Asian Journal of Engineering and Applied Technology
ISSN: 2249-068X (P) Vol. 5 No. 2, 2016, pp.36-39

DOI: https://doi.org/10.51983/ajeat-2016.5.2.801

A Review of Vapour Compression Cascade Refrigeration System

Umesh C. Rajmane
Asst. Professor, Mechanical Engineering Department, Sanjay Bhokare Group of Institutes, Miraj, Maharashtra, India.
E-mail: rajmaneumesh@gmail.com

(Received 20 August 2016; Revised 6 September 2016; Accepted 24 September 2016; Available online 30 September 2016)

***Abstract* - Different types of refrigerant are available for cascade refrigeration technologies. this paper study provides the advantages of vapour compression cascade refrigeration system. And also summaries various techniques used in cascade refrigeration system. The operating parameters considered in this study include condensing, sub cooling, evaporating and super heating temperatures in high-temperature circuit, and temperature difference in the cascade heat exchanger, evaporating, superheating, condensing and sub cooling in the low-temperature circuit.**

***Keywords:* cascade refrigeration system, absorption, vapour compression system**

INTRODUCTION

This study deals with cascade refrigeration system for low temperature application. Refrigerant have been used in all refrigeration applications due to their favorable thermodynamic properties. Many industrial applications requires low temperature refrigeration such as quick freezing, biomedical preservations, manufacturing of dry ice, liquefaction of petroleum vapours, pharmaceutical reactions etc. where evaporating temperature requires between - 40ºC to-70ºC.Condensing temperature is governed by temperature of cooling tower .Water which is about 35ºC. Thus, system has to work for wide range of temperature. Single stage vapour compression system is not feasible for such application and its performance decreases below -35 ºC. Multistage or compound systems can be useful but no refrigerants available to work efficiently for high temperature. Also, Very few refrigerants are suitable to use upto -70 to -80 ºC.

II. DESCRIPTION OF THE CASCADE REFRIGERATION SYSTEM

A cascade system consists of two or three separate simple cycles operating in conjunction with each other at different temperature levels. The connecting point is a heat exchanger between the stages. This interstate heat exchanger is the condenser for the first stage and the evaporator for the second stage .Beginning with the low pressure cycle, the vapour from the evaporator is compressed in the stage compressor and goes to the interstate heat exchanger where it gives up it's heat to the second evaporator coil. The condensed liquid then flows to the first stage expansion valve and the evaporator, competing the low pressure cycle. The vapour which is generated in the coil of heat exchanger, due to the heat it had absorbed and compressed in the second and pass through the cooling chamber. The figure 1 shows two stage cascade refrigeration system.

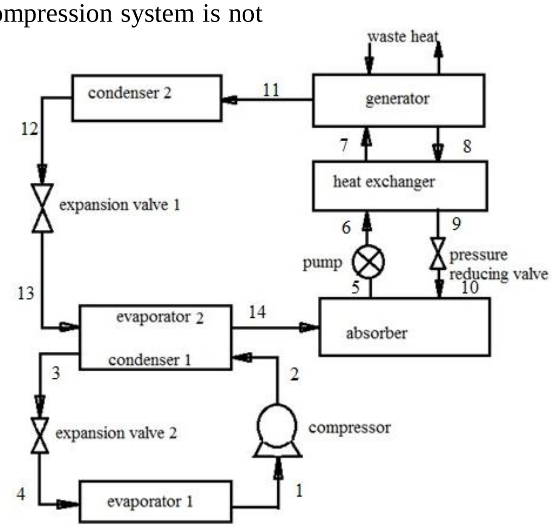

Fig. 1 Two stage cascade refrigeration system

Stepwise process of cascade refrigeration system
Process 1-2: Isentropic compression of saturated vapour in compressor
Process 2-3: Isobaric heat rejection in condenser
Process 3-4: Isenthalpic expansion of saturated liquid in expansion device
Process 4-1: Isobaric heat extraction in the evaporator

For absorption system
Process 5-6: Pump work
Process 6-7: heat supplied to heat exchanger
Process 13-14: Heat absorbed in evaporator
Process 11-12: Heat rejected in condenser
Process 14-5: Heat rejected in the absorber
Process 11-7,:Heat rejected in the generator from the source

III. LITERATURE RIVIEW

Prasanna et.al. [1] studied comparison of synthetic and natural refrigerants in cascade refrigeration system for low temperature application. Synthetic refrigerants have been used in all refrigeration applications due to their favorable thermodynamic properties. CFCs are phased out; HCFCs are scheduled to phase out following to Montreal protocol and its subsequent amendments. Thus, natural refrigerants being eco-friendly are reviewed as alternative to synthetic refrigerants. And also Theoretical analyzed and comparison of various refrigerant pairs such as R507-R23,R717-R23, R290-N2O, R717- N_2O. System performance is estimated with variation in evaporating, condensing temperature, isentropic efficiency of compressor, temperature overlap in cascade condenser. Results shows that, COP of the system with R717-N_2O is higher than other pairs and it can be used as alternative refrigerant for low temperature application in cascade refrigeration system.

Mishra [2] work carried out critical issue in the field of green technologies is to develop the relationship between ODP and GWP and suggest new and alternative refrigerants which do not damage ozone layer and not to increase global warming. The Numerical computation have been carried out using first and second law thermodynamic analysis (i.e. Energy and Exergy Analysis) of two and three stages cascade vapor refrigeration system of 10 ton capacity for seven eco-friendly refrigerants such as R-1234yf and R-1234ze in high temperature circuit, and R134a , R-404a, R-407C, R-502, propane(R-290), isobutene(R-600a), butane (R-600)) in lower temperature circuit in two stage and above refrigerants in intermediate circuit in three stage system. The performance parameters such as COP, EDR, exegetic efficiency, have been predicted.

Dr. Nimai et.al. [3] concluded preserving food products in the cold storage, good quality of food can be supplied throughout the year, minimizing the damage and enhancing the agricultural economy. Huge amount of electric energy is required to run a cold storage. Minimizing the use of electrical energy or proper utilization of electrical energy and thus by enhancing the COP would definitely be the major factor for sustainability of the cold storage and the decrease of the price of preserving the food in it. Theoretical modeling of solar-assisted cascade refrigeration system in cold storage is studied in this work. The system consists of electricity-driven vapor compression refrigeration system and solar-driven vapor absorption refrigeration system. The vapor compression refrigeration system is connected in series with vapor absorption refrigeration system. The results shows higher COP as compared with the conventional vapor compression refrigeration system. COP of this type refrigeration system increases as sunlight becomes intense.

Parmar et.al. [4]studied thermodynamic analysis of eco-friendly/natural fluids used in cascade refrigeration systems. Supermarket is a large grocery store which stores the all frozen product and chilled product in different cold temperature condition. According to the Montreal protocol and Kyoto protocol underlined the need of substitution of CFC's and HCFC's due to their adverse impact on atmospheric ozone layer which protects earth from U.V rays. HFC refrigerants which are harmless to ozone layer. Natural refrigerants are used in refrigerating system due to have low ODP and GWP in nature. A Thermodynamic analysis of a cascade refrigeration cycle with different refrigerant pair is presented in this paper. R744 is used in Low-temperature cycle whereas R134a, R290, R717 and R404a (R125 (44%)/R143a (52%)/R134a (4%)) are used in the High-temperature cycle. Effect of various operating parameters i.e. evaporator temperature, condenser temperature, temperature difference in cascade condenser and low temperature cycle condenser temperature on performance parameters viz. COP and refrigerant mass flow ratio have been studied. Thermodynamic analysis shows that out of all refrigerant pairs, the COP of R744-R717 refrigerant pair is highest as compared to other cascade refrigerant pairs and also most promising pairs for supermarket application.

M. Idrus Alhamid et.al. [5] studied Global warming is a very pertinent issue these days because the effects of extreme climate change are becoming quite apparent. Therefore, the first problem to address is the formation of strict regulations regarding emissions into the air. The main emissions to tackle are CFC and HCFC refrigerants. Conventional cascade refrigeration systems until now have been dependent on refrigerants and it is time to find a substitute that is environmentally friendly. This study builds a prototype cascade refrigeration machine using the environmentally friendly hydrocarbon refrigerants (propane, ethane and CO). Resulting from this research, the characteristics of the pressure and temperature of each component and the COP value at low temperature circuit of load variations using an electric heater at 90 W, 120 W and 150 W result in a COP value of 0.35, 0.48 and 0.60 respectively.

Lima et.al. [6] presented a thermodynamic analysis of a cascade refrigeration system using the refrigerant R22 as the working fluid in the high temperature circuit (HT) and the refrigerant R404a as the working fluid in the low temperature circuit (LT). The present analysis aimed to obtain the condensing temperature of the LT that provides an optimal value for the coefficient of performance (COP) of the cycle. Parameters involved in the analysis included the evaporation temperature, the condensing temperature and the difference between the condensing temperature of the LT (T)and evaporation temperature of the HT (TE_HT) – ΔT. Simulations were performed using the software EES (Engineering Equation Solver). In addition to the analysis, experimental data obtained from a prototype was compared with the simulated results which showed good agreement. The COP varies with the increase in the intermediate temperature; however this variation does not exceed 1 %.

Winkler et.al.[7] discussed on a cascade system simulation algorithm and implemented with the help of a component-based modeling tool for vapor compression systems. The low temperature and high temperature vapor compression systems consisted of multiple compressors and the high temperature system utilized two condensers. The simulation tool, despite using simple heat exchanger models, predicted the COP with an average error of 4.4% and a maximum error of 11.3%.

Gami et.al. [8] reported a thermodynamic energy and exergy analysis cascade refrigeration system using refrigerants pairs R134a R23and R290-R23 is presented in this paper to optimize the operating parameters of the system. The results show that COP and exergetic efficiency decreases when degree of superheating increases in LT system and increases when degree of superheating increases in HT system and remain constant when degree of superheating increases in HT and LT system . The results show that COP and exergetic efficiency increases when degree of sub cooling increases in all three cases as discussed above.

Messineo et.al.[9] the thermodynamic analysis of a cascade refrigeration system working at TE=-35^{o}c and TC= 35^{o}c is reported. In particular, six different refrigerants were analyzed in the HTC, of which three were natural refrigerants (R717, R290 and R600), and three were synthetic refrigerants (R404A, R410A and R134a). In the Low temperature circuit, carbon dioxide was considered exclusively. In conclusion, the results obtained show that a cascade refrigeration system using natural refrigerants is an interesting alternative to systems using synthetic refrigerants for energetic, security and environmental reasons.

Messineo [10] presented a thermodynamic analysis of a cascade refrigeration system using as refrigerant carbon dioxide in low-temperature circuit and ammonia in high-temperature circuit. The operating parameters considered in this paper include condensing, evaporating, superheating and sub cooling temperatures in the ammonia (R717) high temperature circuit and in the carbon dioxide(R744) low-temperature circuit. Diagrams of COP versus operating parameters have been obtained. In addition, values for R744-R717 cascade refrigeration system are compared with the values obtained for a partial injection two-stage refrigeration system using the synthetic refrigerant R404A, a nearly azeotropic blend, specially used for commercial refrigeration. Results show that a carbon dioxide-ammonia cascade refrigeration system is an interesting alternative toR404A two-stage refrigeration system for low evaporating temperatures (–30°C÷ –50°C) in commercial refrigeration for energy, security and environmental reasons.

Rawat et.al. [11] developed thermodynamic model and also used Engineering Equation Solver software, for cascade refrigeration system using NH in high temperature circuit (HTC) and CO in low temperature circuit (LTC). Thermodynamic analysis of cascade refrigeration system has been carried out at different operating conditions to know the effect of various designs and operating parameters on the performance of the cycle. The design and operating parameters include: condenser temperature; evaporator temperature; coupling temperature; compressor isentropic efficiency; and temperature difference in cascade heat exchanger. Furthermore cascade refrigeration system, with internal heat exchanger, without internal heat exchanger and with different degree of sub cooling and superheating in both circuits are compared regarding COP. Results show that use of internal heat exchanger has undesirable effect on the performance of the R744-R717 cascade system. Therefore it is advisable that, internal heat exchanger should be never used for this pair of refrigerants in cascade system. However, degree of sub cooling always desirable in R744-R717 cascade system.

Dopazo et.al. [12] analyzed of the parameters of design and operation of a CO cascade cooling system and their influence over the system's COP and exergetic efficiency is reported. The analysis was carried out based on a general mathematical model. The system's COP and it's exergetic efficiency can be expressed as a function of six design/operating parameters. A statistical procedure has been used to analyse the parametric study results obtained. The analysis reveals that all the evaluated parameters have a statistically significant effect.

IV. CONCLUSION

The various refrigerant pairs are compared with operating parameters to check alternatives for synthetic refrigerants in cascade refrigeration system. R717-N_2O pair has the maximum COP for variation of all parameters considered and R507A-R23 has lowest COP among refrigerant pairs considered.

REFERENCES

[1] Prasanna Songire, Kundalik V. Mali, "Comparative Assessment of Alternative Refrigerants in Cascade Refrigeration System". ISSN (Print): 2319-3182, Volume -4, Issue-2, 2015 .

[2] R. S. Mishra , "Thermodynamic analysis of three stages cascade vapour Compression refrigeration system for biomedical applications", Journal of Multi Disciplinary Engineering Technologies Volume 7 No.1 Jan. 2013

[3] Dr. Nimai Mukhopadhyay, ER. Someshwar Chowdhury Performance Analysis of Solar Assisted Cascade Refrigeration System of Cold Storage System, IJAREEIE Vol. 2, Issue 4, April 2013

[4] Gajendrasinh G. Parmar, Dr. R. G. KapadiaThermodynamic Analysis of Cascade Refrigeration System using a Natural

Refrigerants for Supermarket Application,ijirset Vol. 4, Special Issue 6, May 2015

[5] M.Idrus Alhamid,Nasruddin, Darwin R.B.S., Arnas Lubis, “Characteristics And Cop Cascade Refrigeration System Using hydrocarbon Refrigerant (Propane, Ethane And Co) At Low Temperature Circuit (Ltc) International Journal of Technology (2013) 2: 112-120 ISSN 2086-9614

[6] C. U. S. Lima, J. J. Fiori, and V. Silveira Junior, “Theoretic-Experimental Evaluation Of A Cascade Refrigeration System For Low Temperature Applications Using The Pair R22/R404A”, Engenharia Térmica (Thermal Engineering), Vol. 11 • No. 1-2 • June and December 2012 • p. 07-14

[7] Winkler, J., Aute, V., and Radermacher, R. “Simulation and Validation of a R404A/CO2 Cascade Refrigeration System”, International Refrigeration and Air Conditioning Conference at Purdue, July 14-17, 2008.

[8] Heena M. Gami, Mohammad Azim Aijaz, “Thermodynamic analysis of cascade refrigeration system using refrigerants pairs R134a-R23 and R290-R23”, International Journal of Engineering Sciences & Research Technology3(4): April, 2014 ISSN: 2277-9655.

[9] Antonio Messineo, Domenico Panno, “Performance Evaluation Of Cascade Refrigeration Systems Using Different Refrigerants”, International Journal of Air-Conditioning and Refrigeration Vol. 20, No. 3 (2012) 1250010.

[10] Antonio Messineo, “R744-R717 Cascade Refrigeration System: Performance Evaluation compared with a HFC Two-Stage System”, Article in Energy Procedia December 2012 DOI:10.1016/j.egypro.2011.12.896.

[11] K.S. Rawat, R. Kshetri, H. Khulve, A.K. Pratihar, “Parametric Study of R744-R717 Cascade Refrigeration System”,IJREST, VOLUME-2, ISSUE-7, JULY-2015

[12] J. Alberto Dopazo, Jos_e Fern_andez-Seara, Jaime Sieres, Francisco J. Uhia, “Theoretical analysis of a CO-NH cascade refrigeration system for cooling applications at low-temperatures”, Applied Thermal Engineering(2008) 10.1016/j.applthermaleng.2008.07.006.