PERFORMANCE ANALYSIS OF VAPOUR COMPRESSION CASCADE REFRIGERATION SYSTEM USING REFRIGERANTS R404A AND R134a

Akash Shakya[1], Nadeem Faisal[2], Trilok Chauhan[2]
[1]Research Scholar Assistant Professor[2]
Department of Mechanical, ITM University, Gwalior, India

***Abstract*: This paper assign for experimental analysis of cascade refrigeration system. Cascade refrigeration system is the composition of two cycles for obtaining maximum effect of refrigeration. This system succeeds to gain temperature range up to -30^{0}C for application of cold storage and blood banks. In this system working fluids are R404A (LTC) and R134a (HTC), these specific refrigerants are used for acceptable difference in boiling point for find out sensible outcome of the system. These working fluids non-toxic to the environment and global warming potential and ozone depletion potential is minimum. The main objective of this system is designed to calculate the parameters of cascade refrigeration system like refrigerating effect, total work done, coefficient of performance, Qcascade condenser and primary condenser of the system.**

***Keywords*: Cascade refrigeration system, COP, work done, refrigerating effect GWP (global warming potential) and ODP (ozone depletion potential) etc.**

INTRODUCTION

Cascade refrigeration system produce temperature range about (-30^{0}C to -40^{0}C) Cascade refrigeration system working on two cycle first one is the low temperature cycle and second one is the high temperature cycle these cycle thermally combine to the heat exchanger. This heat exchanger also called the cascade condenser in this system two refrigerant pair is used having different boiling point and freezing point. The high temperature refrigerant uses as NH_3 or R22 and low temperature refrigerant uses as CO_2 ethylene, methane etc. cascade refrigeration first used in 1877 by Pictet for liquefaction of O_2, SO_2 and CO_2 as in-between refrigerants and another frequently used for liquefaction of the gases is three stage cascade refrigeration system as ammonia, ethylene and methane. Ammonia is used in high temperature cascade system for construct of solid carbon dioxide. The advantages of cascade refrigeration system in oil from one compressor to other compressor cannot admiration its generally happens in the multistage cascade refrigeration system. [1]

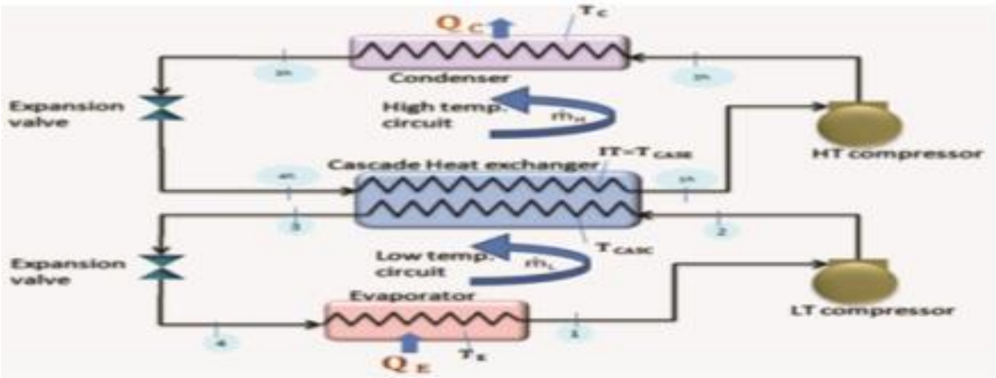


Fig-1: Line diagram of cascade refrigeration system

A D Parekh et al. [1] has been designed the condenser for the cascade refrigeration system to operate eco-friendly refrigerant pair R (404) A-R (508) A this refrigerant pair have zero ozone utilization likely and minimum global warming effect. The main objective of this model to find out heat transfer coefficient of both condensers. It is initiate that heat transfer are both condenser reduce temperature difference of cascade condenser and are large expand.

Ashutosh Mate et al. [5] this paper has been assigned for to study of cascade refrigeration system. Cascade refrigeration system is the integration of two refrigeration cycles. This system is thermally combined to the evaporator of high temperature cycle and condenser of the low temperature cycle. This system generally designed to achieve temperature range up to -20^{0}C for the examination like cold storage, medical science in blood banks and other freezing system.

Carlos Sanz-Kock et al. [11] has been experimental analysis of cascade refrigeration plant by using refrigerant pair R134a/CO_2 and design this model for the low temperature evaporation in enterprise refrigeration applications. In experimental analysis evaporating temperature varies up to from range about -40^{0}C to -30^{0}C and condensing temperature varies up to from range 30^{0}C to 50^{0}C.

Gulshan Sachdeva et al. [7] have been designed a model cascade refrigeration system on the basis of vapour compression cycle. In this study we uses working fluid in low temperature cycle in carbon dioxide (R744), ammonia (R717), propane(R290), propylene(R1270), R(404)A and High temperature cycle in we use the R12 refrigerant. After that we comparing the performance of the curve of ammonia, propane, propylene and R404A with R12 and we find out ammonia is the best in comparing to the R12.

H.M Getu et al. [3] have been designed cascade refrigeration system to modified the design and control all parameters of the system. . temperature difference of cascade heat exchanger and evaporating, superheating, condensing and sub cooling in the carbon dioxide R(744)A at low temperature cycle. This model operated -50^{0}C (evaporating) and 40^{0}C (condensing) temperature. It was show COP_{max} for ethanol followed by the R (717) A and low for R (404) A for same conditions.

Hansaem Park et al. [14] has been determine the optimal intermediate temperature of cascade refrigeration by using of R134a and R410A we have to find out R134a uses of a condensing temperature and R410A use as evaporating temperature. When R134a condensing temperature is enlarging the optimal intermediate temperature is also overhead and in case maximum COP is reduces.

J. Alberto Dopazo et al. [13] has been designed a cascade refrigeration system we used CO_2 and NH_3 as a working fluids at the low temperature cycle and high temperature cycle this system has been design to calculate the COP of the system. In this system we find out the COP enlarge 70%, when temperature of carbon dioxide in evaporator temperature change from range about -55^{0}C to -30^{0}C in case COP is always enlarges. The COP enlarges 45% and temperature of ammonia in condenser change from range about 25^{0}C to 50^{0}C

J. S. Jadhav et al. [9] has been designed of a cascade refrigeration system with using different refrigerant pairs and thermodynamic parameters R744 is used at low temperature cycle and R134A, R290, R717 are used at high temperature cycle. cascade refrigeration working fluid pairs R744-R717 has the maximum COP. The COP of the R744-R717 system expands from 1.236 to 2.08 at LTC evaporator temperature range diverse from -55^{0}C to -30^{0}C and other parameter are constant.

M. Raja et al. [6] have been investigation on cascade refrigeration system. This model generally designed to use of concept with and without phase change material. In cascade refrigeration system low temperature obtained by vapour compression refrigeration system. In this system ethylene glycol use as a phase change material PCM can be stored cooling for long time and remove the heat from refrigerated area.

Nasruddin et al. [8] in this study we have designed the cascade refrigeration system using a mixture of refrigerants name implies that carbon dioxide and hydrocarbons (propane ethane or ethylene) as the refrigerant at low temperature cycle. To solved the effectiveness limit of carbon dioxide, connected to the triple point of CO_2 was mixed with hydrocarbons and the recommendation value of carbon dioxide is 37% and ethylene 63% the calculated value of the cascade system reached approximately 0.65

ROLE OF REFRIGERANTS

Impact of refrigerant plays very important role in the outcome and efficiency of the cascade system. In today's large no. of different refrigerants are available. While selection of refrigerants many important properties are observed such as boiling point, freezing point, molecular weight, critical temperature, critical pressure, critical volume etc. Now industries are focused on natural refrigerant due to the properties like minimum GWP and ODP non toxic to the environment refrigerants like CO2 (R744) and NH3 (R717) are highly considering for the compression of refrigerant CO2 (R744) required high pressure range up to 10Mpa and temperature rating leads to super critical pressure as the temperature are increases in case pressure also increases due to the specific volume of compressor also increases and reducing volumetric efficiency of compressor and it obvious the reduction of mass inside of the compression cycle due to the temperature increases which is further leads to low process of pressure and the other hand refrigerants like R22 and R134a having a low critical pressure (722Kpa and 590Kpa respectively) as comparing to the CO2 and NH3 So this help construct a compact system and also increase efficiency of the compressor.[2]

EXPERIMENTAL METHODOLOGY

After the prepared of final setup, we have used following methodology for experiments perform are as:

Fig- Experimental setup

a) First, established set up at top floor of Kirlosker block in RAC lab at ITM University Gwalior(m.p).

b) Took seven reading in a single day at every regular interval of time period from 10am to 11am.

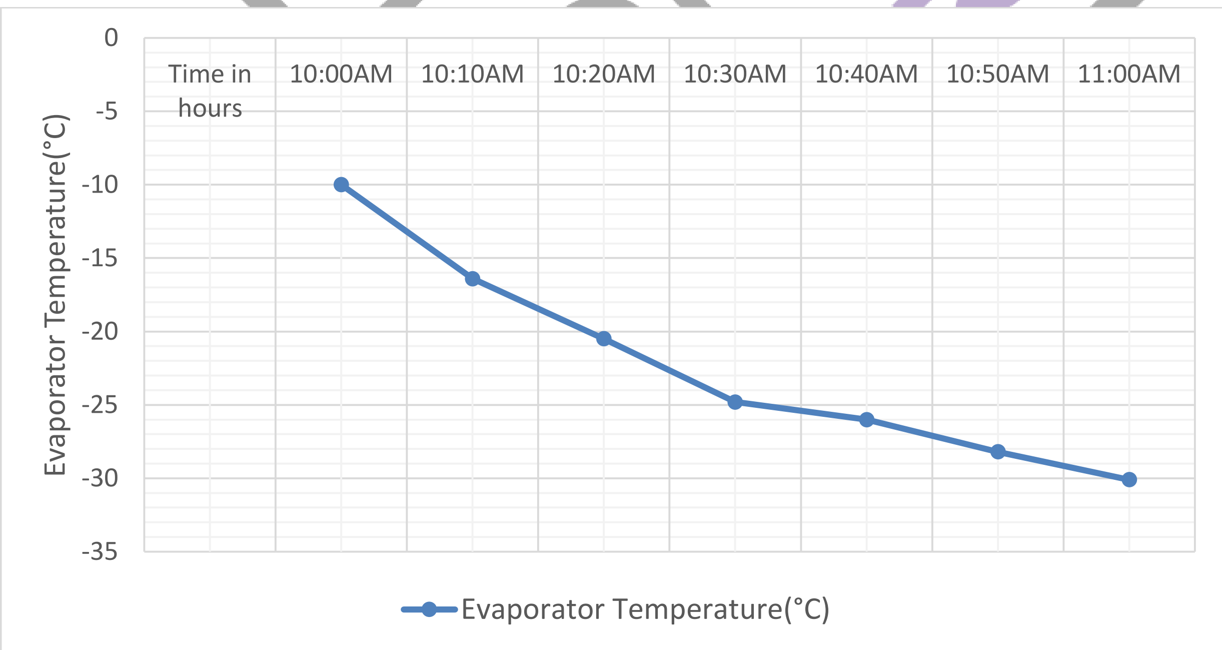
c) First we have measure temperature reading with the help of thermocouple.

d) Reading measure at inlet and outlet temperature of system all component.

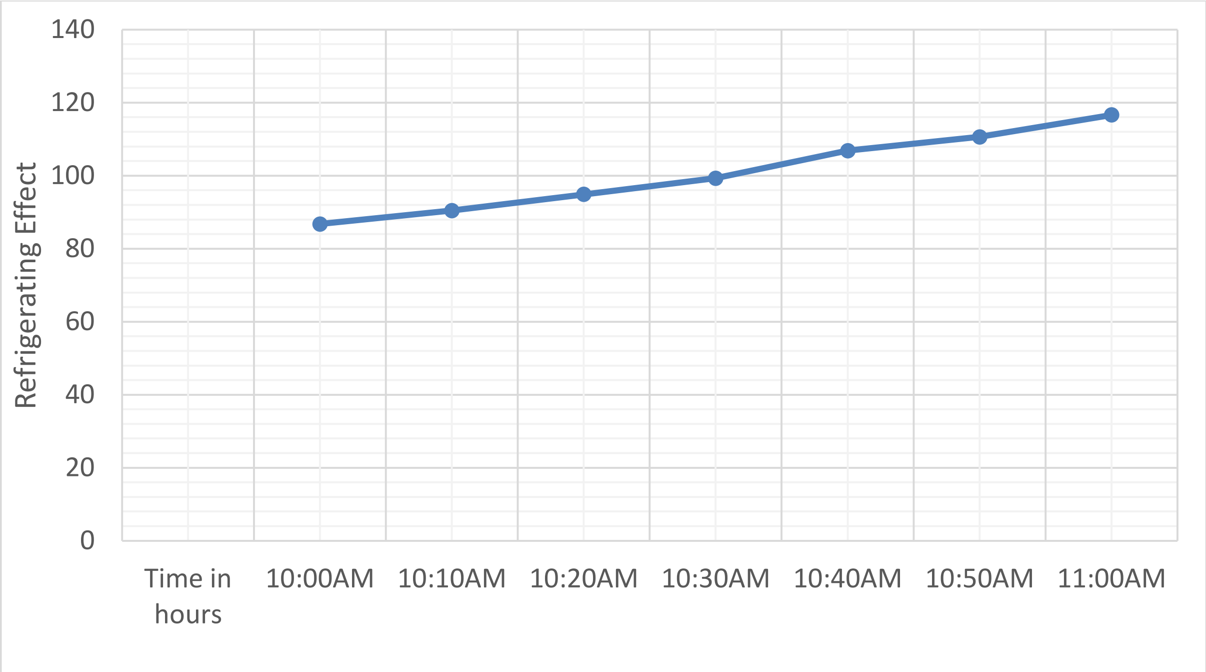
e) After we have calculated enthalpy at each temperature with the help of Ts diagram of cascade refrigeration.

f) After that we have calculated different parameter of the system as(refrigerating effect, total work done coefficient of performance, Qcascade condenser and Qprimary condenser).

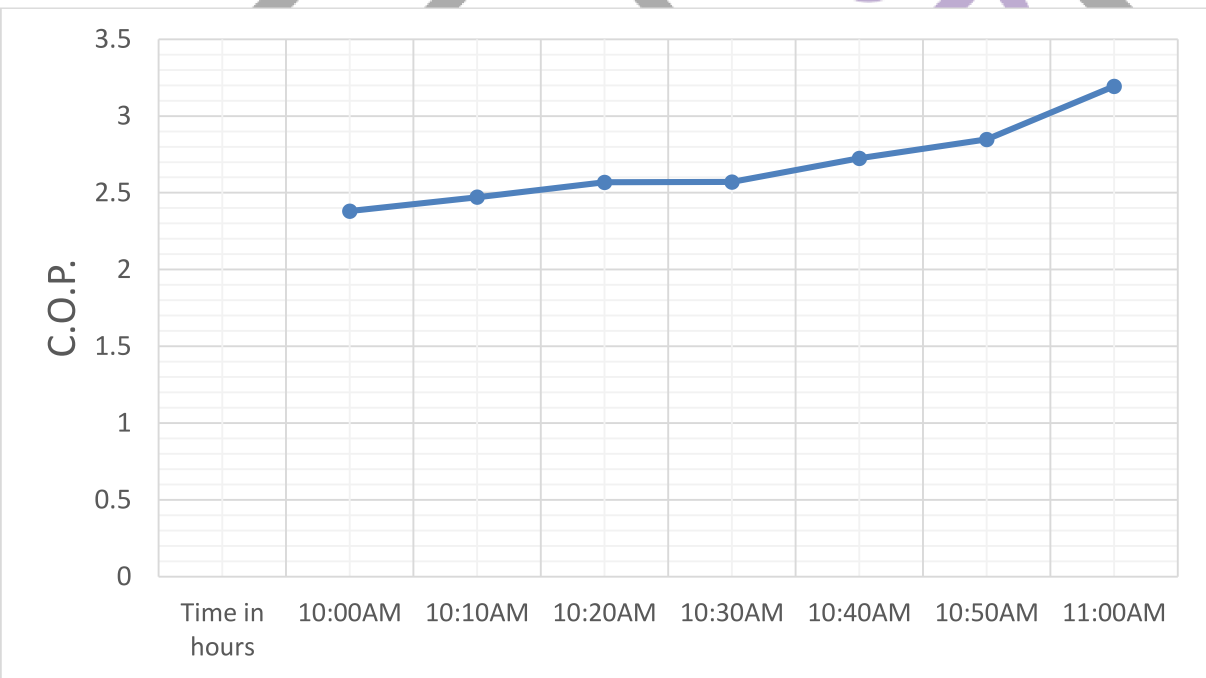
Variation of evaporator temperature with respect to time



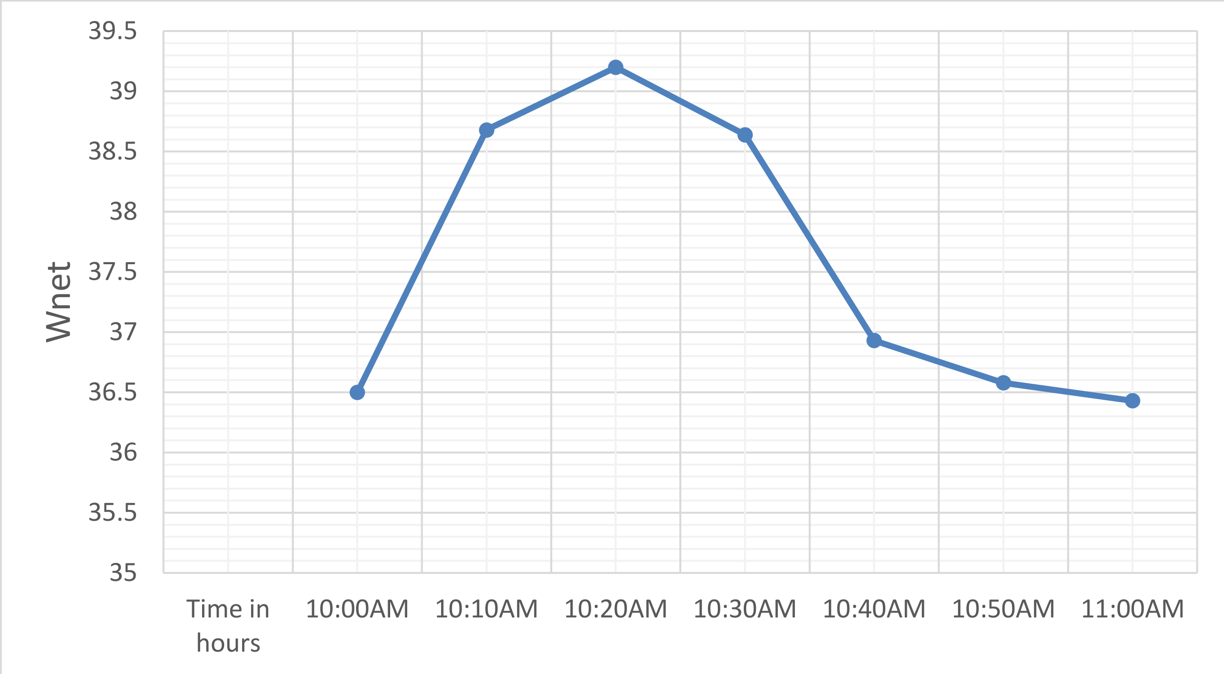
Variation of Refrigerating effect with respect to time



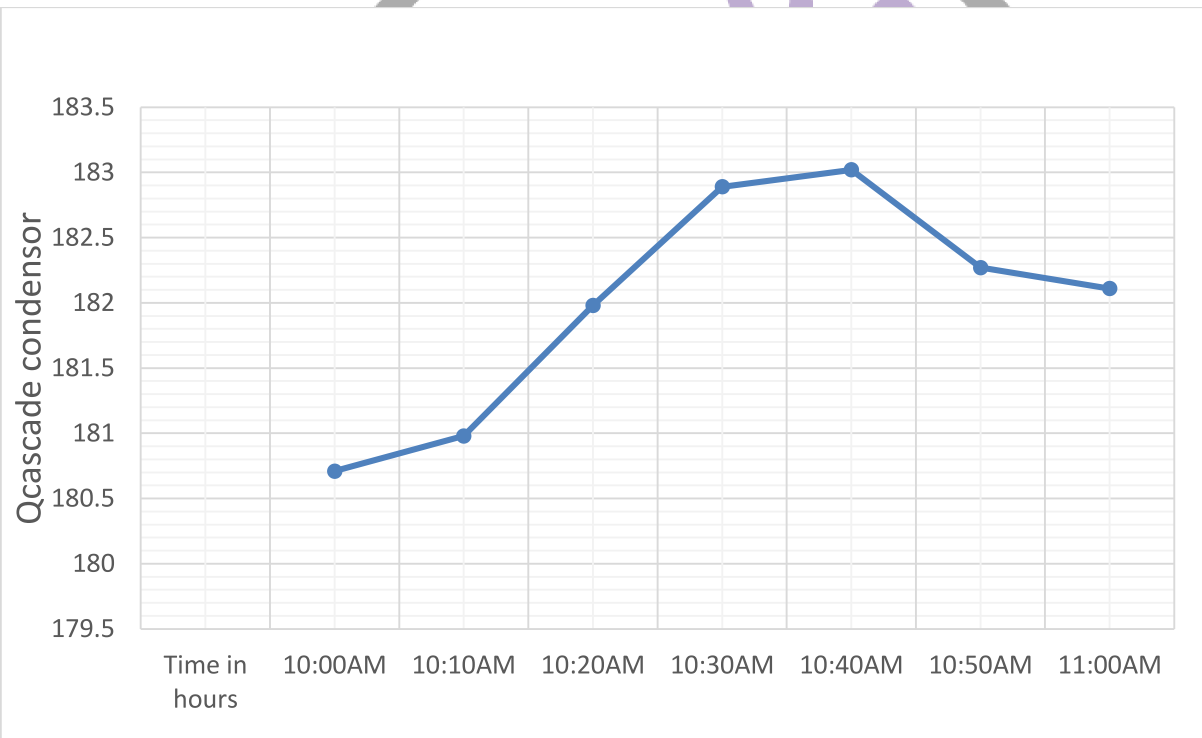
Variation of coeffiecient of performance with respect to time



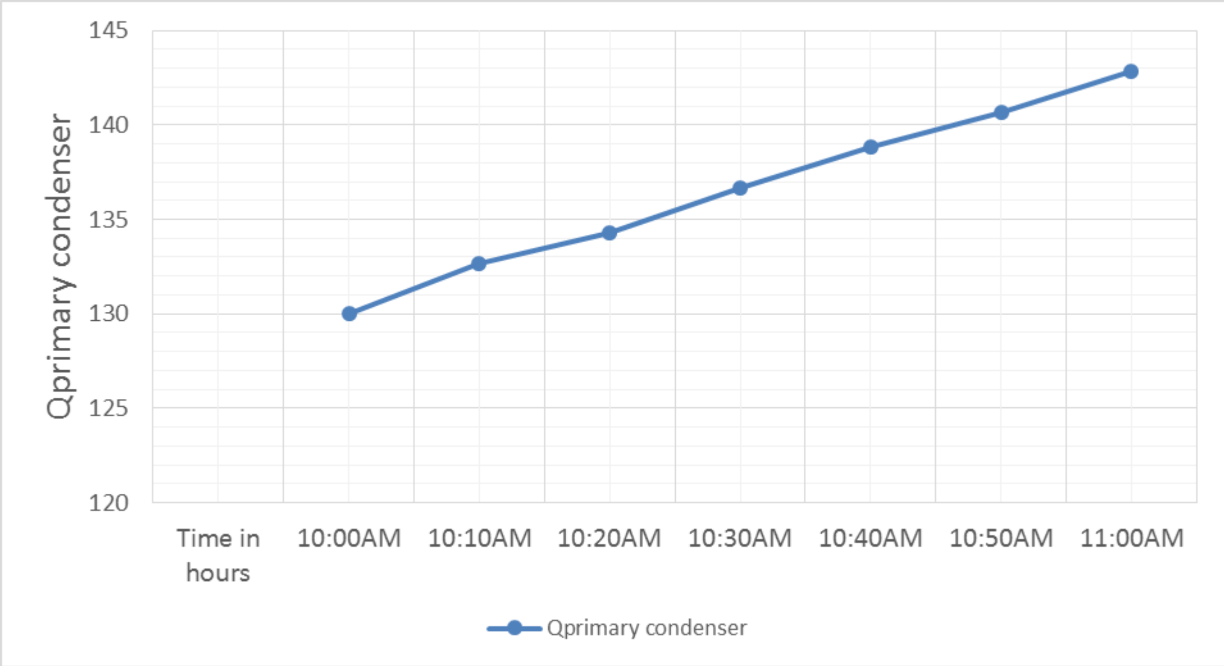
Variation of total work done of with respect to time



Variation of Qcascade condenser of with respect to time



Variation of Qcascade condenser of with respect to time



RESULTS & DISCUSSION

After conducting the experiments, the following conclusions are found at constant temperature

We have found out the ultra low temperature of main evaporator = -30°C

We have find out the refrigerating effect=116.2 kj/kg

Total work done of the system=36.43 kj/kg

Coefficient of performance=3.194

Qcascade condenser=181.41 kj/kg

Qprimary condenser=142.86 kj/kg

CONCLUSION

The simulation of R404Aa-R134a cascade refrigeration system is carried out. Analysis of this cascade refrigeration system is carried out by using Ts diagram of cascade refrigeration system and the result from the following equation states that COP of this system increases with the increasing LTC evaporator temperature while decreases with increase in HTC evaporator temperature. Components used in this system which can be affordable for low cost of industrial application total cost of this system was ₹27000 only. Particular system is design to reduce the work done and achieve maximum refrigeration effect in minimum work done by the system.

FUTURE SCOPE

Cascade refrigeration system may be used in liquefaction of gas and industrial purpose of freezing system in use of research for future work we used new arrival refrigerant HCF Oily fin R1234YF in market this refrigerant non-toxic to the environment global warming potential and ozone depletion potential is very less.

REFERENCES

[1] C.P ARORA “Refrigeration and air conditioning” third Edition ISBN-13:978-93-5134-016-4.

[2] A. D. Parekh, P. R. Tailor, H.R Jivanramajiwala “Optimization of R507A-R23 Cascade Refrigeration System using Genetic Algorithm” International Journal of Mechanical and Mechatronics Engineering Vol:4, No:10, 2010.

[3] Ashutosh Mate, Prayag Panhale, Vandana shinde, Pritesh Mane “System Design And Development Of Cascade Refrigeration” volume: 04 Issue: 06 June -2017 International Research Journal of Engineering and Technology (IRJET).

[4] Carlos Sanz-Kock, Rodrigo Llopis, Daniel S anchez a "Experimental evaluation of a R134a/CO2 cascade refrigeration plant" Elsevier Applied Thermal Engineering 73 (2014) 39e48.

[5] Gulshan Sachdeva, Vaibhav Jain, S. S. Kachhwaha "Performance Study of Cascade Refrigeration System Using Alternative Refrigerants" International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:8, No:3, 2014.

[6] H.M. Getu, P.K. Bansal "Thermodynamic analysis of an R744–R717 cascade refrigeration system" Elsevier. international journal of refrigeration 31 (2008) 45–54.

[7]. Hansaem Park, Dong Ho Kim, Min Soo Kim has done "Thermodynamic analysis of cascade refrigeration system for optimal intermediate temperatures in R134aeR410A" Applied Thermal Engineering 54 (2013) 319-327.

[8] J.S.Jadhav, A.D.Apte "Review on cascade refrigeration system with different refrigerant pairs" International journal of innovations in engineering research and technology [IJIERT] ISSN: 2394-3696 VOLUME 2, ISSUE 6, june-2015.

[9] J. Alberto Dopazo, José Fernández-Seara , Jaime Sieres, Francisco J. Uhía "Theoretical analysis of a CO2–NH3 cascade refrigeration system for cooling applications at low temperatures" Elsevier Applied Thermal Engineering 29 (2009) 1577–1583.

[10] M.Raja, G. Maruthi Prasad Yadav "Experimental Investigation on Cascade Refrigeration System with And without Phase Change Material" International Journal of Scientific Research Engineering & Technology (IJSRET), ISSN 2278 – 0882 Volume 4, Issue 2, February 2015.

[11] Nasruddin, Arnas, Ahmad Faqih , and Niccolo Giannetti "Thermoeconomic Optimization of Cascade Refrigeration System Using Mixed Carbon Dioxide and Hydrocarbons at Low Temperature Circuit" Makara J. Technol. 20/3 (2016), 132-138 doi: 10.7454/mst.v20i3.3068.