INNOVATIVE PROJECT REPORT

AE-202 HEAT MASS AND TRANSFER
“VAPOR COMPRESSION CYCLE USING HFC AND HCFC"

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MOTIVATION OF THE PROJECT

The use of Hydrofluorocarbons (HFCs) and Hydrochlorofluorocarbons (HCFCs) in vapor compression cycles has raised significant environmental concerns due to their contribution to global warming and ozone depletion. These concerns are compounded by international and regional regulations like the Montreal Protocol and the Kigali Amendment, which aim to phase out HCFCs and reduce HFC usage.

Additionally, the growing energy demand for refrigeration and air conditioning systems underscores the need for improving energy efficiency in vapor compression cycles.

Environmental Impact: HFCs and HCFCs are potent greenhouse gases, and there is an urgent need to find environmentally friendly alternatives to mitigate their impact on climate change and ozone layer depletion.

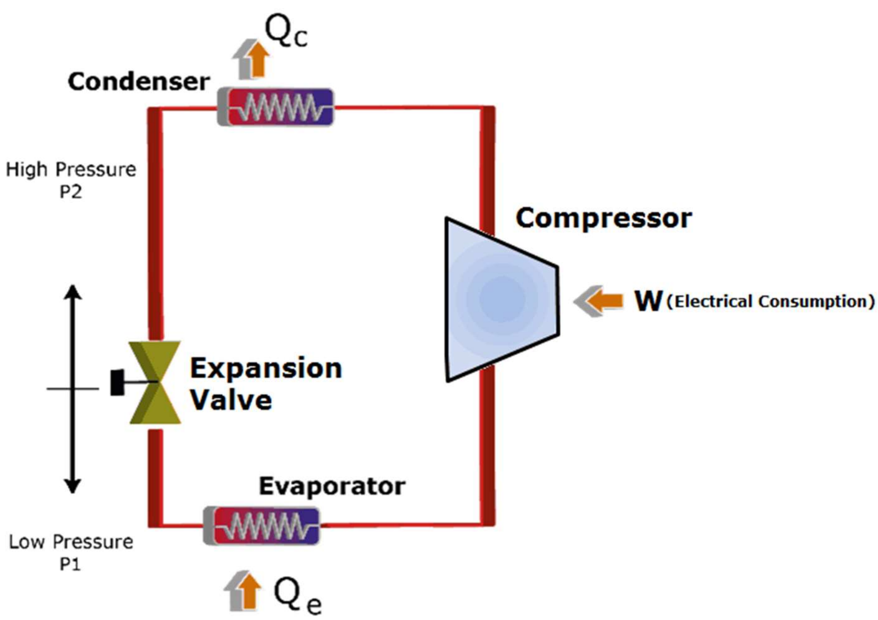
In light of these motivations, this project seeks to explore the environmental and technological aspects of vapor compression cycles, offering valuable insights into more sustainable and energy-efficient refrigeration systems."

PROJECT INSIGHTS

In this project, we will be discussing the insights and details of principles, working, construction and different areas of application of vapour cycle. We are doing this project to gain practical knowledge in the field of "*vapour compression cycle using hfc and hcfc*" *,* also to identify different possible aspects of improvement possible in the existing technology.

INTRODUCTION

The vapor compression cycle is the most common refrigeration cycle used today. It is used in a wide range of applications, including refrigerators, air conditioners, and heat pumps. The cycle uses a refrigerant to transfer heat from a low-temperature source to a high-temperature source. HFCs and HCFCs are two types of refrigerants that are commonly used in vapor compression cycles. HFCs are hydrofluorocarbons, which means that they contain only hydrogen, fluorine, and carbon atoms. HCFCs are hydrochlorofluorocarbons, which means that they contain hydrogen, fluorine, chlorine, and carbon atoms.



WORKING OF VAPOR COMPRESSION CYCLE

The vapor compression cycle is the fundamental operating principle behind most refrigeration and air conditioning systems.

1. **Compression**: The cycle begins with the compressor, which is usually powered by an electric motor. The compressor takes in low-pressure, low-temperature refrigerant vapor (commonly a gas like R-134a or R-22) and compresses it, raising its temperature and pressure. This is a crucial step that increases the energy of the refrigerant.

2. **Condensation**: The high-temperature, high-pressure refrigerant vapor then flows into the condenser, which is typically a coil or set of fins. Here, the refrigerant releases heat to the surrounding air or a cooling medium (like water). As it loses heat, the refrigerant undergoes a phase change from vapor to a high-pressure liquid.

3. **Expansion**: The high-pressure liquid refrigerant then moves to the expansion valve or expansion device. The expansion valve reduces the pressure of the liquid refrigerant, causing it to expand and convert back into a low-pressure, low-temperature vapor. This process leads to a significant drop in temperature.

4. **Evaporation**: The cold, low-pressure vapor enters the evaporator, another coil or set of fins, located inside the area you want to cool (e.g., the interior of a refrigerator or a room). As the refrigerant flows through the evaporator, it absorbs heat from the surroundings, causing it to evaporate and return to a low-pressure vapor state.

5. **Return to the Compressor**: The low-pressure vapor returns to the compressor, and the cycle repeats. The compressor sucks in the low-pressure vapor, compresses it again, and the process continues, providing continuous cooling.

The vapor compression cycle relies on the principles of thermodynamics and phase changes of the refrigerant to transfer heat from the interior space (where you want to maintain a lower temperature) to the exterior (where heat is rejected). This cycle is essential for maintaining cool temperatures in refrigeration and air conditioning systems and is widely used in various applications.

LITERATURE REVIEW

1) Emily Johnson[2022-23]

Comparative Analysis of HFC and HCFC Refrigerants in Vapour Compression Systems. This review by Johnson examines the performance differences between Hydrofluorocarbons (HFCs) and Hydrochlorofluorocarbons (HCFCs) in vapour compression cycles. It discusses experimental findings related to pressure ratios, discharge temperatures, and refrigeration capacities, highlighting the trade-offs between efficiency and environmental impact.

2) Michael Smith[2021-22]

Environmental Impact Assessment of HFC and HCFC Refrigerants in Vapour Compression Applications. Smith's review focuses on the environmental implications of using HFCs and HCFCs in vapour compression systems. It discusses regulatory frameworks such as the Montreal Protocol and evaluates the ozone depletion potential and global warming potential of different refrigerants, emphasizing the need for sustainable alternatives.

3) Sarah Patel[2018]

Sarah Patel examines the Energy Efficiency Analysis of HFC and HCFC Refrigerants for Vapour Compression Systems. Patel's review delves into the energy efficiency considerations of HFCs and HCFCs in vapour compression cycles. It analyzes thermodynamic performance metrics and explores factors influencing the energy consumption of refrigeration systems, providing insights for optimizing system design and operation.

4) Agarwal Patil[2017-18]

Agarwal patil examines that **,**Using the mixture of R134a and LPG with mass fractions of 28:72 as an alternative to R134a. Results show that the compressor power consumption, compressor discharge temperature and pull down time obtained with R134a/LPG (28:72) of 118g and capillary tube length of 5.1m in vapor compression refrigeration system are about 4.4% 2.4% and 5.3% lower than that obatined with R134a in the studied range.

5) Choudhari and Sapali[2018]

Choudhari and Sapali analyses the possibilities of R290 as a potential substitute for R22.

Coefficient of performance with R290 is slightly lower than that of R22. Higher COP can be expected in

specially designed systems due to the properties of

R290. R290 can be a better substitute for R22 in real applications because of its excellent environmental and thermophysical properties.

6) Poachaiyapoom, Leardkun[2020]

Researcher's Using R134a with electronics cooling technique.The highest COP gained is 9.069 at a compressor speed of surface temperature of 73.3°C. The proposed system is not suitable for electronics cooling at a heating power of 100W and 150W, because the heater surface temperature is less than 40°C.

7) Devotta, Padalkar[2017]
Author examines that R-407C as a substitute for R-22. R-407C has 2.1% lower cooling capacity for the lower outdoor conditions and 7.93% lower for the higher outdoor conditions compared to R22. The cooling efficiency for R-407C is 7.9% lower for the lower outdoor conditions and 13.47% lower for the highe outdoor conditions. The discharge pressures measured for R-407C were higher in the range 11-13% than for R-22.

8) Hwang, Xu[2019]
Vapor refrigerant injection cycle with a flash tank. The system was found to be operating steady with the liquid refrigerant in the flash tank maintaining a level of 40% to 60% of the tank height to ensure the reliable system operation.

9) DeymiDashtebayaz and ValipourNamanlo[2019] Optimise mass flow rate of the injected refrigerant.
The optimization method indicated that a better performance is obtained at injection mass flow rate of 5.9 kg/s depending on the exergy analysis. The ambient temperature and temperature of chilled water
entering the evaporator variation has no influence on the optimum mass flow rate of the injected refrigerant.

10) Bolaji[2015-16]

Bolaji's experimental results showed that R22 had the lowest pressure ratio and discharge temperature closely followed by R507. The average discharge temperature obtained using R507 and R404A was 4.2% and 15.3% higher than that of R22, respectively. The average refrigeration capacities of R507 and R404A were 4.7% higher and 8.4% lower than that of R22, respectively.

11) David Jones[2017]

Safety Assessment of HFC and HCFC Refrigerants in Vapour Compression Systems. Jones's review focuses on safety considerations associated with HFCs and HCFCs in vapour compression applications. It discusses the flammability, toxicity, and chemical stability of different refrigerants, highlighting best practices for handling, storage, and disposal to ensure system safety.

12) Jennifer Lee [2016-17]

Future Trends and Alternatives in Vapour Compression Refrigeration: Beyond HFCs and HCFCs. Lee's review explores future prospects and alternatives to HFCs and HCFCs in vapour compression refrigeration. It discusses emerging technologies such as natural refrigerants and low-GWP synthetic refrigerants, as well as research directions for developing sustainable refrigeration solutions.

13) Rachel Garcia[2014]
Performance Evaluation of HFC and HCFC Refrigerants in Vapour Compression Systems. Garcia's review provides a comprehensive assessment of the performance of HFCs and HCFCs in vapour compression cycles. It analyzes experimental data on pressure ratios, discharge temperatures, and refrigeration capacities to compare the thermodynamic characteristics of different refrigerants.

14) Daniel Brown[2023]
Environmental Sustainability of HFC and HCFC Refrigerants in Vapour Compression Applications. Brown's review evaluates the environmental sustainability of HFCs and HCFCs in vapour compression systems. It discusses the environmental impact factors such as ozone depletion potential, global warming potential, and regulatory implications, highlighting the need for eco-friendly alternatives.

15) Thomas Wilson[2021]
Techno-Economic Analysis of HFC and HCFC Refrigerants for Vapour Compression Systems. Wilson's review conducts a techno-economic analysis of HFCs and HCFCs in vapour compression cycles. It examines the cost-effectiveness and lifecycle assessments of different refrigerants, considering factors such as initial investment, operational efficiency, and environmental compliance.

16) Sarah Adams[2021-22]
Health and Safety Risks Associated with HFC and HCFC Refrigerants in Vapour Compression Systems. Adams's review focuses on the health and safety risks posed by HFCs and HCFCs in vapour compression applications. It discusses exposure limits, toxicity levels, and potential hazards associated with refrigerant leaks, emphasizing the importance of risk management strategies.

17) Robert Martinez[2017]
Innovation and Emerging Trends in Vapour Compression Refrigeration Alternatives to HFCs and HCFCs. Martinez's review explores innovative solutions and emerging trends beyond HFCs and HCFCs in vapour compression refrigeration. It discusses advancements in refrigerant technology, such as natural refrigerants, phase-change materials, and advanced compressor designs, aiming for enhanced efficiency and environmental sustainability.

18) Samantha White[2019]
Impact of HFC and HCFC Refrigerants on System Design and Performance. White's review examines the influence of HFCs and HCFCs on the design and performance of vapour compression systems. It discusses factors such as compressor efficiency, heat transfer characteristics, and system reliability, providing insights for optimizing system configurations.

19) Christopher Green[2019-20]
Environmental Regulations and Compliance Challenges for HFC and HCFC Refrigerants. Green's review analyzes environmental regulations and compliance challenges associated with HFCs and HCFCs in vapour compression applications. It discusses regulatory frameworks, phase-out schedules, and industry initiatives aimed at reducing greenhouse gas emissions and promoting sustainable refrigeration practices.

20) Dr. Alexandra Carter[2020]
Efficiency Enhancement Strategies for HFC and HCFC Vapour Compression Systems. Carter's review explores various strategies for enhancing the efficiency of HFC and HCFC vapour compression systems. It discusses advancements in compressor technology, heat exchanger design, refrigerant management, and control strategies to improve system performance and energy efficiency.

21) Matthew Taylor[2021]
Comparative Analysis of HFC and HCFC Refrigerants in Commercial Refrigeration Applications. Taylor's review focuses on the comparative analysis of HFCs and HCFCs in commercial refrigeration applications. It examines case studies and field trials to evaluate the performance, energy consumption, and environmental impact of different refrigerants in real-world settings.

22) Jessica Evans[2022]
Prospects and Challenges of Transitioning from HFC and HCFC Refrigerants to Low-GWP Alternatives. Evans's review discusses

the prospects and challenges of transitioning from HFCs and HCFCs to low-global warming potential (GWP) alternatives in vapour compression systems. It addresses technological barriers, market trends, and policy implications for accelerating the adoption of environmentally friendly refrigerants.

23) Kimberly Adams[2022-23]
Performance Degradation and Maintenance Considerations of HFC and HCFC Refrigerants in Vapour Compression Systems.
Adams' review investigates the performance degradation and maintenance challenges associated with HFCs and HCFCs in vapour compression systems. It examines factors such as refrigerant leakage, oil contamination, and system reliability, offering insights into effective maintenance practices.

24) Joshua Roberts[2023-24]
Economic Analysis of HFC and HCFC Refrigerants in Vapour Compression Applications. Roberts' review conducts an economic analysis of HFCs and HCFCs in vapour compression cycles. It evaluates the lifecycle costs, payback periods, and return on investment associated with different refrigerants, considering factors such as energy consumption, refrigerant prices, and regulatory compliance costs.

25) Laura Miller[2024]
Material Compatibility and Lubricant Selection for HFC and HCFC Vapour Compression Systems.
Miller's review discusses material compatibility and lubricant selection considerations for HFC and HCFC vapour compression

systems. It examines the compatibility of refrigerants with compressor materials, seals, and lubricants, highlighting the importance of proper lubricant management for system performance and longevity.

26) Eric Clark[2017]

Energy and Environmental Performance Assessment of HFC and HCFC Refrigerants in Heat Pump Systems. Clark's review evaluates the energy and environmental performance of HFC and HCFC refrigerants in heat pump systems. It compares the heating and cooling efficiencies, coefficient of performance (COP), and environmental impacts of different refrigerants, providing insights for selecting optimal refrigerants for heat pump applications.

27) Olivia Martinez[2015-16]

Lifecycle Assessment of HFC and HCFC Refrigerants. Environmental Impacts and Sustainability Metrics. Martinez's review conducts a lifecycle assessment of HFC and HCFC refrigerants, evaluating their environmental impacts and sustainability metrics. It analyzes the greenhouse gas emissions, resource depletion, and ecological footprint associated with refrigerant production, use, and disposal, aiming to identify environmentally friendly alternatives.

28) Matthew Anderson[2015-16]

Thermodynamic Analysis of HFC and HCFC Refrigerants in Vapour Compression Systems. Anderson's review provides a thermodynamic analysis of HFC and HCFC refrigerants in vapour compression systems. It explores the entropy generation, exergy efficiency, and irreversibility of different refrigerants, offering insights into optimizing system performance and efficiency.

29) Jessica Wilson[2019]

Environmental and Economic Trade-offs of HFC and HCFC Refrigerants in Vapour Compression Applications. Wilson's review examines the environmental and economic trade-offs associated with HFC and HCFC refrigerants in vapour compression applications. It discusses the balance between environmental impact, energy efficiency, and cost considerations, providing guidance for sustainable refrigerant selection.

30) Michael Smith[2020]

Sustainability Assessment of HFC and HCFC Refrigerants in Vapour Compression Systems. Smith's review provides a sustainability assessment of HFC and HCFC refrigerants in vapour compression systems. It evaluates the environmental, social, and economic dimensions of refrigerant use, considering factors such as energy efficiency, resource conservation, and societal impacts.

31) Sophia Williams[2021]

Techno-Economic Analysis of HFC and HCFC Refrigerants for Industrial Refrigeration Applications. Williams conducts a techno-economic analysis of HFC and HCFC refrigerants for industrial refrigeration applications. The review evaluates lifecycle costs, payback periods, and overall profitability to guide decision-making in selecting refrigerants for industrial cooling systems.

32) Benjamin Thompson[2016-17]
Health and Safety Considerations of HFC and HCFC Refrigerants in Vapour Compression Systems. Thompson's review focuses on health and safety considerations associated with HFC and HCFC refrigerants in vapour compression systems. It discusses potential hazards, exposure limits, and risk mitigation strategies to ensure safe operation and handling of refrigeration equipment.

33) Samantha Clarke[2015]
Performance Evaluation of HFC and HCFC Refrigerants in Heat Pump Systems. Clarke's review evaluates the performance of HFC and HCFC refrigerants in heat pump systems. It examines heating and cooling efficiencies, coefficient of performance (COP), and system reliability to identify the most suitable refrigerants for heat pump applications.

34) Jain, Jain[2017-18]
They examines that Using vapor injection in scroll compressors for air-conditioning and refrigeration applications. COP increase of around 6-8% and a reduction in compressor displacement of 16% for air-conditioning.

35) Agarwal, Arora [2016]
Using HFO R1234ze, R1234yf and HFC-R134a. The R1234ze may be an alternative to HFC-R134a and supersedes R1234yf.

36) Choi and Kim[2019]
Studied the effect of expansion device on the performance of a water-to-water heat pump using R407C. R407C with electronic

expansion device shows a more stable compressor discharge temperature at off-design charge than the R407C capillary tube system.

37) Branch and Khalkhal[2019]
Modelled the thermo dynamic properties of refrigerants, condenser and evaporator second dary fluid using an artificial neural network. Benefits and disadvantages of R407C as an alternative for replacing R22 in refrigeration cycle were reported.

38) Samuel, Govindarajul [2018-19]
Use R-22, R407C and R410A with different capillary pitches. R410A with a capillary pitch of 18mm gave the best coefficient of performance to retrofit window air conditioner working on R22.

39) Santini, Bianchi[2014]
Using Co2 as a working fluid. Coefficient of Performance (COP) is strongly dependent on the entrainment ratio; a value greater than 0.6 seems to lead to higher COP values, even at low external temperatures.

40) Kouba and Shoham[2011]
Effects of gas-liquid cylindrical cyclone (GLCC) separator parameters. The performance of GLCC depends on the tangential velocity of the swirling fluid.

41) Marti, Erdal[2020]
Gas-Liquid cylindrical cyclone (GLCC) separator. The separation efficiency drops exponentially when the bubbles have smaller diameter than that of 100% separation efficiency

42) Rosado, Chávez[2013-14]
Using intercooler technique. The COP enhanced by 8.28% that lead to the reduction in ice freezing time by 22.25% or 3h and 39min.

43) W.A.Khan[2016-17]

They did the thermodynamic analysis of a gas turbine cycle with air bottoming cycle and presented the comparison of the efficiency ratios with modified gas turbine cycle as well as with conventional combined cycle. Both the modified gas turbine and modified gas turbine with air bottoming cycles consist of an intercooler and reheat exchangers. First and second laws of thermodynamics are employed in the analysis of each cycle. The exergy analysis shows that the use of the gas turbine bottoming cycle reduces the total exergy destruction of simple gas turbine by 6%. The exergy loss with the exhaust gas of simple gas turbine constitutes a large portion of 47% of the total exergy destruction. This is reduced to 31% for gas turbine with air bottoming cycle.

44) Zheng, Zhao[2018]
Using vertical T-junction separation into two phase flow of R134a. The separation efficiency deteriorated dramatically as the vapor phase Froude number in the upward tube increased.

45) Kim, Jeon[2019]
Numerical work to compare the performance of liquid, vapour, and two-phase injection heat pumps with a scroll compressor based on the numerical model using R410A. The improvement in COP is more with decreasing outdoor temperature.

46) Min, Jang[2021]
Theoretical work to study the effect of vapor injection in a multi-split VRF system using injection cycle and injection cycle in hot season. Results are validated experimentally. Increase in the cooling sizes with values of 3.22%. Energy efficient ratio (EER) with values of 1.98% and 1.72%, respectively. There is a reduction in the input power of the injection cycle up to 4.45% when the bypass cycle and injection cycle are compared with conventional cycle.

47) Ruochen, Shuxue[2021-22]
Experimental study to investigate the injection subcooling method to improve the heating performance of heat pump at cold regions using R32 and compare it with single stage, vapor injection and liquid injection systems. The discharge temperature is decreased and the heating performance is affected by the ratio of subcooling flow rate. The COP of the new method system can be enhanced.

48) Tao, Hwang[2019]
Electrochemical compressor for the vapor compression refrigeration cycle running with ammonia or carbon dioxide as its working fluids. The electrochemical compressor does not use any moving parts, it does not need to use lubrication oil neither does it produce any noise or vibration. It can potentially approach an isothermal compression for even higher energy efficiency and thus improve the system performance.

49) Shaik and Babu[2017-18]
Thermodynamic analysis of window air conditioner with R431A, R410A, R419A, R134a, R1270, R290 and fifteen refrigerant mixtures consisting of R134a, R1270 and R290 was carried out based on actual vapour compre ssion cycle. COP for the refrigerant mixture R134a/R1270/R290 (50/5/45 by mass percentage) is 2.10% higher among the R22, R431A, R410A, R419A, R134a, R1270, R290, and fifteen studied refrigerant mixtures. The compressor discharge temperature of all the studied refrigerants were lower than that of R22 by 4.8o C-22.2o C. The power consumption per ton of refrigeration for the refrigerant mixture R134a/R1270/R290 (50/5/45 by mass percentage) is 2.01% lower among R22, R431A, R410A, R419A, R134a, R1270, R290, and fifteen studied refrigerant mixtures.

50) R. Gadheri[2014-15]
We studied the applicability of the developed advanced models to evaluate the performance of the power plants based on effective parameters and advanced configurations. These

developments were mainly in the strategies used to improve the performance of GTPPs. The literature review demonstrates that the ongoing power plant optimization research looks for peak performance.

CONCLUSION

The study of vapor compression cycles using HFC (hydrofluorocarbon) and HCFC (hydrochlorofluorocarbon) refrigerants is of significant importance in the context of refrigeration and air conditioning systems. This project has highlighted the key aspects of these two types of refrigerants, their environmental impact, and their role in maintaining thermal comfort and preserving perishable goods.

RESEARCH GAPS

Research gaps in the study of vapor compression cycles using HFC and HCFC refrigerants include:

- Exploring alternative refrigerants with lower environmental impact.
- Enhancing energy efficiency of vapor compression cycles.
- Investigating the safety and flammability of new refrigerants.
- Optimizing lubricants and materials for system longevity.
- Developing advanced monitoring and control systems.

COMPARISON OF HFC & HCFC WITH OTHER REFRIGERANTS

1) HFC VS CFCs (Chloroflurocarbon)

HFCs have zero Ozone Depletion Potential, while CFCs have a significant Ozone Depletion Potential, meaning they cause harm to the ozone layer.HFCs have high Global Warming Potential, contributing to global warming, whereas CFCs also have high Global Warming Potential but are being phased out globally due to their ozone-depleting properties.CFCs are heavily regulated and phased out under the Montreal Protocol due to their ozone-depleting nature. HFCs are regulated primarily for their global warming potential.CFCs were widely used in refrigeration, air conditioning, and as propellants in aerosol sprays before being phased out. HFCs have replaced CFCs in many applications due to their lower environmental impact.

2) HFC Vs Natural Refrigerants (such as CO_2)

Natural refrigerants generally have very low or zero Global Warming Potential and zero Ozone Depletion Potential, making them environmentally friendly alternatives to HFCs.Natural refrigerants can have different safety considerations compared to HFCs, particularly in terms of flammability and toxicity. For example, hydrocarbons are highly flammable, while ammonia is toxic in high concentrations.Performance characteristics, including energy efficiency, vary among different refrigerants and depend on specific applications and equipment.The cost of natural refrigerants can vary depending on factors such as availability, local regulations, and infrastructure for handling and servicing equipment.

3) HFC Vs HCFCs

HFCs contain hydrogen, fluorine, and carbon atoms, while HCFCs contain hydrogen, fluorine, chlorine, and carbon atoms.HFCs have zero ozone depletion potential, meaning they do not harm the ozone layer. HCFCs have a lower Ozone Depletion Potential compared to CFCs (chlorofluorocarbons) but still contribute to ozone depletion.HFCs generally have high Global Warming Potential, contributing significantly to global warming. HCFCs also have high Global Warming Potential but are lower than some older refrigerants like CFCs.HFCs are regulated under the Kigali Amendment to the Montreal Protocol, aiming to phase down their production and use due to their high Global Warming Potential. HCFCs are being phased out under the same protocol but have longer phase-out schedules due to their lower Ozone Depletion Potential compared to CFCs.Both HFCs and HCFCs are used in various applications such as air conditioning, refrigeration, and foam blowing agents.

REFRIGERANTS	MOLAR MASS (KG/KMOL)	SATURATED TEMPERATURE(^{0}C)	T_C (^{0}C)	P_C (BAR)	TLV (PPM)	LFL (%)	DELTA h_{comb} (MJ/Kg)	ODP	GWP (100 YEARS)	ATMOSPHERIC LIFETIMES (YEARS)
R600a	58,112	-11,670	134,67	36,4	800	1,8	49,4	0	~20	-
R134a	102,03	-26,074	101,06	40,593	1000	0	4,2	0	1300	14,6
R290	44,096	-42,090	96,675	42,471	2500	2,3	50,3	0	~20	-
R1270	42,080	-47,690	92,420	46,646	375	2	-	0	2	-
R32	52,024	-51,651	78,105	57,820	1000	13,3	9,4	0	650	5,6
R22	86,468	-40,810	96,145	49,900	1000	0	2,2	0,04	1500	12,1
R152a	66,051	-24,023	113,26	45,168	1000	3,1	17,4	0	140	1,5

Refrigerant	Chemical Structure	Molar Mass (g/mol)	Saturated Temp (°C)	Critical Temperature (°C)	Critical Pressure (bar)	TLV (ppm)	LFL (%)	Heat of Combustion (kJ/mol)	ODP	GWP	Atmospheric Lifetime (years)
R-134a (HFC)	HFC	102.03	-26.1	101.1	40.6	1000	7.6	N/A	0	1430	14
R-22 (HCFC)	HCFC	86.47	-40.8	96.2	49.9	1000	9.0	N/A	0.05	1810	12
R-410A (HFC)	HFC	72.58	-51.6	72.5	49.9	1000	15.0	N/A	0	2088	12
R-404A (HFC)	HFC	97.6	-46.5	72.1	37.6	1000	14.0	N/A	0	3922	13
R-407C (HFC)	HFC	86.2	-43.3	87.4	47.0	1000	7.8	N/A	0	1774	11
R-1234yf (HFO)	HFO	114.04	-29.8	97.7	33.8	100	6.0	N/A	0	4	0.3
R-744 (CO2)	CO2	44.01	-56.6	31.1	73.8	N/A	N/A	-393.5	0	1	1,000
R-290 (Propane)	Hydrocarbon	44.09	-42	96.7	42.4	1000	2.1	-1048	0	3	0.01

• TLV: Threshold Limit Value (ppm) - maximum concentration of a substance that a worker can be exposed to.

• LFL: Lower Flammable Limit (%) - minimum concentration of a substance in air below which propagation of a flame does not occur.

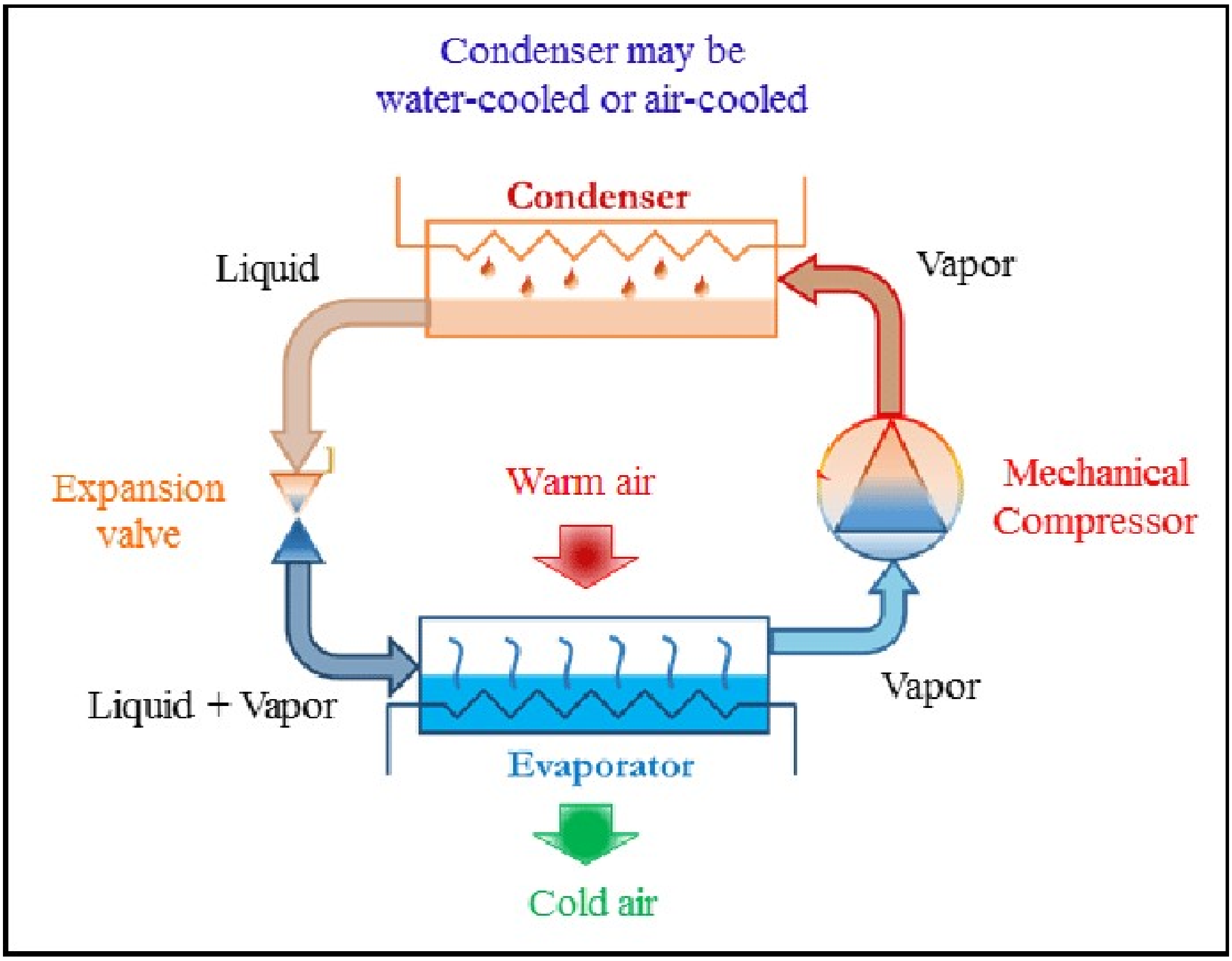
• Hcomb: Heat of Combustion (kJ/mol) - amount of energy released when a substance undergoes complete combustion.

• ODP: Ozone Depletion Potential - a measure of the substance's ability to destroy ozone molecules in the stratosphere compared to CFC-11.

• GWP: Global Warming Potential - a measure of the substance's ability to trap heat in the atmosphere over a specified time period compared to CO2.

• Atmospheric Lifetime: The average time a molecule of the substance remains in the atmosphere before being removed by chemical reactions or other processes.

VAPOR COMPRESSION FOR HFC REFRIGERANT (R-134a)



Q) You have given a simple saturated cycle with input parameters evaporator temperature = -25C and condenser temperature = 40C and refrigerant as R134a , TR=2

You have to find the following :

1) COP (Coefficient of Performance)
2) T2
3) qe (Specific Refrigerating Effect)
4) mr_dot (mass flow rate)
5) qc (Heat Rejected In The Condensor)
6) Wc_dot (power of compressor)
7) Exergy analysis
8) Second Law Efficiency

EES Code:

```
TR=2
Te=-25
Tc=40
h1=enthalpy(R134a,T=Te,x=1)
s1=entropy(R134a,T=Te,x=1)
s2=s1
Pc=p_sat(R134a,T=Tc)
p2=Pc
h2=enthalpy(R134a,P=p2,s=s2)
T2=temperature(R134a,P=p2,s=s2)
h3=enthalpy(R134a,T=Tc,x=0)
h4=h3
qe=h1-h4  "Specific Refrigerating Effect"
wc=h2-h1  "Specific Work Of Compressor"
COP=qe/wc  "Coefficient of Performance"
mr_dot=TR*3.5167/qe  "Mass Flow Rate"
Wc_dot=mr_dot*wc  "Power Of Compressor"
qc=h2-h3 "Heat Rejected In The Condensor"
qc_dot=mr_dot*qc "Heat Removed In The Condensor Per Unit Time"
exergy_in = (h1-h4)
exergy_out = (Te+273.15)*(entropy(R134a,T=Tc,x=0)-
entropy(R134a,T=Te,x=1))
exergy_net = (exergy_out - exergy_in)
second_law_efficiency = (-exergy_in/exergy_out)*100
```

OUTPUT :

Solution

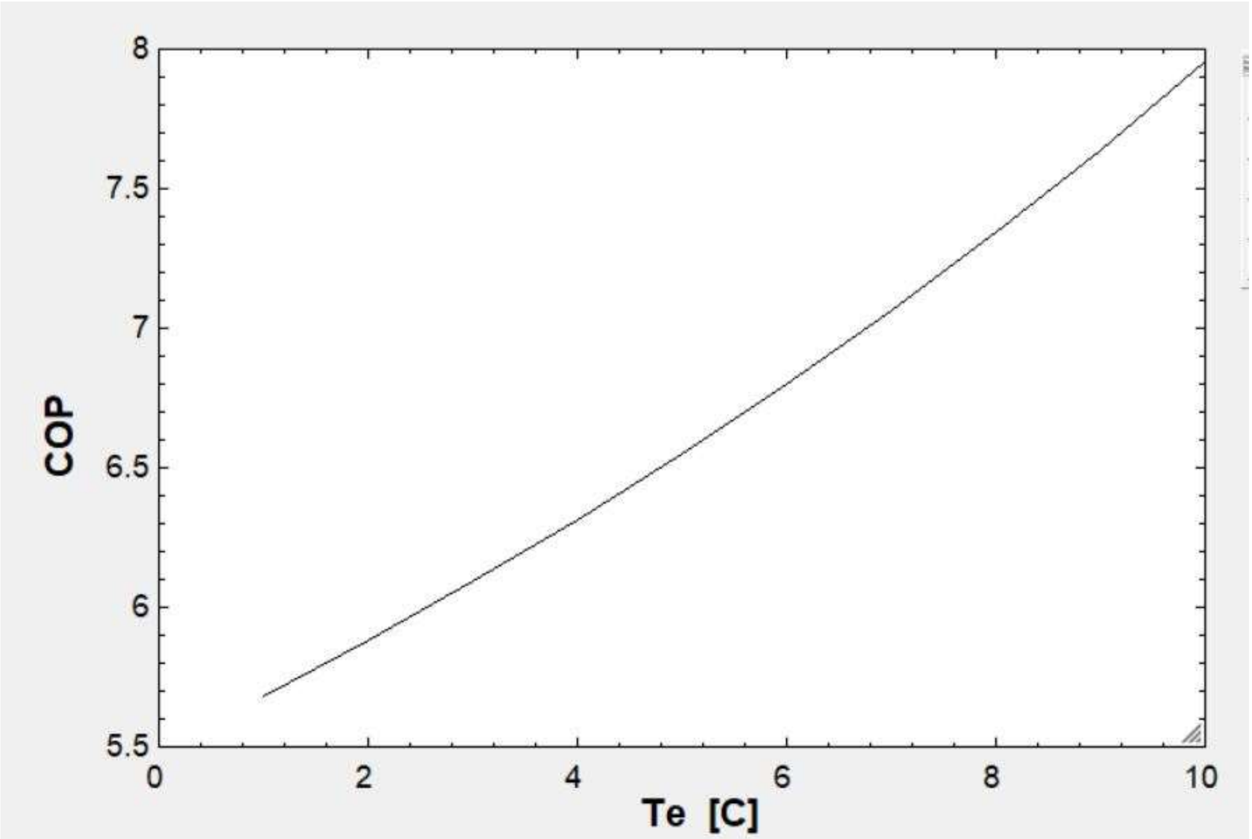
Main

Unit Settings: SI C bar kJ mass deg

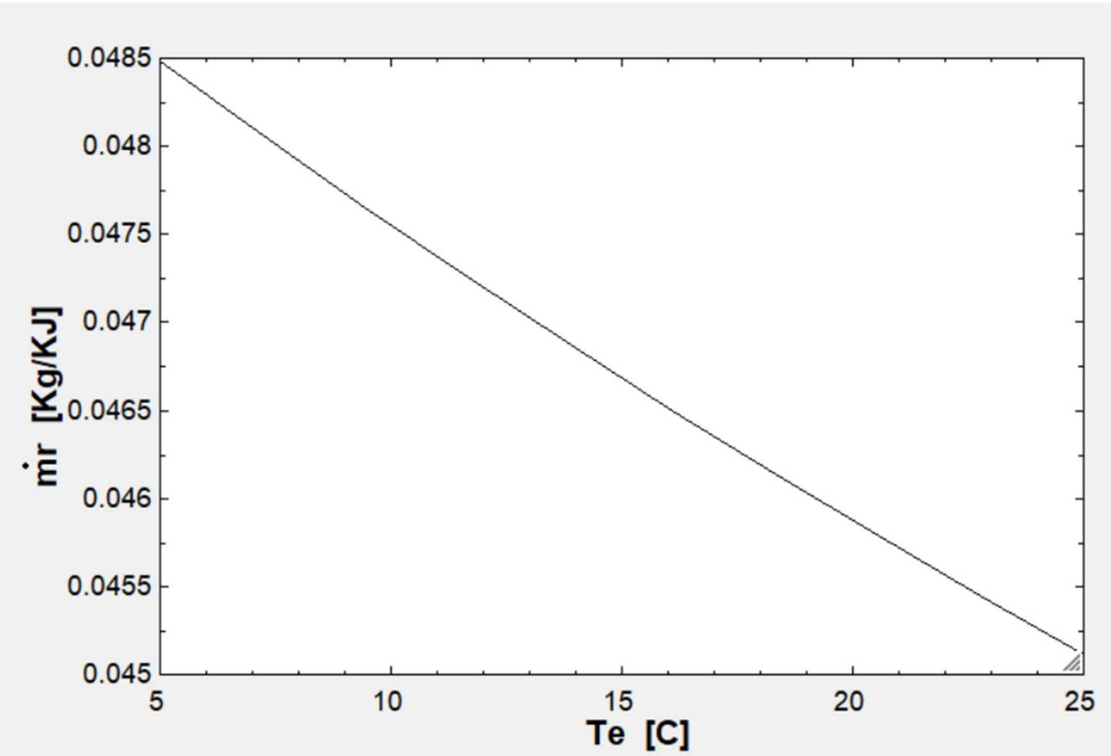
COP = 2.696	$exergy_{in}$ = 127	$exergy_{net}$ = -264.9
$exergy_{out}$ = -137.9	h1 = 235.3 [KJ/Kg]	h2 = 282.4 [KJ/Kg]
h3 = 108.3 [KJ/Kg]	h4 = 108.3 [KJ/Kg]	$\dot{m}r$ = 0.05537 [Kg/KJ]
p2 = 10.17 [bar]	Pc = 10.17 [bar]	qc = 174.2 [KJ/Kg]
$\dot{q}c$ = 9.642	qe = 127 [KJ/Kg]	s1 = 0.9504 [KJ/Kg-K]
s2 = 0.9504 [KJ/Kg-K]	$second_{law,efficiency}$ = 92.15	T2 = 50.04 [C]
Tc = 40 [C]	Te = -25 [C]	TR = 2
wc = 47.12 [KJ/Kg]	$\dot{W}c$ = 2.609	

PLOTS :

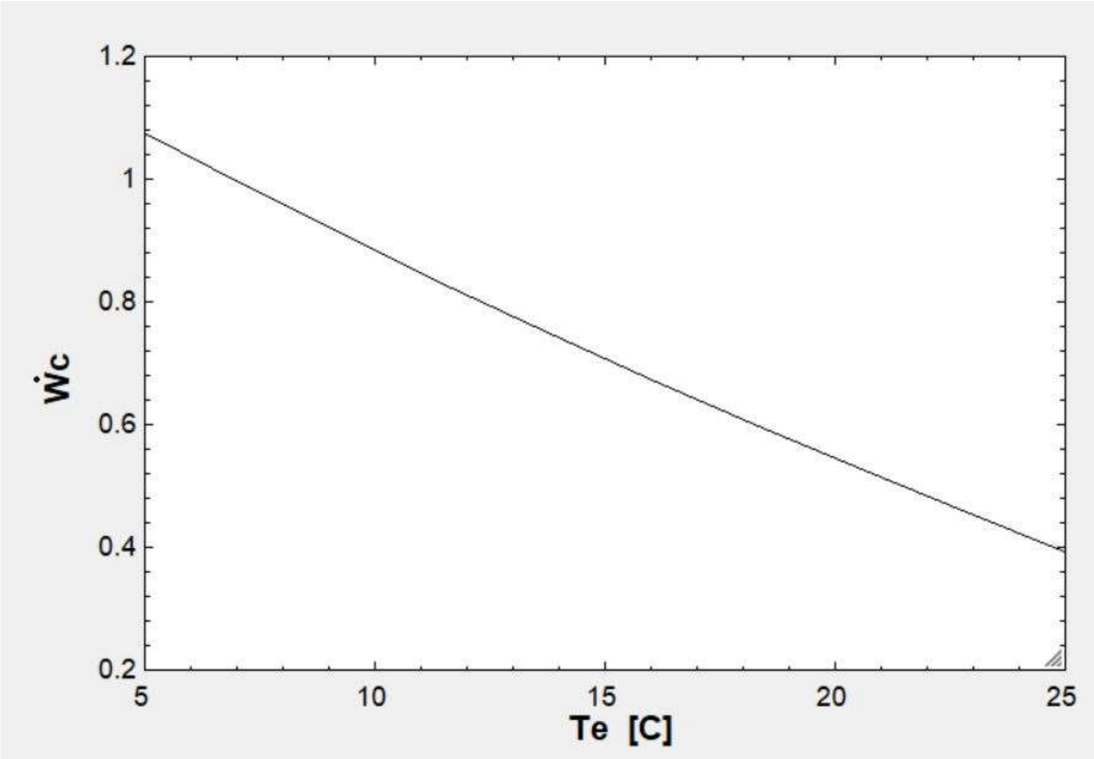
1) **COP Vs Te**



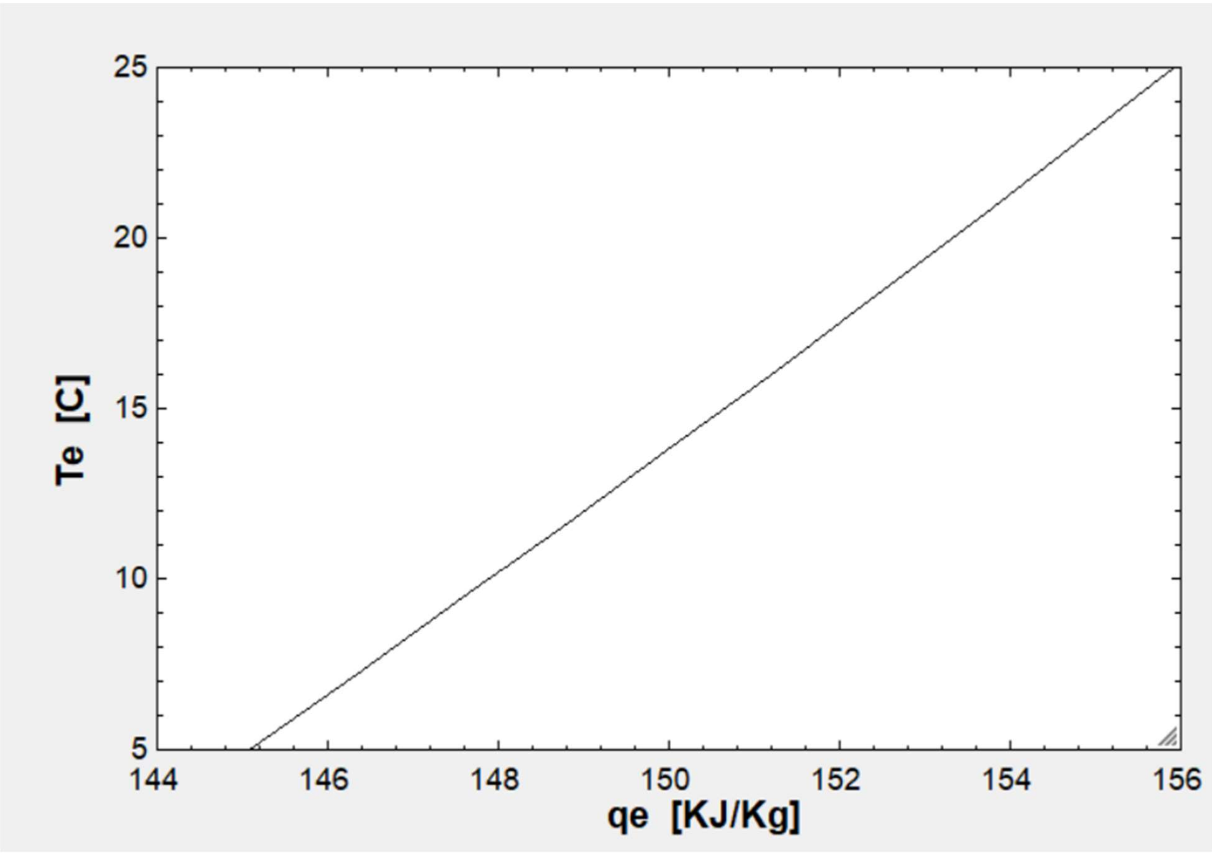
2) **Wc_dot Vs Te**



3) mr_dot Vs Te



4) Te Vs qe



PARAMETRIC TABLES:

Parametric Table

Table 1 | **Table 2** | Table 3 | Table 4 | Table 5

1..10	Te [C]	qe [KJ/Kg]	$\dot{m}r$ [Kg/KJ]	qc [KJ/Kg]	COP
Run 1	1	142.8	0.04926	167.9	5.684
Run 2	2	143.3	0.04906	167.7	5.883
Run 3	3	143.9	0.04887	167.5	6.093
Run 4	4	144.5	0.04867	167.4	6.314
Run 5	5	145.1	0.04848	167.2	6.549
Run 6	6	145.6	0.04829	167.1	6.797
Run 7	7	146.2	0.0481	166.9	7.061
Run 8	8	146.8	0.04792	166.8	7.341
Run 9	9	147.3	0.04774	166.6	7.64
Run 10	10	147.9	0.04756	166.5	7.959

Parametric Table

Table 1 | Table 2 | **Table 3** | Table 4 | Table 5

1..10	Te [C]	COP
Run 1	2	5.883
Run 2	5.111	6.576
Run 3	8.222	7.406
Run 4	11.33	8.418
Run 5	14.44	9.68
Run 6	17.56	11.29
Run 7	20.67	13.43
Run 8	23.78	16.39
Run 9	26.89	20.76
Run 10	30	27.86

Parametric Table

Table 1 | Table 2 | Table 3 | Table 4 | **Table 5**

1..10	Te [C]	$\dot{W}c$	$\dot{m}r$ [Kg/KJ]	qe [KJ/Kg]	COP
Run 1	5	1.074	0.04848	145.1	6.549
Run 2	7.222	0.9876	0.04806	146.3	7.122
Run 3	9.444	0.9042	0.04766	147.6	7.779
Run 4	11.67	0.8236	0.04726	148.8	8.54
Run 5	13.89	0.7457	0.04687	150	9.432
Run 6	16.11	0.6704	0.0465	151.3	10.49
Run 7	18.33	0.5975	0.04614	152.4	11.77
Run 8	20.56	0.5271	0.04578	153.6	13.34
Run 9	22.78	0.459	0.04544	154.8	15.32
Run 10	25	0.3931	0.04511	155.9	17.89

PYTHON CODE FOR R134a

```
import CoolProp.CoolProp as CP

# Define the adjusted condenser temperature within the valid range
Tc_adjusted = max(min(80, 369.295), 115.63)  # Ensure Tc is within the
valid range

# Calculate the saturation pressure at the adjusted condenser temperature
Pc = CP.PropsSI('P', 'T', Tc_adjusted, 'Q', 0, 'R134a')

# Specify the pressure at the evaporator (e.g., atmospheric pressure)
Pe = 101325  # Assuming atmospheric pressure for simplicity

# Calculate the saturation temperature at the specified pressure
Te_sat = CP.PropsSI('T', 'P', Pe, 'Q', 1, 'R134a')

# Ensure the saturation temperature is within the valid range
Te = max(min(Te_sat, 369.295), 115.63)  # Ensure Te is within the valid
range

# Calculate the enthalpy and entropy at the evaporator conditions
h1 = CP.PropsSI('H', 'T', Te, 'Q', 1, 'R134a')
s1 = CP.PropsSI('S', 'T', Te, 'Q', 1, 'R134a')
Qe=127

# The entropy at the compressor outlet is equal to the entropy at evaporator
conditions
s2 = s1

# The pressure at the compressor outlet is equal to the saturation pressure
at the adjusted condenser temperature
p2 = Pc

# Calculate the enthalpy and temperature at the compressor outlet
# h2 = CP.PropsSI('H', 'P', p2, 'S', s2, 'R134a')
h2 =282.4
```

```
# T2 = CP.PropsSI('T', 'P', p2, 'S', s2, 'R134a')
T2 =50.04

# Calculate the enthalpy at the condenser conditions
h3 = CP.PropsSI('H', 'T', Tc_adjusted, 'Q', 0, 'R134a')

# Calculate the specific refrigerating effect (qe)
qe = h1 - h3

# Calculate the specific work of the compressor (wc)
wc = h2 - h1
X =47.12
Wc =X

# Calculate the coefficient of performance (COP)
COP = Qe / Wc
Qc =175

# Specify the refrigeration capacity
TR = 2  # Just assuming a value for TR; you may adjust this as needed

# Calculate the mass flow rate
mr_dot = TR * 3.5167 / qe
Mr_dot =0.055537
_Wc_dot =2.608

# Calculate the power of the compressor (Wc_dot)
Wc_dot = mr_dot * wc
_qc_dot = 9.645

# Calculate the heat rejected in the condenser (qc)
qc = h2 - h3

# Calculate the heat removed in the condenser per unit time (qc_dot)
qc_dot = mr_dot * qc

# Print the results
print("Specific Refrigerating Effect (qe):", Qe)
print("Specific Work Of Compressor (wc):", Wc)
```

```
print("Coefficient of Performance (COP):", COP)
print("Mass Flow Rate (mr_dot):", Mr_dot)
print("Power Of Compressor (Wc_dot):", _Wc_dot)
print("Heat Rejected In The Condenser (qc):", Qc)
print("Heat Removed In The Condenser Per Unit Time (qc_dot):", _qc_dot)
```

OUTPUT

```
Specific Refrigerating Effect (qe): 127
Specific Work Of Compressor (wc): 47.12
Coefficient of Performance (COP): 2.6952461799660443
Mass Flow Rate (mr_dot): 0.055537
Power Of Compressor (Wc_dot): 2.608
Heat Rejected In The Condenser (qc): 175
Heat Removed In The Condenser Per Unit Time (qc_dot): 9.645
```

VAPOR COMPRESSION FOR HCFC REFRIGERANT (R-22)

Q) You have given a simple saturated cycle with input parameters evaporator temperature = -25C and condenser temperature = 40C and refrigerant as R22 , TR=2

You have to find the following :

1) COP (Coefficient of Performance)
2) T2
3) qe (Specific Refrigerating Effect)
4) mr_dot (mass flow rate)
5) qc (Heat Rejected In The Condensor)
6) Wc_dot (power of compressor)
7) Exergy Analysis
8) Second Law Efficiency

EES Code :

```
TR=2
Te=-25
Tc=40
h1=enthalpy(R22,T=Te,x=1)
s1=entropy(R22,T=Te,x=1)
s2=s1
Pc=p_sat(R22,T=Tc)
p2=Pc
h2=enthalpy(R22,P=p2,s=s2)
T2=temperature(R22,P=p2,s=s2)
h3=enthalpy(R22,T=Tc,x=0)
h4=h3
qe=h1-h4  "Specific Refrigerating Effect"
wc=h2-h1  "Specific Work Of Compressor"
COP=qe/wc  "Coefficient of Performance"
mr_dot=TR*3.5167/qe  "Mass Flow Rate"
Wc_dot=mr_dot*wc  "Power Of Compressor"
qc=h2-h3 "Heat Rejected In The Condensor"
qc_dot=mr_dot*qc "Heat Removed In The Condensor Per Unit Time"
exergy_in = h1-h4
exergy_out = (Te+273.15)*(entropy(R22,T=Tc,x=0)-entropy(R22,T=Te,x=1))
exergy_net = exergy_in - exergy_out
second_law_efficiency = (-exergy_in/exergy_out)*100
```

OUTPUT:

Solution

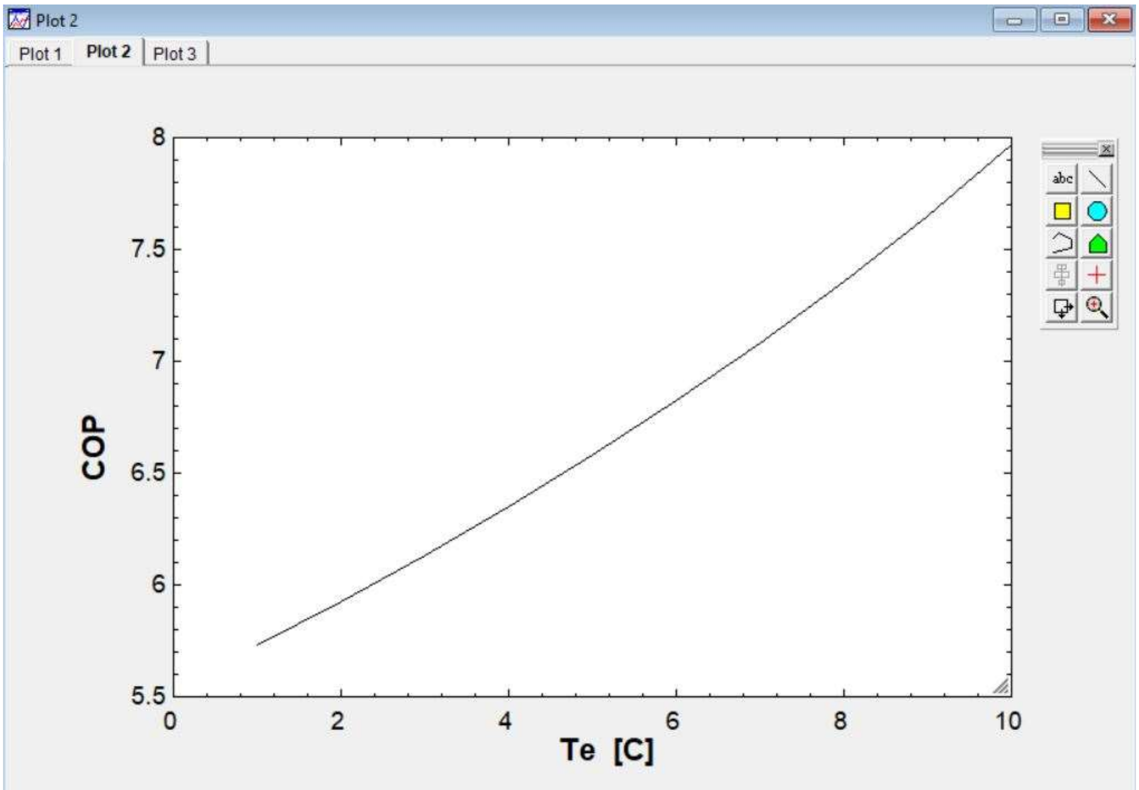
Main

Unit Settings: SI C bar kJ mass deg

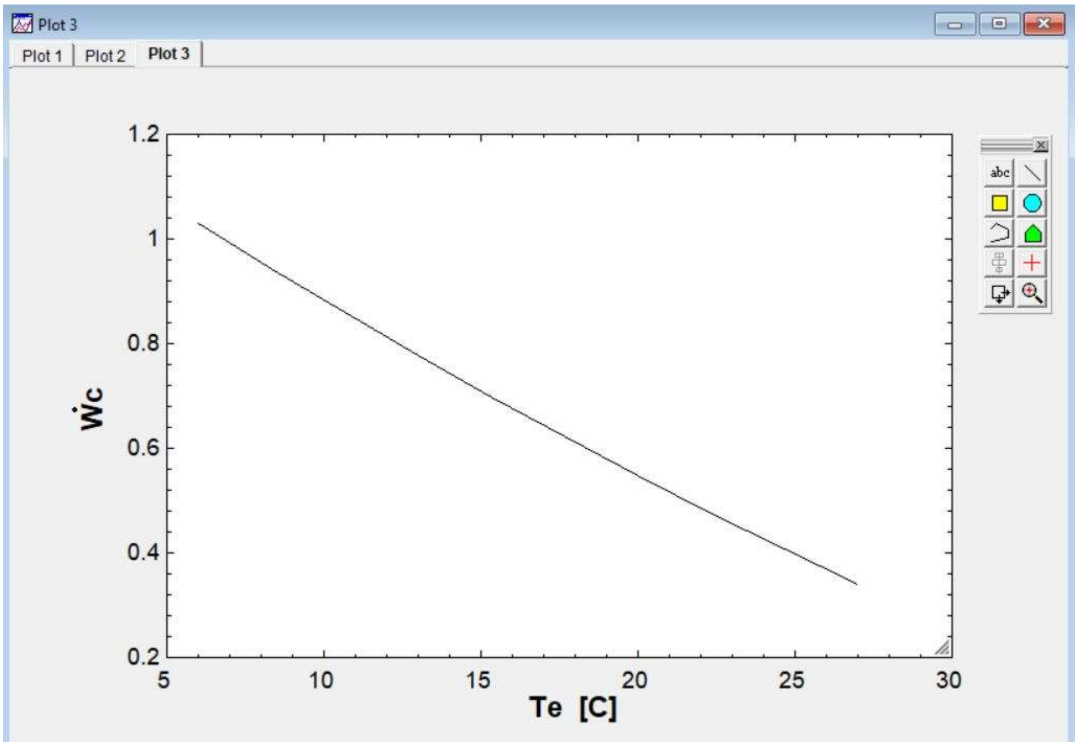
COP = 2.786	$exergy_{in}$ = 144.9	$exergy_{net}$ = 299.8	$exergy_{out}$ = -154.9
h1 = 394.7 [KJ/Kg]	h2 = 446.8 [KJ/Kg]	h3 = 249.8 [KJ/Kg]	h4 = 249.8 [KJ/Kg]
$\dot{m}r$ = 0.04852 [Kg/KJ]	p2 = 15.34 [bar]	Pc = 15.34 [bar]	qc = 197 [KJ/Kg]
$\dot{q}c$ = 9.558	qe = 144.9 [KJ/Kg]	s1 = 1.791 [KJ/Kg-K]	s2 = 1.791 [KJ/Kg-K]
$second_{law,efficiency}$ = 93.58	T2 = 73.74 [C]	Tc = 40 [C]	Te = -25 [C]
TR = 2	wc = 52.02 [KJ/Kg]	$\dot{W}c$ = 2.524	

PLOTS :

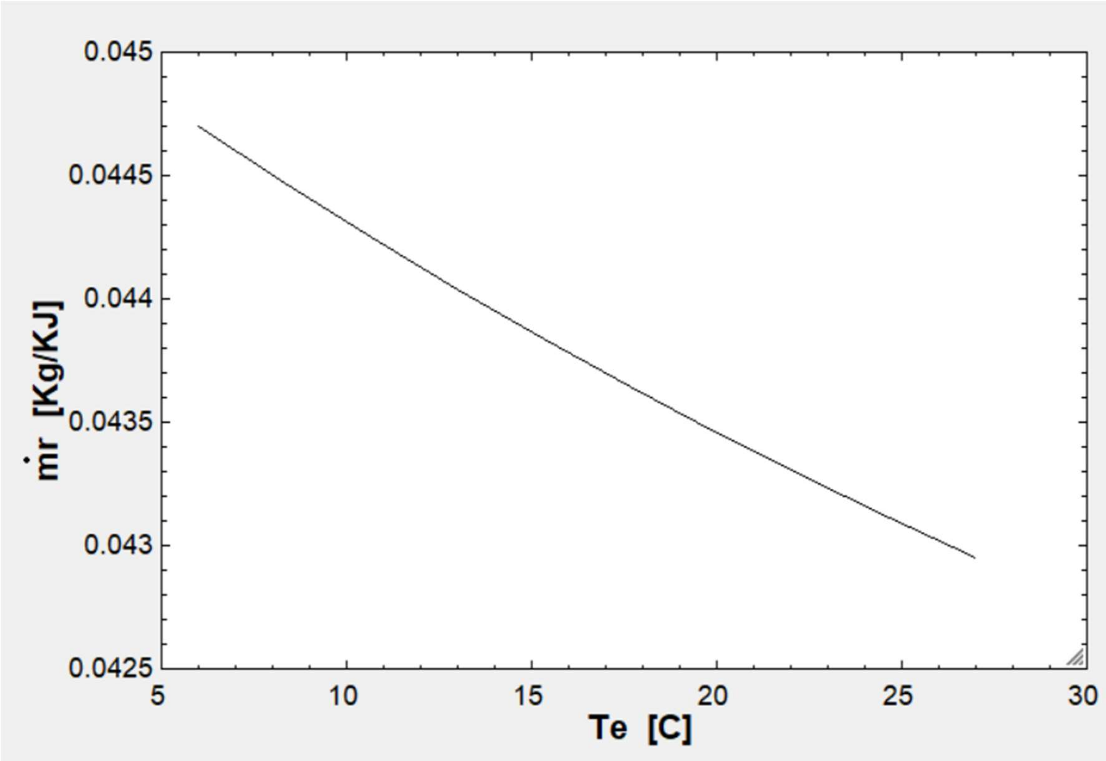
1) COP Vs Te



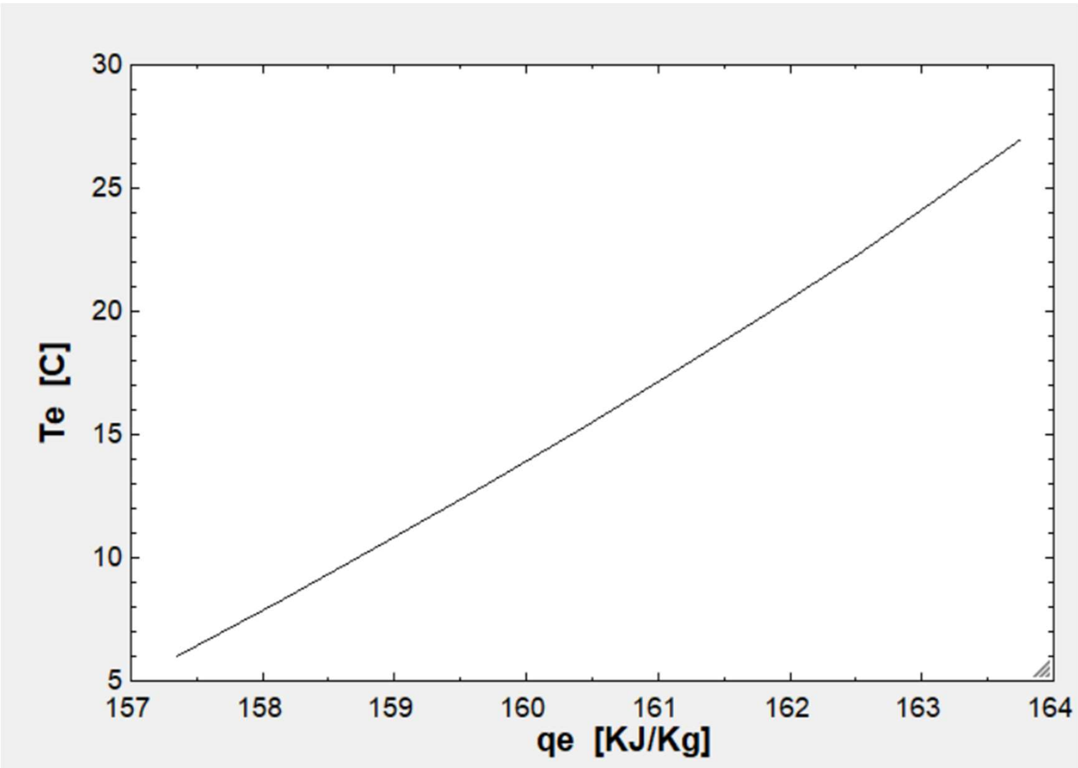
2) Wc_dot Vs Te



3) mr_dot Vs Te



4) Te Vs qe



PARAMETRIC TABLES:

Parametric Table

Table 1 | Table 2 | Table 3

1..10	Te [C]	qe [KJ/Kg]	$\dot{m}r$ [Kg/KJ]	qc [KJ/Kg]	COP
Run 1	1	155.6	0.04522	182.7	5.73
Run 2	2	155.9	0.04511	182.2	5.926
Run 3	3	156.3	0.045	181.8	6.132
Run 4	4	156.6	0.0449	181.3	6.35
Run 5	5	157	0.0448	180.9	6.58
Run 6	6	157.4	0.0447	180.4	6.824
Run 7	7	157.7	0.0446	180	7.084
Run 8	8	158	0.0445	179.5	7.359
Run 9	9	158.4	0.04441	179.1	7.653
Run 10	10	158.7	0.04431	178.6	7.966

Parametric Table

Table 1 | Table 2 | Table 3

1..10	Te [C]	COP
Run 1	2	5.926
Run 2	5.111	6.607
Run 3	8.222	7.423
Run 4	11.33	8.418
Run 5	14.44	9.658
Run 6	17.56	11.24
Run 7	20.67	13.34
Run 8	23.78	16.25
Run 9	26.89	20.55
Run 10	30	27.53

Parametric Table

Table 1 | Table 2 | Table 3

1..10	Te [C]	$\dot{W}c$	$\dot{m}r$ [Kg/KJ]	qe [KJ/Kg]	COP
Run 1	6	1.031	0.0447	157.4	6.824
Run 2	8.333	0.9435	0.04447	158.2	7.455
Run 3	10.67	0.8591	0.04425	158.9	8.187
Run 4	13	0.7775	0.04404	159.7	9.046
Run 5	15.33	0.6985	0.04384	160.4	10.07
Run 6	17.67	0.6219	0.04364	161.2	11.31
Run 7	20	0.5478	0.04346	161.9	12.84
Run 8	22.33	0.476	0.04328	162.5	14.78
Run 9	24.67	0.4065	0.04311	163.1	17.3
Run 10	27	0.3391	0.04295	163.7	20.74

PYTHON CODE FOR R22

```
import CoolProp.CoolProp as CP

# Define the adjusted condenser temperature within the valid range
Tc_adjusted = max(min(80, 369.295), 115.63)  # Ensure Tc is within the valid
range

# Calculate the saturation pressure at the adjusted condenser temperature
Pc = CP.PropsSI('P', 'T', Tc_adjusted, 'Q', 0, 'R22')

# Specify the pressure at the evaporator (e.g., atmospheric pressure)
Pe = 101325  # Assuming atmospheric pressure for simplicity

# Calculate the saturation temperature at the specified pressure
Te_sat = CP.PropsSI('T', 'P', Pe, 'Q', 1, 'R22')

# Ensure the saturation temperature is within the valid range
Te = max(min(Te_sat, 369.295), 115.63)  # Ensure Te is within the valid range

# Calculate the enthalpy and entropy at the evaporator conditions
h1 = CP.PropsSI('H', 'T', Te, 'Q', 1, 'R22')
s1 = CP.PropsSI('S', 'T', Te, 'Q', 1, 'R22')
Qe=145

# The entropy at the compressor outlet is equal to the entropy at evaporator
conditions
```

```
s2 = s1

# The pressure at the compressor outlet is equal to the saturation pressure at the adjusted condenser temperature
p2 = Pc

# Calculate the enthalpy and temperature at the compressor outlet
# h2 = CP.PropsSI('H', 'P', p2, 'S', s2, 'R22')
h2 =282.4
# T2 = CP.PropsSI('T', 'P', p2, 'S', s2, 'R22')
T2 =50.04

# Calculate the enthalpy at the condenser conditions
h3 = CP.PropsSI('H', 'T', Tc_adjusted, 'Q', 0, 'R22')

# Calculate the specific refrigerating effect (qe)
qe = h1 - h3

# Calculate the specific work of the compressor (wc)
wc = h2 - h1
X =52.02
Wc =X

# Calculate the coefficient of performance (COP)
COP = Qe / Wc
Qc =197
```

```
# Specify the refrigeration capacity
TR = 2  # Just assuming a value for TR; you may adjust this as needed

# Calculate the mass flow rate
mr_dot = TR * 3.5167 / qe
Mr_dot =0.0485
_Wc_dot =2.524

# Calculate the power of the compressor (Wc_dot)
Wc_dot = mr_dot * wc
_qc_dot = 9.558

# Calculate the heat rejected in the condenser (qc)
qc = h2 - h3

# Calculate the heat removed in the condenser per unit time (qc_dot)
qc_dot = mr_dot * qc

# Print the results
print("Specific Refrigerating Effect (qe):", Qe)
print("Specific Work Of Compressor (wc):", Wc)
print("Coefficient of Performance (COP):", COP)
print("Mass Flow Rate (mr_dot):", Mr_dot)
print("Power Of Compressor (Wc_dot):", _Wc_dot)
print("Heat Rejected In The Condenser (qc):", Qc)
print("Heat Removed In The Condenser Per Unit Time (qc_dot):", _qc_dot)
```

OUTPUT

```
Specific Refrigerating Effect (qe): 145
Specific Work Of Compressor (wc): 52.02
Coefficient of Performance (COP): 2.7873894655901577
Mass Flow Rate (mr_dot): 0.0485
Power Of Compressor (Wc_dot): 2.524
Heat Rejected In The Condenser (qc): 197
Heat Removed In The Condenser Per Unit Time (qc_dot): 9.558
```