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Comparison of Thermodynamic Analysis of Cascade Refrigeration System for Refrigerant Pairs R134a-R290 and R407c-R290

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***Abstract*- There has been plenty of research work carried out related to Comparison of Thermodynamic Analysis of Cascade Refrigeration System. However, very few studies are done on different refrigerant pairs to improve the performance of Cascade Refrigeration System. The following research is based on systematic literature review of A. D. Parekh, P. R. Tailor, Thermodynamic Analysis of Cascade Refrigeration System Using R12-R13, R290-R23 and R404A-R23, International Journal of Mechanical Engineering. The published authors have researched Thermodynamic analysis shows that out of three refrigerant pairsR12-R13, R290-R23 and R404A-R23 the COP of R290-R23refrigerant pair is highest. The authors have reviewed various journal papers and suggested to blend various pairs of refrigerant to obtain maximum COP of Cascade Refrigeration System. The review covers working principle, performance of desert cooler with respect to various position. The study focusing on to choose various pairs which has no ozone depletion potential (ODP=0) and no direct global warming potential (GWP=0) & all improve the performance of Cascade Refrigeration System. In addition, certain refrigerants pair are identified that would help researchers in future.**

INTRODUCTION

Refrigeration and air conditioning (RAC) play a very important role in modern human life for cooling and heating requirements. This area covers a wide range of applications starting from food preservation to improving the thermal and hence living standards of people.

The utilization of these equipment's in homes, buildings, vehicles and industries provides for thermal comfort in living/working environment and hence plays a very important in increased industrial production of any country. Due to the increasing demand of energy primarily for RAC & HP applications (around 26-30%) this leads to degradation of environment, global warming and depletion of ozone layer etc., to overcome these aspects there is urgent need of efficient energy utilization besides waste heat recovery for useful applications especially after the Kyoto and Montreal protocols. The scientific community is eagerly concentrating on the alternate and environment friendly refrigerants, especially after the Kyoto and the Montreal protocols. However, in a quest to find out the alternate and environment friendly refrigerants, the energy efficiency of this equipment's while using conventional refrigerants is also very important. The CFCs and HCFCs remain as refrigerant fluids of choice for various applications for many years and now non- ozone depleting HFCs became favored. The Montreal protocol banned production and consumption of ozone depleting compounds in 1987 and also accelerated the rate of phasing out of CFC and HCFC in order to reduce ozone depletion, and this was only possible by using HFCs in many applications. The Kyoto protocol laid down goals for the reduction of global warming substances in the year 1997 and subsequently the heat pump industry has consequently been forced to look for substitutes of CFCs and HCFCs.

SYSTEM MODLING

To aid in analysis of engineering problem it is necessary to realize the Physical model in a mathematical model. To do this, we first write state point equations of thermodynamic properties and then develop a polynomial for thermodynamic properties with the help of software or, directly taken from the reference. Therefore this chapter involves the description of physical model, mass, and energy balance, assumptions, state point equations and thermodynamic properties. To show the superiority of cascade system for low temperature application or to justify the utility of cascade system.

MATHEMATICAL FORMULATION

Mass balance

$$\sum_{in} \dot{m} = \sum_{out} \dot{m}$$

Energy balance:

$$\dot{Q} - \dot{w} = \Sigma_{out} \dot{m}h - \Sigma_{in} \dot{m}h$$

Exergy balance:

$$\dot{X}_{Lost} = \Sigma_{out} \left(1 - \frac{T_o}{T_i}\right) \dot{Q}_i - \dot{w} + \Sigma_{in} \dot{m}\varphi - \Sigma_{out} \dot{m}\varphi$$

Capacity of the evaporator:

$$\dot{Q}_E = \dot{m}_l (h_1 - h_4)$$

Compressor isentropic efficiency for low-temperature circuit:

$$\eta_{isen,L} = \frac{h_{2S} - h_1}{h_2 - h_1}$$

Compressor isentropic efficiency for high-temperature circuit:

$$\eta_{isen,H} = \frac{h_{6S} - h_5}{h_6 - h_5}$$

Compressor power consumption for low-temperature circuit is given as:

$$\dot{w}_l = \dot{m}_l (h_2 - h_1)$$

Compressor power consumption for high-temperature circuit is given as:

$$\dot{w}_h = \dot{m}_h (h_6 - h_5)$$

Total work done or Actual work done:

$$w_{act} = \dot{w}_h + \dot{w}_l$$

The rate of heat transfer in the cascade is determined from-:

$$\dot{Q}_{CC} = \dot{m}_l (h_2 - h_3) = \dot{m}_h (h_5 - h_8)$$

The rate of heat rejection by the air-cooled condenser is given as:

$$\dot{Q}_H = \dot{m}_h (h_6 - h_7)$$

COP compression system is given by

$$COP_L = \frac{QE_1}{WC_1} = \frac{(h_1 - h_4)}{(h_2 - h_1)}$$

$$COP_H = \frac{QE_2}{WC_2} = \frac{(h_5 - h_8)}{(h_6 - h_5)}$$

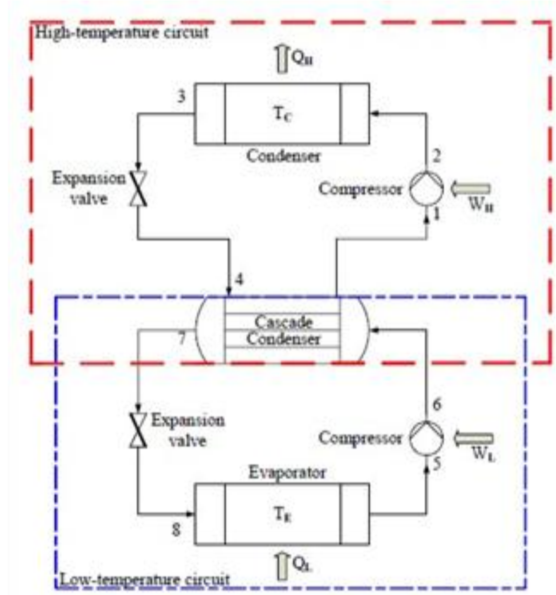
Where,

COP_L-COP of lower compression system

COP_H- COP of higher compression system

COP of the cascade system is given as

$$COP_{CAS} = \frac{QE}{WC_1 + WC_2}$$



THERMODYNAMIC ANALYSIS

The thermo-physical properties of R134a-R290and R407C-R290specified in this work were calculating using a software package called engineering equation solver (EES). A major feature of EES is the high accuracy thermodynamic and transport property database that is provided for hundreds of substances in a manner that allows it to be used with the equation solving capability. The cycle is modelled by applying mass balance and energy balance equation for each individual process of the cycle. The equations for the different component of the cascade refrigeration system are given in the previous chapter. The calculation for the two stage cascade system is initiated by assigning a temperature of (-80°C- 25°C) certain fixed values for the evaporator and condenser temperature. Subsequently, the saturation pressure, the liquid and vapour enthalpies, the entropies, specific heats are computed from EES. The evaporator is assumed to take heat from the cooling space. For this, the evaporator temperature of low temp circuit is initiated by assuming TE=-80°c and then varied as

TE=TE+5 with 50C interval, the TC= 25°c and then varied as TC=TC+5 with 5°C interval. Low temperature cycle condenser temperature (TcasL) = -5°c. Then the optimal condensing temperature has been designed.

OBJECTIVES OF STUDY

The main objective of this work is to compare the performance of two refrigerant pairs R134a-R290 and R407c-R290 in cascade system for a temperature range of -80°C to -35°C which has wide application in medical and industry fields like for precipitation hardening of special alloy steels & to freeze and store blood in blood bank.

Objectives of the present work can be listed as follows-

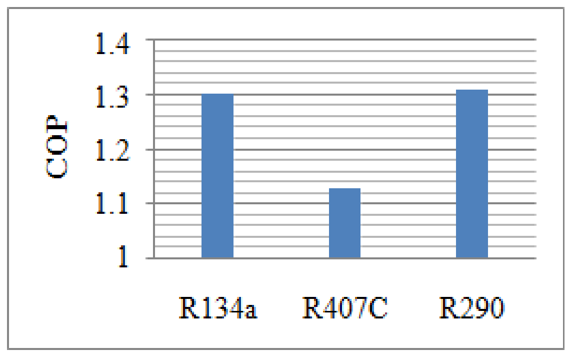
1. To study how to achieve very low temperature in the range of from -85°C to -35°C.
2. To do comparative analysis of thermodynamic performance of cascade refrigeration systems (CRSs) for refrigerant couples R134a-R290 and R407c-R290.
3. To study the effect of operating parameters on the performance of cascade refrigeration systems (CRSs)for refrigerant couples R134- R290 and R407c-R290

RESULTS & DISCUSSION

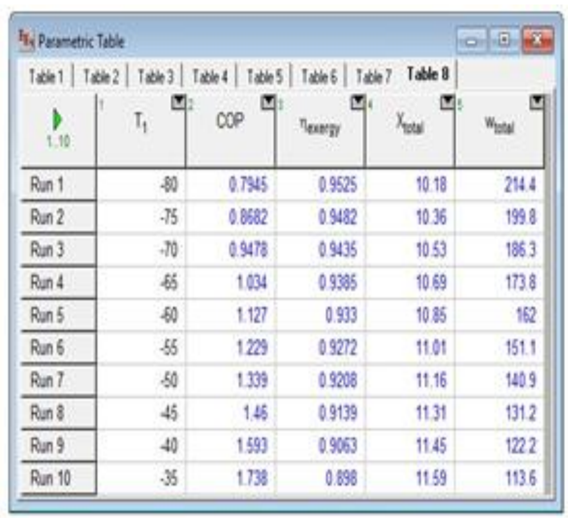
PERFORMANCE OF SINGLE STAGE VAPOUR COMPRESSION SYSTEM USING R134a, R290 and R407C

The calculation for the single stage vapour compression system is initiated by assigning a temperature of -80°c& 25°c the evaporator and condenser temperature. Subsequently, the saturation pressure, the liquid and vapour enthalpies, the entropies, specific heats are computed from EES. The evaporator is assumed to take heat from the cooling space. For this, the evaporator temperature of low temp circuit is initiated by assuming TE=-80°c and then varied as TE=TE+5 with 50C interval, the TC= 25°c and then varied as TC=TC+5 with 5°C interval. Low temperature cycle condenser temperature (TcasL) = -5°c. Then the optimal condensing temperature has been designed under different evaporating temperature corresponding to the minimum energy required. Mass flow rate of the Refrigerant through the cascade condenser (m1) and condenser (m2) are selected as 1Kg/s.

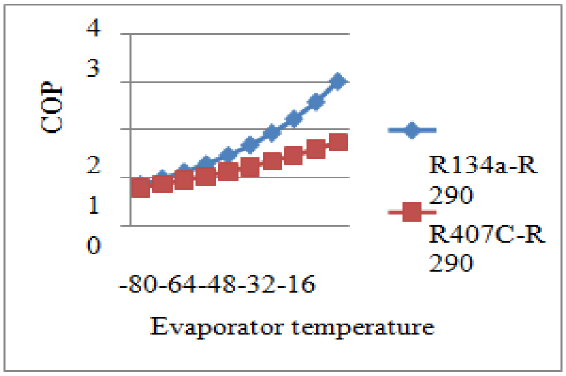
Refrigerant	COP
R134a	1.301
R407C	1.126
R290	1.311



Obtained COP with varying evaporator temperature of refrigerant pairs R134a-R290 &R407c-R290-:


Parametric Table

1..10	T_1	COP	η_{exergy}	X_{total}	W_{total}
Run 1	-80	0.7945	0.9525	10.18	214.4
Run 2	-75	0.8682	0.9482	10.36	199.8
Run 3	-70	0.9478	0.9435	10.53	186.3
Run 4	-65	1.034	0.9385	10.69	173.8
Run 5	-60	1.127	0.933	10.85	162
Run 6	-55	1.229	0.9272	11.01	151.1
Run 7	-50	1.339	0.9208	11.16	140.9
Run 8	-45	1.46	0.9139	11.31	131.2
Run 9	-40	1.593	0.9063	11.45	122.2
Run 10	-35	1.738	0.898	11.59	113.6



CONCLUSION

We have obtained some important conclusion by using pairs R134a-R290 and R407c-R290in cascade system which are listed below-:

1. It is observed that max. COP in single stage vapour compression system is achieved with R290 in the given temperature range -80°C to-35°C when using refrigerant like R134a, R407c and R290.
2. When evaporator temperature varied from -80°C to -35°C in the interval of 5°C keeping other parameters constant then we observe that-:
   - R134a-R290 pairs have higher COP than R407c-R290.
   - Exergentic efficiency is obtained maximum by using pairs R407c-R290.
3. When condenser temperature varied from 25°C to 70°C in the interval 5°C of keeping other parameters constant then we observe that -:
   - COP of R134a-R290 pairs decrease slowly than COP of R407c-R290.
   - Exergentic efficiency is obtained maximum while using R134a-R290.
4. Comparison the performance of COP of refrigerant used in present work with conventional pair i.e, R404a-R23.

FUTURE RECOMMENDATION

We will have to blend other pairs like R134a-R23 & R407C-R

REFERENCES

[1] A. D. Parekh, P. R. Tailor, Thermodynamic Analysis of Cascade Refrigeration System Using R12-R13, R290-R23 and R404A-R23, International Journal of Mechanical and Mechatronics Engineering, 8(8), 1351-1356.

[2] Kanoglu, Mehmet, Exergy analysis of multistage cascade refrigeration cycle used for natural gas liquefaction." International Journal of energy Research 26(2002): 763-74.