR(sys)	5.28	4.48	3.78	3.42	2.43

E. R1141:

Table 5(a): Variation of Evaporating Temperature with Thermal Performance for R1141

Temp Evap (deg C)	-20	-15	-10	-5	0
COP	2.61	3.01	3.32	3.72	4.33
Efficiency	0.29	0.27	0.26	0.24	0.24
Q(cond)	12.82	13.14	13.57	13.84	14.55
W(comp)	4.12	3.84	3.67	3.39	2.99
Exergy Product	1.91	1.83	1.8	1.7	1.62
Q(evap)	10.77	11.57	12.2	12.61	12.93
EDR(sys)	2.34	2.48	2.6	2.94	3.31

Table 5(b): Variation of Condensing Temperature with Thermal Performance for R1141

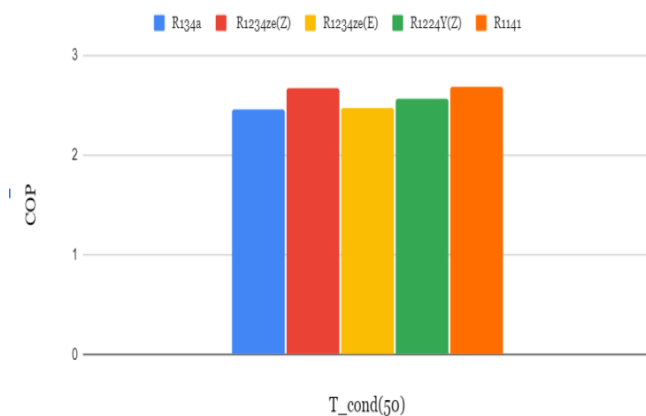
Temp Cond (deg C)	60	55	50	45	40
COP	1.99	2.28	2.68	2.96	3.36
Efficiency	0.26	0.29	0.31	0.34	0.38
Q(cond)	12.93	13.56	13.93	13.99	14.48
W(comp)	7.77	4.28	3.98	3.84	3.27
Exergy Product	1.46	1.68	1.7	1.45	1.55
Q(evap)	8.63	9.17	9.89	10.59	10.97
EDR(sys)	5.38	4.82	3.46	3.23	2.84

F. Comparison Between Refrigerants:

Table 6(a): Comparison Between Refrigerants at Tcond(50)

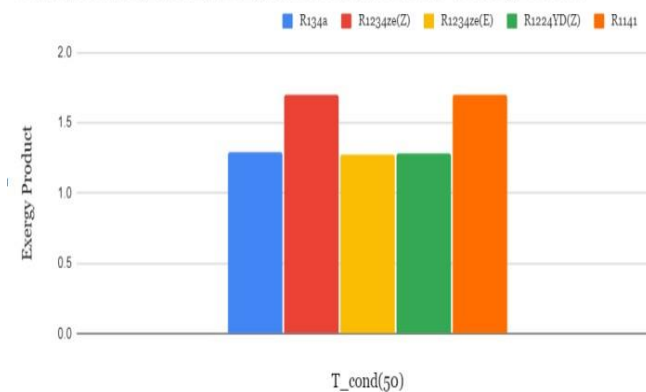
T_cond(50)	COP	Exergy Product	EDR	Q(cond)	Comp Work	Q(evap)	Efficiency
R134a	2.46	1.29	3.73	13.61	3.93	9.68	0.21
R1234ze(Z)	2.67	1.7	3.48	13.82	3.93	9.88	0.31
R1234ze(E)	2.47	1.27	3.78	13.65	3.99	9.633	0.2112
R1224YD(Z)	2.56	1.28	3.78	13.79	3.96	9.69	0.21
R1141	2.68	1.7	3.46	13.93	3.98	9.89	0.31

R134a, R1234ze(Z), R1234ze(E), R1224YD(Z) and R1141 vs COP



Graph 1: The graph compares the refrigerants based on their COP at T_cond(50). The results demonstrate that R1234ze(Z), R1234ze(E), R1224YD(Z), and R1141 have higher COP than R134a.

R134a, R1234ze(Z), R1234ze(E), R1224YD(Z) and R1141 vs Exergy Product



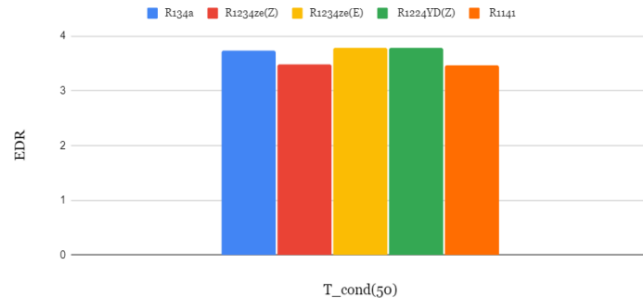
Graph 2: The graph compares the refrigerants based on their Exergy Product at T_cond(50). The results demonstrate that R1234ze(Z) and R1141 have higher Exergy Product than R134a whereas R1234ze(E) and R1224YD(Z) have lower Exergy Product than R134a.

Retrieval Number: 100.1/ijese.F95690512623

DOI: 10.35940/ijese.F9569.12050424

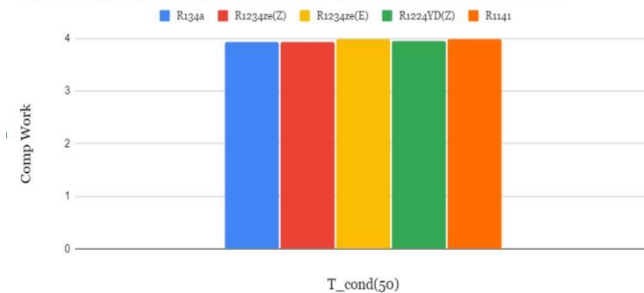
Journal Website: www.ijese.org

R134a, R1234ze(Z), R1234ze(E), R1224YD(Z) and R1141 vs EDR



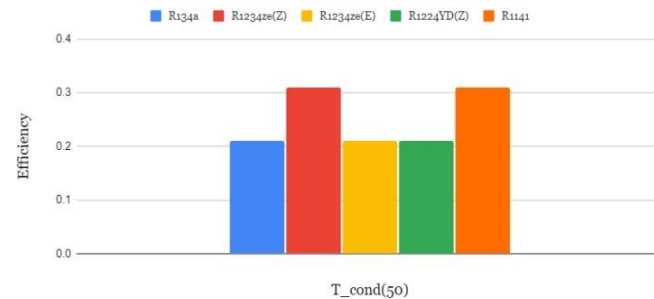
Graph 3: The graph compares the refrigerants based on their EDR at T_cond(50). The results demonstrate that R1234ze(Z) and R1141 have lower EDR than R134a whereas R1234ze(E) and R1224YD(Z) have higher EDR than R134a.

R134a, R1234ze(Z), R1234ze(E), R1224YD(Z) and R1141 vs Comp Work



Graph 4: The graph compares the refrigerants based on their Comp Work at T_cond(50). The results demonstrate that R1234ze(E), R1224YD(Z) and R1141 have higher Comp work than R134a whereas R1234ze(Z) have the same Comp work as R134a.

R134a, R1234ze(Z), R1234ze(E), R1224YD(Z) and R1141 vs Efficiency



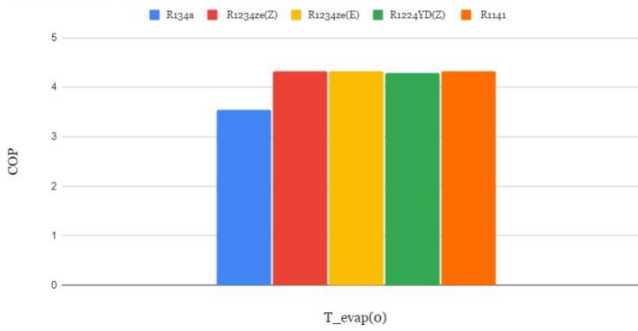
Graph 5: The graph compares the refrigerants based on their Efficiency at T_cond(50). The results demonstrate that R1234ze(Z) and R1141 have higher Efficiency than R134a whereas R1234ze(E) and R1224YD(Z) have the same Efficiency than R134a.

Table 6(b): Comparison Between Refrigerants at T_evap(0)

T_evap(0)	COP	Exergy Product	EDR	Q(evap)	Comp Work	Q(cond)	Efficiency
R134a	3.54	1.04	3.2	11.37	2.58	13.96	0.23
R1234ze(Z)	4.33	1.62	3.31	12.93	2.99	14.55	0.24
R1234ze(E)	4.322	1.11	3.211	11.08	2.56	14	0.23
R1224YD(Z)	4.29	1.7	3.12	11.1	2.59	13.91	0.23
R1141	4.33	1.62	3.31	12.93	2.99	14.55	0.24

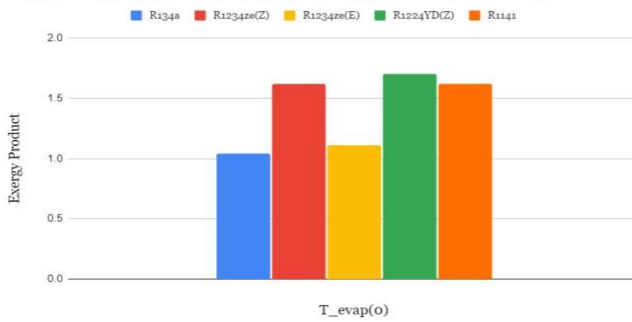
Methods of Improving Thermal Performance of Vapour Compression Based Refrigeration System Through Eco Friendly Refrigerants to Reduce Their Environmental Impact

R134a, R1234ze(Z), R1234ze(E), R1224YD(Z) and R1141 vs COP



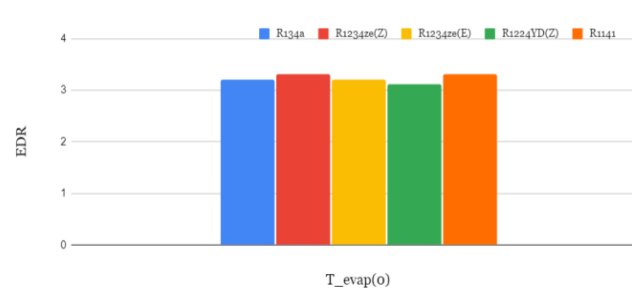
Graph 6: The graph compares the refrigerants based on their COP at $T_{\text{evap}}(0)$. The results demonstrate that R1234ze(Z), R1234ze(E), R1224YD(Z), and R1141 have higher COP than R134a.

R134a, R1234ze(Z), R1234ze(E), R1224YD(Z) and R1141 vs Exergy Product



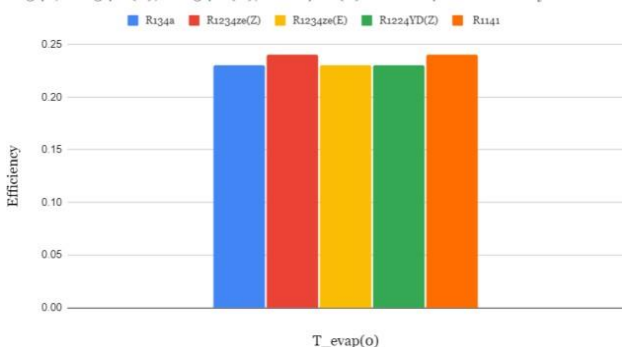
Graph 7: The graph compares the refrigerants based on their Exergy Product at $T_{\text{evap}}(0)$. The results demonstrate that R1234ze(Z), R1234ze(E), R1224YD(Z), and R1141 have higher Exergy Product than R134a.

R134a, R1234ze(Z), R1234ze(E), R1224YD(Z) and R1141 vs EDR



Graph 8: The graph compares the refrigerants based on their EDR at $T_{\text{evap}}(0)$. The results demonstrate that R1234ze(Z), R1234ze(E) and R1141 have higher EDR than R134a whereas R1224YD(Z) have lower EDR than R134a.

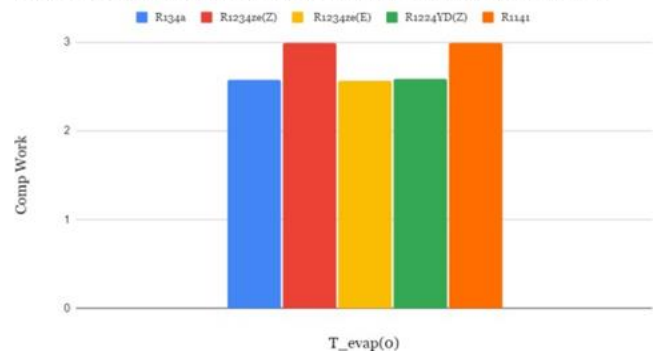
R134a, R1234ze(Z), R1234ze(E), R1224YD(Z) and R1141 vs Efficiency



Graph 9: The graph compares the refrigerants based on their Efficiency at $T_{\text{evap}}(0)$. The results demonstrate that R1234ze(Z) and R1141 have higher Efficiency than R134a

whereas R1234ze(E) and R1224YD(Z) have the same Efficiency than R134a.

R134a, R1234ze(Z), R1234ze(E), R1224YD(Z) and R1141 vs Comp Work



Graph 10: The graph compares the refrigerants based on their Comp Work at $T_{\text{evap}}(0)$. The results demonstrate that R1234ze(Z), R1224YD(Z), and R1141 have higher Comp Work than R134a whereas R1234ze(E) have lesser Comp Work than R134a. Based on comprehensive investigation and comparison, it has been shown that R1234 ze (Z) and R1141 are the most efficient refrigerants when compared to R134a.

VI. CONCLUSION

To improve the overall performance of the vapour compression system, the temperature differential between the evaporator and condenser must be reduced. In order to enhance the performance of the compressor, it is necessary to boost the motor's efficiency and the lubrication system. Operating the system at low condensing and high evaporating temperature ranges will result in a high coefficient of performance (COP) and minimal energy loss. The following findings were reached as a result of the current investigation:

1. R1234ZE(Z) is the most efficient refrigerant.
2. Exergy, also known as availability, is the greatest amount of work that a fluid stream may do during a cyclic mechanism before achieving thermal equilibrium with its surroundings. Second law analysis evaluates the effectiveness in a thermodynamic system. Unlike energy, exergy is not conserved and may be destroyed. Energy efficiency declines as evaporator temperature rises. This is brought on by the components' increased irreversibility as the evaporator temperature rises.
3. Eco-friendly refrigerants have better thermodynamic properties than traditional refrigerants, resulting in improved energy efficiency. This means that the system will require less energy to operate, resulting in lower operating costs and energy bills over time.
4. Improved energy efficiency, reduced maintenance costs, and compliance with regulations can result in significant cost savings and improved profitability over time. Additionally, the environmental benefits of using eco-friendly refrigerants can also result in positive social and economic impacts that are difficult to quantify but are nonetheless valuable.

ACKNOWLEDGEMENT

We express our sincere gratitude to Prof. S.K. Garg (HOD), Mechanical Department, Delhi Technological University, for giving us the motivation to strive for the stars and the opportunity to complete the project. They helped us accomplish our project, and we owe them a great deal for their motivating leadership, supportive guidance, and gracious monitoring. We would especially want to thank PROF. R.S. MISHRA for all of the time and effort he put into this semester as our supervisor. We sincerely appreciate the suggestions and counsel you provided while we worked on the project. You have our eternal gratitude for this. Not least among all of these sources of inspiration are our parents. With all due respect, I say. We want to thank them for their help.

DECLARATION STATEMENT

Funding	No, I did not receive.
Conflicts of Interest	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material	Not relevant.
Authors Contributions	All authors having equal contribution for this article.

REFERENCES

- Mishra, r. S. "methods for improving thermal performance of vapour compression refrigeration system using multiple evaporators compressors system." *journal of multi disciplinary engineering technologies* volume 7 (2013): 1.
- Mishra, R. S. "Performance improvement of vapour compression refrigeration system (VCRS) using eco friendly refrigerants." (2020).
- Arora, Akhilesh, and S. C. Kaushik. "Theoretical analysis of a vapour compression refrigeration system with R502, R404A and R507A." *International journal of refrigeration* 31, no. 6 (2008): 998-1005. <https://doi.org/10.1016/j.jirefrig.2007.12.015>
- Arora, Akhilesh, and S. C. Kaushik. "Energy and exergy analyses of a two-stage vapour compression refrigeration system." *International Journal of Energy Research* 34, no. 10 (2010): 907-923. <https://doi.org/10.1002/er.1594>
- Anand, S., and S. K. Tyagi. "Exergy analysis and experimental study of a vapour compression refrigeration cycle: a technical note." *Journal of thermal analysis and calorimetry* 110, no. 2 (2012): 961-971. <https://doi.org/10.1007/s10973-011-1904-z>
- Chopra, Kapil, V. Sahni, and R. S. Mishra. "Energy, exergy and sustainability analysis of two-stage vapour compression refrigeration systems." *Journal of Thermal Engineering* 1, no. 4 (2015): 440-445. <https://doi.org/10.18186/jte.95418>
- Huang, Zhiwei, Jiazhen Ling, Yunho Hwang, Vikrant Aute, and Reinhard Radermacher. "Design and numerical parametric study of a compact air-cooled heat exchanger." *Science and Technology for the Built Environment* 23, no. 6 (2017): 970-982. <https://doi.org/10.1080/23744731.2017.1335164>
- Ansari, Naushad Ahmad, Akhilesh Arora, and K. Manjunath. "The effect of eco-friendly refrigerants on performance of vapour compression refrigeration system with dedicated mechanical subcooling." In *Advances in Energy and Built Environment*, pp. 43-54. Springer, Singapore, 2020. https://doi.org/10.1007/978-981-13-7557-6_4
- Thavamani, Jeyaraj, and Ramalingam Senthil. "Performance analysis of retrofitted domestic vapour compression refrigeration systems using hydrocarbon refrigerants." *International Journal of Ambient Energy* 43, no. 1 (2022): 2549-2556. <https://doi.org/10.1080/01430750.2020.1751284>
- Bolaji, Bukola Olaleken. "Selection of environment-friendly refrigerants and the current alternatives in vapour compression refrigeration systems." (2011).
- Agrawal, Neeraj, Shriganesh Patil, and Prasant Nanda. "Experimental studies of a domestic refrigerator using R290/R600a zeotropic blends." *Energy Procedia* 109 (2017): 425-430. <https://doi.org/10.1016/j.egypro.2017.03.051>

- Saengsikhiao, Piyanut, Juntakan Taweekun, Kittinan Maliwan, Somchai Sae-ung, and Thanansak Theppaya. "Development of Environmentally-Friendly and Energy Efficient Refrigerant for Medium Temperature Refrigeration Systems." *Journal of Advanced Research in Materials Science* 71, no. 1 (2020): 12-31. <https://doi.org/10.37934/arms.71.1.1231>
- Kumaş, Kazım, and Ali Özhan AKYÜZ. "Performance analysis of R450A refrigerant in vapor compression cooling system for sustainable environment." *Akademika Doğa ve İnsan Bilimleri Dergisi* 6, no. 1 (2020): 57-71.
- Yataganbaba, Alptug, Ali Kilicarslan, and İrfan Kurtbaş. "Exergy analysis of R1234yf and R1234ze as R134a replacements in a two evaporator vapour compression refrigeration system." *International journal of refrigeration* 60 (2015): 26-37. <https://doi.org/10.1016/j.jirefrig.2015.08.010>
- Chavhan, Sandip P., and S. D. Mahajan. "Experimental performance evaluation of R152a to replace R134a in vapour compression refrigeration system." *International journal of modern engineering research* 5, no.2 (2015): 37-47.
- Mishra, Lalit, Sunil Kumar Chaturvedi, and Abhishek Bhandari. "Performance Analysis Of R-134a With Eco Friendly Refrigerant In Vapour Compression Refrigeration Cycle." *International Research Journal of Engineering and Technology (IRJET)* e-ISSN (2019): 2395-0056.
- Tarish, A. L., J. Al Douri, V. Apostol, H. L. Pop, and Ionita. "Exergy and performance analyses of impact subcooling for vapour compression refrigeration systems utilising eco-friendly refrigerants." In *IOP Conference Series: Materials Science and Engineering*, vol. 997, no. 1, p. 012158. IOP Publishing, 2020. <https://doi.org/10.1088/1757-899X/997/1/012158>
- Prasad, Uma Shankar, R. S. Mishra, and R. K. Das. "Experimental studies of vapour compression refrigeration systems with eco-Friendly primary refrigerant and brine mixed with nano particles as secondary refrigerant." (2019).
- Panda, A., & Kund, N. K. (2019). Experimental Performance Determination of COP and TR for R12 Vapour Compression Refrigeration System. In *International Journal of Innovative Technology and Exploring Engineering* (Vol. 9, Issue 2, pp. 887-891). <https://doi.org/10.35940/ijitee.b7122.129219>
- Harun-Or-Rashid, Dr. M., Ashraf, M. I., & Khan, Md. S. (2022). Performance Enhancement of the Refrigeration System by Adding Capacitor and Replacing Refrigerant- Experimental Study. In *International Journal of Engineering and Advanced Technology* (Vol. 11, Issue 3, pp. 76-79). <https://doi.org/10.35940/ijeat.b2107.0211322>
- Sairamakrishna, B., Rao, T. G., & Krishna, N. R. (2021). Cop Enhancement of Vapour Compression Refrigeration System. In *Indian Journal of Production and Thermal Engineering* (Vol. 1, Issue 2, pp. 1-6). <https://doi.org/10.54105/ijpte.b2004.061221>
- S R, H., Kumar K, S., P V, N., & S P, N. (2019). Development of Multi use Refrigeration System. In *International Journal of Recent Technology and Engineering (IJRTE)* (Vol. 8, Issue 2, pp. 2387-2390). <https://doi.org/10.35940/ijrte.a9251.078219>
- Janardhan, N., & Chowdary, R. P. (2020). Performance of Semi Adiabatic DI Diesel Engine with Supercharged air using Crude Jatropa Oil. In *International Journal of Soft Computing and Engineering* (Vol. 9, Issue 5, pp. 10-16). <https://doi.org/10.35940/ijsc.e3344.019520>

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)/ journal and/or the editor(s). The Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP) and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.