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"THERMAL PERFORMANCE ANALYSIS OF CRS (CASCADE REFRIGERATION SYSTEM) OPERATED BY VARIOUS REFRIGERANTS"

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ABSTRACT

Low temperature Cascade Refrigeration Systems (CRS) are used when the temperature that has to be maintained by the refrigeration system is very low. When a single stage vapour compression system or a vapour absorption system are unable to achieve very low temperatures, a low temperature CRS is utilized. Successful design of CRS mainly depends upon the selection of refrigerants for both temperature circuits: high temperature circuit &low temperature circuit. The main objective of my research work is to compare different CRS using refrigerant pairs R12-R13, R290-R23, & R404A-R23. Thermal performance analysis is carried out by developing computational model in Engineering Equation solver (EES). The impact of different operational factors, such as evaporator and condenser temperatures on performance measures such as COP, exergetic efficiency, as well as refrigerant mass flow ratio has been investigated. Thermodynamic research reveals that the R290-R23 refrigerant pair has the greatest COP among the three refrigerant pairings R12-R13, R290-R23, & R404A-R23.

KEYWORDS: CRS, EES, COP, THERMAL PERFORMANCE.

INTRODUCTION

Energy usage as well as the detrimental impact of refrigerants on the climate is major challenges in refrigeration systems that must be addressed [1]. The type of refrigerant utilized has an impact on the system's performance. Changing the refrigerant causes the refrigerant compressor to do different compression work [2]. The Montreal Protocol & Kyoto Protocol both emphasized the need of replacing CFCs & HCFCs due to their negative influence on the ozone layer, which shields the planet from ultraviolet radiation. A great deal of study is being done to evaluate the performance of CRS that use alternative refrigerants.

CRS:

A cascade refrigeration system (CRS) is made up of two single-stage refrigeration systems that are controlled separately. A lower system that provides a refrigeration effect by maintaining a lower evaporating temperature & a higher system that functions at a greater evaporation temperature. Single-stage vapor compression refrigeration cycles are unsuitable for some industrial applications that demand relatively low temperatures with a significant temperature and pressure difference. In such instances, one approach is to execute refrigeration in two or more stages that run in parallel. Cascade Refrigeration System (CRS) are the name for these refrigeration cycles. As a result, cascade systems are used to achieve high-temperature divergences between both the heat source and the heat sink, with temperatures ranging from 70°C to -100°C. Because refrigerants have difficulty reaching their freezing temperatures, the usage of a three-stage vapour compression refrigeration system for evaporating temperatures below 70°C is limited.

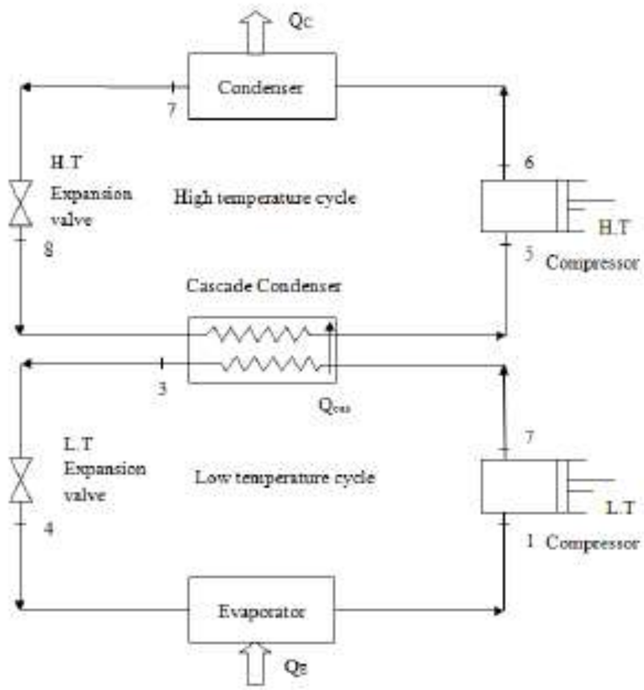

FIG. 1 CRS

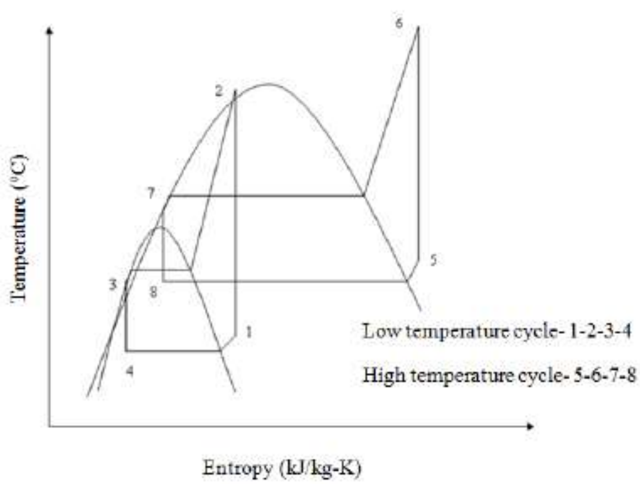

FIG. 2 T-S DIAGRAM OF CRS

The low temp cycle refrigerant is compressed isentropic ally during procedure 1-2. It next goes via a cascade condenser, where it transfers heat to a higher-temperature-cycle refrigerant (process 2-3). It expands at the throttling mechanism (process 3-4) before continuing to the evaporator (process 4-1) to achieve the required refrigerating effect. The refrigerant enters the compressor in a high-temperature cycle compressor (process 5-6) at the higher stages, and then it passes through a condenser, which rejects heat (process 6-7). It expand isentropic ally in the throttle device (process 7-8) before continuing to the cascade condenser, where heat is transferred between two refrigerants.

LITERATURE REVIEW

***REVIEW OF PAST STUDIES*:**

HÜSAMETTIN TAN & ALI ERİŞEN (2022) [1] review, a CRS involving gas and fume pressure cycles working at super low temperature was planned. In the thermodynamic examinations, R744, R404A, and R410A refrigerants in the high temperature cycle (HTC), and R1150, R170, and R23 in the low temperature cycle (LTC) were utilized. Thermodynamic examinations were done utilizing the Engineering Equation Solver bundle program. Yields considered were: System performance (COP), pressure proportion, mass stream proportion and HTC course outlet temperature. Results show that, at various LTC condenser temperature values, R404A/R23 has the most noteworthy COP esteem, in the LTC, R23 has the most noteworthy pressure proportion, while R1150 has the least one, in the HTC, R404A has the most noteworthy pressure proportion, while R744 has the most minimal one, the exhibition of the framework expanded with the reduction of the mass stream proportion.

ALKHULAIFI, Y. M. et.al (2022) [2] proposed a novel and proficient CRS for concurrent age of significant freshwater and cooling impact. The framework doesn't need committed parts for desalinating seawater since it is a result of the proposed CRS. Using the course setup upgrades energy productivity by bringing down the pressure work while further developing energy recuperation by using the hotness dismissed from the condenser of low-temperature cycle to disintegrate seawater for desalination in the evaporator of the great temperature pattern of the proposed course framework. A numerical model of the imaginative framework in view of thermodynamic and monetary standards has been created and used to foresee the proposed framework's warm exhibition and cost-investment funds. A thorough investigation has been directed to concentrate on the impact of different boundaries, for example, the evaporator, condenser, and salt water bubbling temperatures. The really concentrated on boundaries were COP, GOR, freshwater creation, and absolute expense reserve funds. For a 10 tons of refrigeration (TR) unit, the freshwater creation was somewhere in the range of 56.11 and 73.36 kg/h, with cost-reserve funds coming to 2226 US$/year. It was observed that the freshwater creation expanded with condenser and brackish water bubbling temperature however diminished with evaporator temperature. The COP improvement can be however much 26% over the reference cooling framework without desalination.

VICTOR ADEBAYO Et al. (2020) [3] analyzed four different refrigerant sets for CRS in regard of its COP, exergetic productivity, TEWI values. Four distinct refrigerant pair mixes are NH_3-CO_2, R134A-CO_2, HFE7000-CO_2 and HFE7100-CO_2 .COP, exergetic proficiency, Total blower work, energy productivity are investigated for various upsides of evaporator temperature, condenser temperature, heat exchanger adequacy. He compared different refrigerant sets in regard of ODP and GWP values. Greatest worth of COP achieved by NH_3-CO_2 pair which is 1.398 and least worth of COP accomplished by HFE7100-CO_2 pair which is1.221.NH_3-CO_2 pair having most extreme in general execution contrasted with different sets. Based on outcome, HFE 7000 is an elective substitute for R134A, which is a most encouraging eco agreeable refrigerant.

SHYAM AGARWAL Et al. (2020) [4] dissected the CRS three phase system. In assimilation, LiBr-h_2o is chosen and in pressure, R1234yf is chosen. EES programming is utilized for thermodynamic investigation. LiBr - h_2o is a characteristic refrigerant and R1234yf is an eco agreeable refrigerant. COP, Exergetic effectiveness, complete exergetic misfortune are determined for various upsides of evaporator temperature, safeguard temperature, generator temperature. Triple impact CRS having better execution as contrast with others.

YOUSUF ALHENDAL Et al. (2020) [5] read up utilized for figure out the best elective refrigerant for auto A.C. system which one is eco amicable. This study assist us with figuring out option of R134A.Three likely substitutes of R134A are R152A,R1234YF and R1234ze(E).Exergy investigation and energy examination is done for wide scope of condenser temperature ,evaporator temperature and for stream pace of refrigerant. R1234ze (E) shows best execution among these three refrigerants. It is additionally a best eco amicable refrigerant among all.

K.LOGESH Et al. (2019) [6] thermodynamically investigated different refrigerant matches: (a)R170-R404A(b)R23-R410A(c)R23-R134A(d)R404A-R508B(e)R23-R290(f)R23-R404A(g)R23-R407C(h)R134A-R508B(i)R290-R508B(J)R404A-R508B(k)R407C-R508B(l)R410A-R508B (m)R134A-R170. Execution of these refrigerant sets is checked for various working circumstances like TE lies between (- 700C)- (- 500C),TC lies between (300C)- (500C),superheating and sub cooling temperature are 100C and 50C. Result shows that COP is most extreme for R170-R404A and least for R404A-R508B. Most minimal mass stream rate for R134A-R170.

SOUVIK BHATTACHARYYA Et al. (2007) [7] investigated of an end reversible two-stage cascade cycle has been carried out and ideal middle of the road temperature for most extreme exergy & refrigeration impact have been acquired scientifically. Further, the hotness repository temperatures have been streamlined autonomously. A far reaching mathematical model of a transcritical CO_2-

C_3H_8 cascade refrigeration system was created with expectation to confirm the hypothetical outcomes. It is seen that the reproduction results concur well for ideal TL however go astray unobtrusively from the hypothetical ideal of TH. It has additionally been seen that system execution improves as TH increments and not at all like hypothetical expectations, no ideal TH is available inside achievable working temperatures

H.M. GETU AND P.K. BANSAL (2008) [8] conveyed Thermodynamic examination of a R744-R717 cascade Refrigeration system, they showed that an expansion in gathering temperature brought about a diminishing in COP & an expansion in refrigerant mass stream proportions. An expansion in dissipating temperature expanded COP of the framework & diminished mass stream proportions. An expansion in temperature contrast in cascade condenser decreased both COP & mass stream proportions.

J. ALBERTO DOPAZO et al.(2009) [9] conveyed Theoretical investigation of a CO_2-NH_3 CRS for cooling applications at low temperatures; they inferred that COP increments 70% when the TE fluctuates from - 55°C to - 30°C. The COP decreases 45% when the TC increments from 25°C to 50°C. The framework COP decreases 9% when DTCC fluctuates from 3°C to 6°C. The exergetic effectiveness diminishes 45% & 9% with the increments demonstrated above in TC and DTCC.

D. PYASI AND R. C. GUPTA (2011) [10] conveyed work on Performance investigation of R404A-R508b Cascade Refrigeration cycle for low temperature, they reasoned that System COP & Exergetic effectiveness gets expanded by 0.88 to 1.19 & 0.60 to 0.626 as the evaporator temperature is fluctuated from - 900C to-700C while different boundaries are kept consistent, The framework COP diminishes by 1.06 to 0.61 & exergetic productivity disintegrates by 0.65 to 0.43 when condenser temperature of high stage is shifted from 30°C to 50°C keeping other boundary steady, System COP falls apart by 0.95 to 0.84 and Exergy by 0.60 to 0.53 when temperature distinction of course condenser is changed from 2°C to 10°C. Mass stream proportion is diminished from 1.84 to 1.34)when low stage condenser temperature is fluctuated from - 45°C to - 20°C keeping different other boundary consistent.

ASSUMPTIONS IN MATHEMATICAL MODELING

The following general assumptions guided the thermodynamic study of the two-stage CRS:

1. In the pipe, there is no significant pressure or heat losses or gains, components of a system or networks.

2. T0=25°C & P0=1 atm are the dead states.

3. Energetic & possible energy changes are negligible.

4. In expansion valves, there is isenthalpic expansion of refrigerants.

MATHEMATICAL CORELATIONS

a. The equation RE is used to calculate the evaporator's capacity:

$$RE = m_L(h_1 - h_4)$$

b. Equation W_H is used to compute the amount of power utilised by the HT cycle compressor:

$$W_H = m_H(h_6 - h_5)$$

c. The equation W_L is used to compute the amount of power consumed by the LT compressor:

$$W_L = m_L(h_2 - h_1)$$

d. The equation Q_{CAS} is used to determine the heat exchanged by refrigerants in a cascade condenser.

$$Q_{cas} = m_L(h_2 - h_3) = m_H(h_5 - h_8)$$

e. The equation m_H / m_L is used to compute the refrigerant mass flow ratio:

$$\frac{m_H}{m_L} = \frac{(h_2 - h_3)}{(h_3 - h_8)}$$

f.. Heat rejected by condenser calculated by the equation Q_C:

$$Q_C = m_H(h_6 - h_7)$$

g. Equation COP is used to obtain the system's performance coefficient:

$$COP = \frac{Q_E}{W_L+W_H}$$

h. This equation is used to calculate the system's energetic efficiency.

$$\eta_{exe} = \frac{W_{rev}}{W_{act}}$$

i. The equation W_{rev} calculates the system's reversible work input.

$$W_{rev}= m_L(h_1 - h_4) \left[\frac{T_0}{T_1} - 1\right]$$

These equations are used to simulate the thermodynamics of a CRS.

RESULTS AND DISCUSSIONS

In EES, a computational model was created to determine the influence of different design and operational factors on the performance characteristics, which include the COP, exergetic efficiency, & refrigerant mass flow ratio. This section lists the many operational parameters that are modified throughout thermodynamic analysis & their influence on the performance parameter.

The variable parameters are discussed here.

1. The temperature of the evaporator (TE) ranged from -80°C to -60°C.

2. The temperature of the condenser (TC) ranged from 25°C to 45°C.

A.. **EVAPORATOR TEMPERATURE (TE) EFFECT:**

The impact on COP, exergetic efficiency, as well as refrigerant mass flow ratio when evaporator temperature increased from -80°C to -60°C in 5°C increments while other parameters remained constant is illustrated in Figs. 3 a, b, & c. The pressure rate increased as the evaporator temperature falls at a particular condensing temperature.

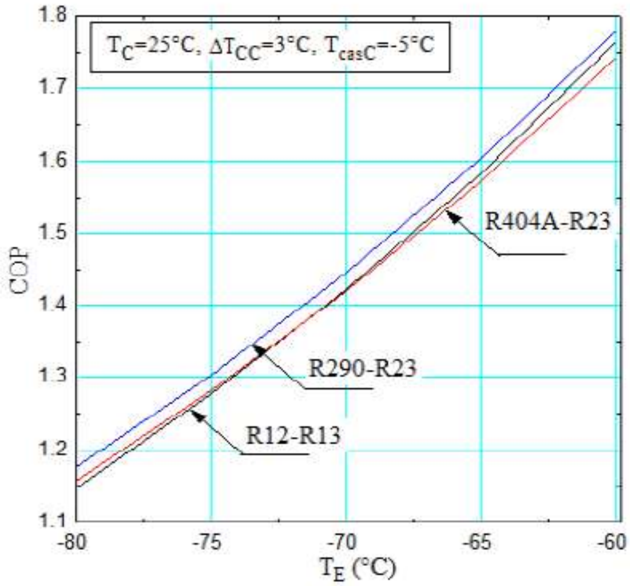

FIG3.a EFFECT OF T_E ON COP

FIG. 3 .a illustrates that as the evaporator temperature rises, so does the COP. For R12-R13, R290-R23, and R404A-R23, the COP ranges from 1.147 to 1.764, 1.176 to 1.779, and 1.158 to 1.743, respectively. R12-R13 has the greatest COP change of any of the three pairs, following by R290-R23 & R404A-R23.

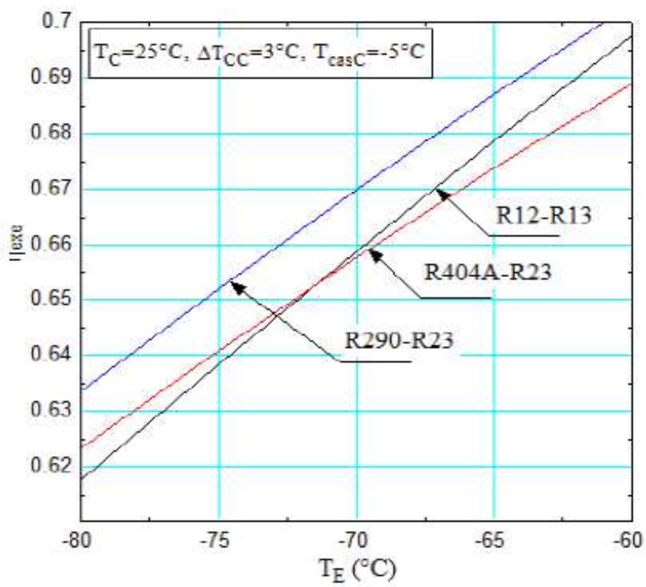

FIG3.b EFFECT OF T_E ON EXERGETIC EFFFIENCY

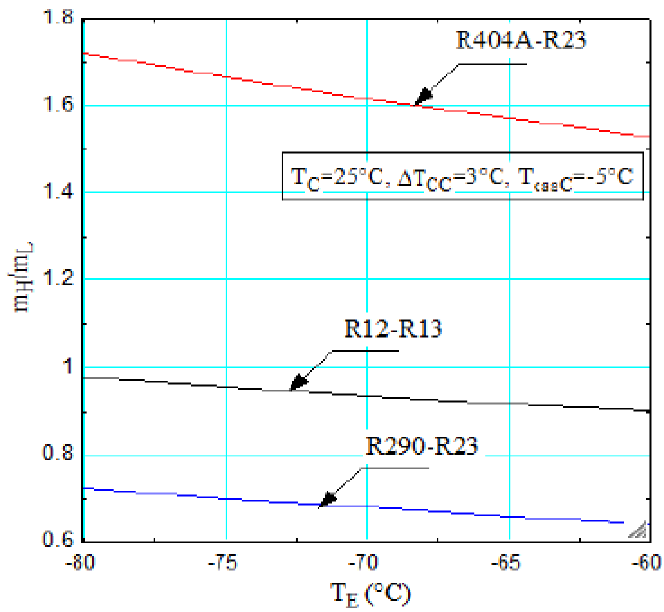

FIG3.c EFFECT OF T_E ON MASS FLOW RATIO

. FIG 3.b & 3.c indicate that when evaporator temperature rises, exergetic efficiency rises but mass flow rate falls. Exergetic efficiency ranges from 0.6175 to 0.6976, 0.6335 to 0.7033, & 0.6233 to 0.689 for R12-R13, R290-R23, and R404A-R23, respectively. The change of exergetic efficiency is greatest for R12-R13, followed by R290-R23 & R404A-R23.

B. CONDENSER TEMPERATURE (TC) EFFECT:

The condenser temp is altered from 25°C to 45°C in 5°C increments, while all other parameters remain fixed. Figs. 4 a, b, & c demonstrate the influence on COP, exergetic efficiency, as well as refrigerant mass flow ratio, respectively.

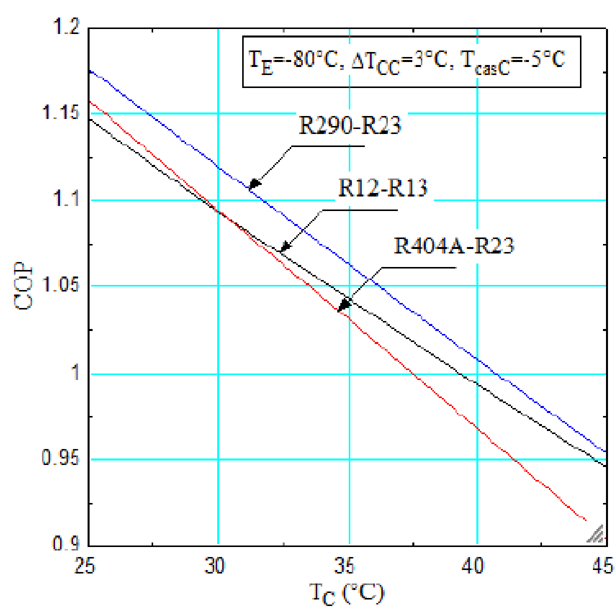

FIG4.a EFFECT OF T_c ON COP

When the condensing temperature is changed from 25°C to 45°C, the COP of the system drops from 1.147 to 0.9453, 1.176 to 0.9536, & 1.158 to 0.9038 for R12-R13, R290-R23, & R404A-R23, respectively.R404A-R23 exhibits the greatest change among the three refrigerant pairings, following by R290-R23 & R12-R13.

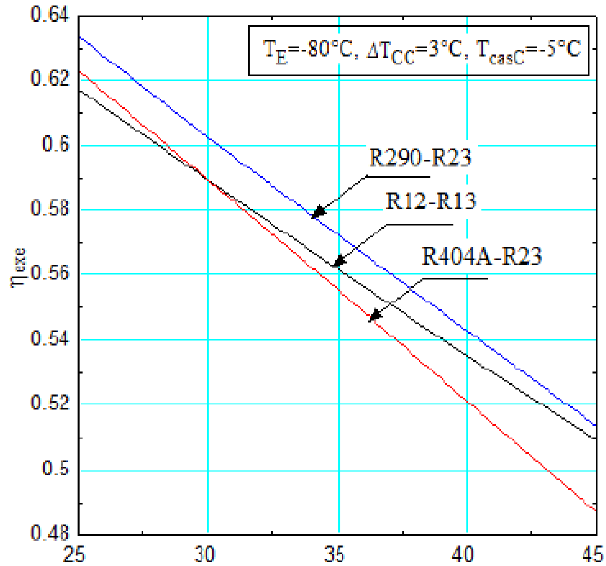

FIG4.b EFFECT OF T_C ON EXERGETIC EFFFIENCY

Exergetic efficiency diminishes as condensing temperature rises, as seen in Fig. 4.b. R12-R13, R290-R23, & R404A-R23 exergetic efficiency drops by 0.6175 to 0.509, 0.6335 to 0.5135, & 0.6233 to 0.4867, respectively. For condensing temperature change, R404A-R23 has the most fluctuation, followed by R290-R23 & R12-R13.

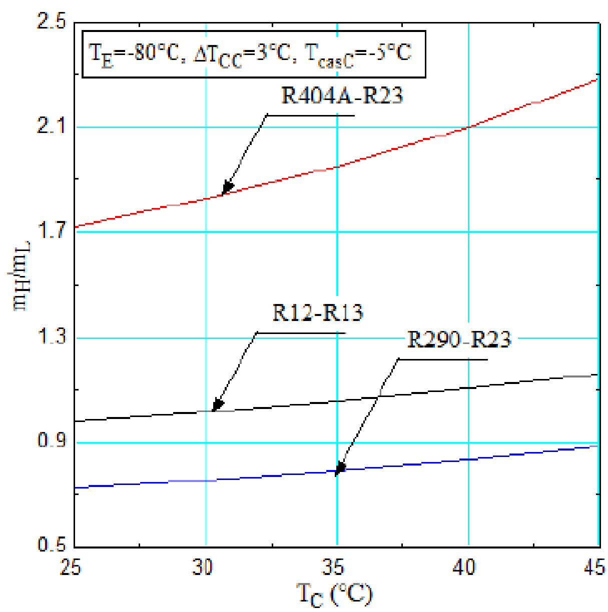

FIG4.c EFFECT OF T_C ON MASS FLOW RATIO

The refrigerant mass flow ratio increases as the condensing temperature rises, as seen in Fig. 4.c. For R12-R13, R290-R23, & R404A-R23, the increases are all from 0.9769 to 1.157, 0.7217 to 0.883, & 1.719 to 2.28, respectively. R404A-R23 has the most variance, followed by R12-R13 & R290-R23, in that order.

CONCLUSION

Thermodynamic analysis of a CRS was carried out in this study by constructing a computer model in Engineering Equation Solver to determine the impact of various operating parameters on performance parameters.

The following are the findings of this research:

1. Thermodynamic research reveals that the R290-R23 refrigerant pair has the greatest COP among the three refrigerant pairings R12-R13, R290-R23, & R404A-R23.

2. The COP rose by 53.8 percent for R12-R13, 51.2 percent for R290-R23, & 50.51 percent for R404A-R23 whenever the evaporator temp was changed from -80°C to -60°C.

3. When the condenser temperature was changed from 25°C to 45°C, the COP of R12-R13, R290-R23, & R404A-R23 declined by 17.5 percent, 18.9 percent, & 21.9 percent, respectively.

REFERENCES

[1].HÜSAMETTIN TAN , ALI ERİŞEN, Novel Design and Thermodynamic Analyses of Cascade Refrigeration System at Ultra-Low Temperature, international journal of thermodynamics(**2022) Volume 25, Issue 1,pp 142-150.**

[2].ALKHULAIFI, Y. M., ALSADAH, J. H., AND MOKHEIMER, E. M. A.Performance Analysis of a Novel Cascade Vapor Compression System for Small-Scale Desalination and Cooling. ASME. *J. Energy Resour. Technol* (2022); 144(9): 092102.

[3]. VICTOR ADEBAYO, MUHAMMAD ABID, MICHAEL ADEDEJI, MUSTAFA DAGBASI, OLUSOLA BAMISILE, Comparative thermodynamic performance analysis of a cascade refrigeration system with new refrigerants paired with CO2, **Elsevier,** Applied Thermal Engineering (2020) 116286.

[4]. SHYAM AGARWAL, AKHILESH ARORA , B.B. ARORA, Energy and exergy analysis of vapor compression–triple effect absorption cascade refrigeration system **, Elsevier,** Engineering Science and Technology, an International Journal 23 (2020) 625–641.

[5]. YOUSUF ALHENDAL, ABDALLA GOMAA, GAMAL BEDAIR AND ABDULRAHIM KALENDAR, Thermal Performance Analysis of Low-GWP Refrigerants in Automotive Air-Conditioning System. Advances in Materials Science and Engineering, Volume (2020) , Article ID 7967812.

[6]. **K.LOGESH, S. BASKAR, MD AZEEMUDEEN.M, B.PRAVEEN REDDY, GAJAVALLI VENKATA SUBBA SAI JAYANTH,** Analysis of Cascade Vapour Refrigeration System with Various Refrigerants, **Elsevier,** 18 (2019) 4659–4664, ICMPC-(2019).

[7] **SOUVIK BHATTACHARYYA, S. BOSE, J. SARKAR,** Exergy maximization of cascade refrigeration cycles and its numerical verification for transcritical CO2-C3H8 system, International Journal of Refrigeration 30 (2007), PP.624-632.

[8] **H.M. GETU, P.K. BANSAL** Thermodynamic analysis of an R744–R717 cascade refrigeration system, International Journal of Refrigeration,31(2008), pp. 45-54.

[9] J. ALBERTO DOPAZO, JOSE FERNANDEZ-SEARA , JAIME SIERES AND FRANCISCO J.UHIA Theoretical analysis of a CO2–NH3 cascade refrigeration system for cooling applications at low temperatures, Applied Thermal Engineering, 29 (2009), pp.1577–1583.

[10] **DEVANSHU PYASI, R.C. GUPTA**, Performance analysis of 404a/508b Cascade Refrigeration cycle for low Temperature, International Journal of Engineering Science and Technology, 3(2011), pp.6501-6507.

[11] **TZONG-SHING LEE, CHENG-HAO LIU, TUNG-WEI CHEN**, Thermodynamic analysis of optimal condensing temperature of cascade-condenser in CO2/NH3 cascade refrigeration systems, International Journal of Refrigeration 29 (2006), PP.1100-1108.

[12] **A.D. PAREKH AND P. R. TAILOR,** Thermodynamic Analysis of R507A-R23 Cascade Refrigeration System, International Journal of Aerospace and Mechanical Engineering 6:1, 2002.

[13] Montreal protocol on substances that deplete the ozone layer. United Nations Environment programme (UNEP), 1987.