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Analysis of Vapour Compression Refrigeration System Using Matrix Heat Exchanger

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ABSTRACT

Power utilization is a key fear in vapor compression refrigeration system .The objective of this research paper is to study the performance of a vapour compression refrigeration system with and without a matrix heat exchanger. As this research aims to augmentation of performance of refrigeration system by subcooling method with matrix heat exchanger, matrix heat exchanger is considered by allowing for some design parameter. Matrix heat exchanger is of counter flow type, by one side liquid refrigerant from condenser flow and from other side water from the evaporator is circulated. In this research work matrix heat exchanger is connected to VCR system after condenser. Performance analysis is done. The testing is done on VCR system using R-134a as a refrigerant. The performance of VCR system is compared with and without matrix heat exchanger for unlike loads. The results show that performance of VCR system is improved using matrix heat exchanger. The system works safely and normally. It is found that theoretical C.O.P of the system with matrix heat exchanger increases by 13.68% (average) and actual C.O.P also increases by 3.14% (average).

Keywords – Vapour compression system, Coefficient of performance, Matrix heat exchanger, Power consumption

1.INTRODUCTION

Refrigeration systems are crucial for soul beings in the recent life. Presently, the mechanical vapor compression systems used for this reason, use big amounts of electrical power that is produced in huge quantity by residue fuel combustion, which is a cause of the global warming. Global warming makes very important need to enlarge another technologies that will allow carrying out cooling applications reducing the utilize of electrical energy. Electrical energy can be remarkably saved by incorporating high efficiency devices or occupying other energy sources such as thermal energy. So there is need of improving coefficient of performance.

The refrigeration may be defined as the procedure of removing heat from a body under controlled conditions. It also includes the procedure of reducing and maintaining the temperature of a body less the general temperature of its surroundings. The refrigeration means a continued removal of heat from a body whose temperature is already lower temperature of its environment. In a refrigerator, heat is virtually pumped from a lower temperature to a higher temperature. According to second law of thermodynamics, this process only is performed with the aid of some external work. It is thus obvious that provide of power is frequently required to drive a refrigerator. Refrigerator is a inverted heat engine or a heat pump which pumps heat from a cold body and delivers it to a hot body. The body which works in a pump to take away heat from a cold body and suggest it to a hot body is known as refrigerant.

Vapor compression refrigeration system is based on vapor compression cycle. Vapor compression refrigeration system is used in domestic refrigeration, food processing and cold storage, industrial refrigeration system, transport refrigeration and electronic cooling. Coefficient of performance of refrigeration system is the ratio refrigerating effect to the work done. So enhancement of performance of system is too important to increase refrigerating effect or to reduce work done by compressor. A lot of efforts have to be done to progress performance of vapor compression refrigeration system.

2. LITERATURE REVIEW

X.She et al. [1] have studied proposes a new subcooling method for vapour compression refrigeration cycle based on expansion power recovery. In a main refrigeration cycle, expander output power is employed to drive a compressor of the auxiliary subcooling cycle, and refrigerant at the outlet of condenser is subcooled by the evaporative cooler, which makes the hybrid system get much higher C.O.P. A variety of refrigerants, including R12, R134a, R22, R32, R404A, R41, R507A, R717, and R744, are considered. Thermodynamic analysis is made to argue the effects of process parameters (expander efficiency and inlet temperature of cooling water) on the system performance. As compared to proposed hybrid VCRS achieves much higher C.O.P than the conventional VCRS, conventional mechanical subcooling system and conventional expansion power recovery system, with greatest C.O.P increments 67.76%, 19.27% and 17.73%, respectively when R744 works as the refrigerant in the core refrigeration cycle. It is most beneficial for R12 and R717 in the supporting subcooling cycle and R744, R404A and R507A in the main refrigeration cycle. E. Hajidavalloo and H. Eghtedari [2] have reported increasing the coefficient of performance of air conditioner with air-cooled condenser is a challenging problem particularly in region with very warm weather conditions. In this research paper application of evaporative cooled air type condenser instead of air-cooled type condenser is proposed as a capable way to resolve the problem. An evaporative cooler was built and coupled to the existing air-cooled condenser of a split-air-conditioner in order to measure its effect on the cycle performance under various ambient air temperatures upto 49oC. Experimental results illustrate that purpose of evaporatively cooled air condenser has significant effect on the performance enhancement of the cycle and the rate of enhancement is increased as ambient air temperature increases .It is also found that by using evaporatively cooled air condenser in warm weather conditions, the power consumption can be reduced up to 20% and the coefficient of performance can be improved around 50%. More improvements expected if a further proficient evaporative cooler is used. Christian and J.L.Hermes [3] have studied the little communication reports of the potential for refrigerant incriminate reduction in vapour compression refrigeration systems by means of a liquid-to-suction heat exchanger. Research was conceded out on exclusively thermodynamic base for refrigerants of up to date significance, such as R134a, R22, R290, R600a and R717, assuming the cooling ability as a limitation so that the evaporating pressure is at no cost to vary. Refrigerant was reduced depending on the thermophysical properties of the refrigerant, the working conditions, and the allege catalog.

X. Shuxue and M.Guoyuan [4] have developed two-stage compression refrigeration system of thermodynamically analytical model with vapour injection system. The optimal volume ratio of the high-pressure cylinder to the low pressure one has been discussed under equally cooling and heating conditions. Based on the above study, the prototype was developed and its experimental setup established. A comprehensive experiment for the prototype have been conducted, and the results show that, compared with the single-stage compression heat pump system, the cooling capacity and cooling C.O.P increase 5%-15% and 10-12%, correspondingly. Also, the heating capacity with the evaporating temperature ranging from 0.3 to 3OC is 92-95% of that under the rate condition with the evaporating temperature of 7 OC, and 58% when the evaporation temperature is between 28 OC and 24OC. N.K. Mohammed et al. [5] have reported the split air conditioning system by using matrix heat exchanger for improvement of performance .The experiment was done using HFC134a as the refrigerant and Polyol-ester oil (POE) as the conventional lubricant in the air conditioning system. The performance of the split air conditioning system with HFC134a/POE oil system was compared with HFC134a/POE oil/MHE for particular load conditions. The effect indicates that the system performance has improved when HFC134a/POE oil/MHE system was used instead of HFC134a/POE oil system and there was also a drop in power consumption at all load conditions. The HFC134a/POE oil/MHE works usually and safely in the air conditioning system. S.A. Klein et al. [6] have reported the heat transfer devices are provided in many refrigeration systems to exchange energy between the cool gaseous refrigerant leaving the evaporator and hot liquid refrigerant exiting the condenser. These suction- line heat exchangers, in a few cases, give mode enhanced system performance while in other cases they demean system performance. Performance of liquid-suction heat exchangers was investigated, this studies well-known from the previous studies in three ways. In this research paper categorize a new dimensionless group to compare performance impacts attributable to liquid-suction heat exchangers. Second, the paper extends previous analyses to include new refrigerants. It concluded that liquid-suction heat exchangers that have a smallest pressure loss on the low pressure side are useful for systems using R507A, and R410A. The liquid-suction heat exchanger is unfavorable to system performance in systems using R22, R32, and R717. Y. Zhu and P. Jiang [7] have developed vapor compression refrigeration system with an ejector cooling cycle. The ejector cooling cycle is drive by the devastate heat from the condenser in the vapor compression refrigeration cycle. The further cooling capacity from the ejector cycle is honestly input into the evaporator of the VCRS the method analysis shows that this refrigeration system effectively progress the C.O.P by the ejector cycle with the refrigerant which has high compressor discharge temperature.

T. Agarwal et al. [8] have Presented a effective method to increase to C.O.P of the domestic refrigerator by using R-134a. It is done by providing a cabin on the top of refrigerator with condenser coil in the cabin.It was observed that C.O.P increased by using cabin on the top if refrigerator. N. Updhyay [9] has reported increase C.O.P of the vapour compression refrigeration system using sub cooling and diffuser. Diffuser is used to convert kinetic energy into pressure energy. By using diffuser power consumption is reduced and hence refrigerating effect increases. Size of of condenser and cost of condenser is reduced. G.G. Momin et al. [10] have noted to improve performance of refrigerating system using recovery heat from condenser. Devastate heat from refrigerated is recovered by thermo siphon. After experimentation it is observed that performance of the system with waste gas recovery system is better than conventional system. U. S. Wankhede [11] has reported the experimental analysis of enhancement of coefficient of performance of air conditioning system. In the experimental analysis, instead of air cooled evapourative condenser is used. Results are discussed in the form of comparative analysis of air cooled condenser with evaporative condenser. Comparative analysis shows that C.O.P. of the is increased by 8%. R. S Patil et al.[12] have noted design and fabrication of vapour compression refrigeration system and experimental investigation of an effect of capillary bore diameter and geometry on refrigerating effect, coefficient of performance and compressor work required for the same length. In order to investigate the same, 450 W cooling capacity VCR system for water cooling application with R134a refrigerant, is designed and made-up.

3. SYSTEM DESIGN & COMPONENT SELECTION

As per design obligation, commercial availability and manufacturing feasibility component required for vapour compression refrigeration system.

3.1 Compressor

After studying all above design considearation reciprocating compressor was selected on the basis of system parameters such as refrigerant mass flow rate, pressure, temperature ranges, applications and market survey considering availability, durability and cost factor a model power cool comp R134a G3-1was selected. It has cooling capacity of 183 Kcal/hr. Capacity of compressor is 1/5 hp.

3.2 Condenser

For this system a micro channel condenser is selected having a maximum heat rejection capacity of 300W and with overall dimensions of 228.6mm × 228.6mm × 50.8mm.Afan is used as a condenser fan which gives a maximum flow rate of 85 CFM. Design parameters of the microchannel condenser are shown in Table 1.

Table 1 Parameters for condenser

Parameter	**Value**
Channel width (mm)	0.7
Channel depth (mm)	1.2
Channel Wall thickness (mm)	0.22
Channel Numbers	16
Fin Width (mm)	16
Fin Height (mm)	8
Overall length (mm)	140
Overall height (mm)	119
Overall width (mm)	20
Fins/inch	21

3.3 Heater

The heat source consists of a cubical copper block with dimensions of 10 mm on a side. Three cartridge heaters were mounted into the base underneath the copper block and controlled with an input power of up to 300 W provided. The copper block-evaporator interface was improved with the thermal conductive paste as shown in Figure 1.

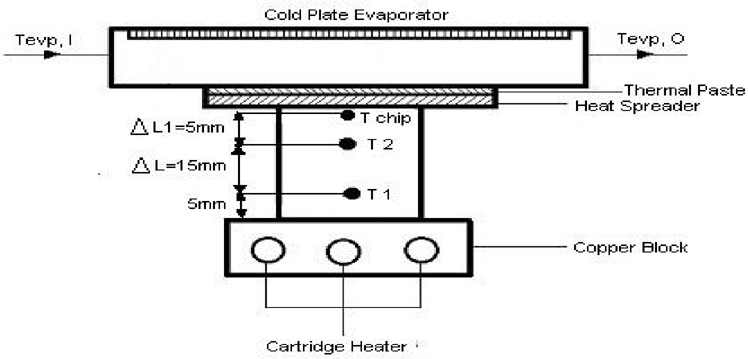

Figure 1. Heater

3.4 Capillary Tube

In this experiment the expansion device is a capillary tube of selected ID and design length with hand-operated needle valves. Experiments with ID 0.8 mm, and design length 500 mm capillary tube and respective flow rates experimentations were performed.

3.5 Evaporator

The evaporator is designed to absorb heat from the heat dissipating unit (cartridge heater) as shown if figure 1. This has a capacity of 300 W. An evaporator for removal of 300 W of heat is designed. A Box made up from metal is used in which a steel box is kept. Box is surrounded by thermacoal to avoid losses.

3.6 Heat Exchanger Design

For this research require at least 5^0 C sub cooling so accordingly following parameters are given to (HTST) software and designed heat exchanger is manufactured as per requirement of this set-up.

Table 2. Parameters of heat exchanger

Inlet temperature of liduid at condenser side 1	30^{0} C
Inlet temperature of liquid at side 2	22^{0} C
Liquid at inlet side 1	R-134a
Liquid inlet at side 2	Water
Mass flow rate of refrigerant	45 LPH

4. EXPERIMENTAL SET-UP

Figure 2. Experiment set-up

Vapour compression refrigeration cycle is very widely used cycle of refrigeration on ground, air space and marine applications. The vapour compression refrigeration system has fundamentally four basic processes. VCR systems consist of following components.

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4.1 Evaporator

Liquid refrigerant at a low pressure evaporates at low temperature and produces refrigerating effect. An evaporator for removal of 300 W of heat is designed. A Box made up from metal is used in which a steel box is kept. Box is surrounded by thermacoal to avoid losses.

4.2 Compressor

Low pressure from evaporator is sucked and compressed to high temp and pressure. The work done by compressor is 1.5. Experimental set-up consist compressor of godrej and it has capacity of 1/5 hp.

4.3 Condenser

High pressure vapours are condensed rejecting heat to cooling media. The system consists of air cooled condenser. In this condenser vapour refrigerant from compressor enters in the condenser and a small electric fan is used for condensing the liquid.

4.4 Expansion Device

High pressure liquid refrigerant from condenser is allowed to pass to the evaporator through the expansion device. A capillary or thermostatic expansion valve is an expansion device used through which the liquid refrigerant is throttled. The present unit has been designed to demonstrate to investigate the effect of different variables on the performance of theoretical cycles and actual cycle of refrigeration. Above setup consist of capillary tube of 0.8 mm dia. and its length is 500 mm.

4.5 Matrix Heat Exchanger

Matrix heat exchanger is provided after condenser for the purpose of subcooling and arrangement is made such that we can perform experiment with and without matrix heat exchanger. As matrix heat exchanger is of counter flow type from opposite side for circulation of cold water a small pump is attached for circulating the cold water.

4.6 Filter and Dryer

After end of compression stroke filter and drier is provided to remove all the moisture content which remains in vapour refrigerant. Following fig shows unit of filter and drier

5. RESULT AND DISCUSSION

Table 3. Results of VCRS without matrix heat exchanger at a cooling load of 100W

Sr. No	Amb. Temp. (^{O}C)	$(COP)_T$	(COP)t	(COP)a	Power Consumption (W)
1	26	5.44	6.59	1.4958	2.7989
2	27	5.35	6.63	1.4965	2.8542
3	28	5.17	6.75	1.5055	2.87.19

The above table shows the experimental results of Vapour Compression Refrigeration System (VCRS) without using matrix heat exchanger with base refrigerant R134a. The results of theoretical c.o.p decreases as ambient temperature increases while Carnot c.o.p increases as ambient temperature increases and actual c.o.p slightly varry and power consumption increases as ambient temperature increases.

Table 4. Results of VCRS with matrix heat exchanger at a cooling load of 100W

Sr. No	Amb.Temp (^{O}C)	$(COP_T$	(COP)t	(COP)a	Power Consumption (W)
1	26	6.34	6.59	1.5442	2.8080
2	27	6.00	6.75	1.5478	2.8585
3	28	5.81	6.75	1.5490	2.8584

The above table 4 shows the experimental results of Vapour Compression Refrigeration System (VCRS) with using matrix heat exchanger with base refrigerant R134a. The results of theoretical C.O.P decreases as ambient temperature increases while Carnot C.O.P increases as ambient temperature increases and actual C.O.P slightly varry and power consumption increases as ambient temperature increases.

5.1 Comparison of Results of V.C.R.S System with and without Matrix Heat Exchanger for 100 W Load

By using matrix heat exchanger theoretical C.O. P. of the system is increased. Blue bar indicate theoretical C.O.P of the Vapour compression refrigeration system. Red bar indicate theoretical C.O.P of the vapour compression refrigeration system with and without matrix heat exchanger. At 26˚C theoretical C.O.P of the system without matrix heat exchanger is 5.44 and with matrix heat exchanger is 6.34.At 27˚C theoretical C.O.P of the system without matrix heat exchanger is 5.35 and with matrix heat exchanger is 6.At 28˚C theoretical C.O.P of the system without matrix heat exchanger is 5.17 and with matrix heat exchanger is 5.81.

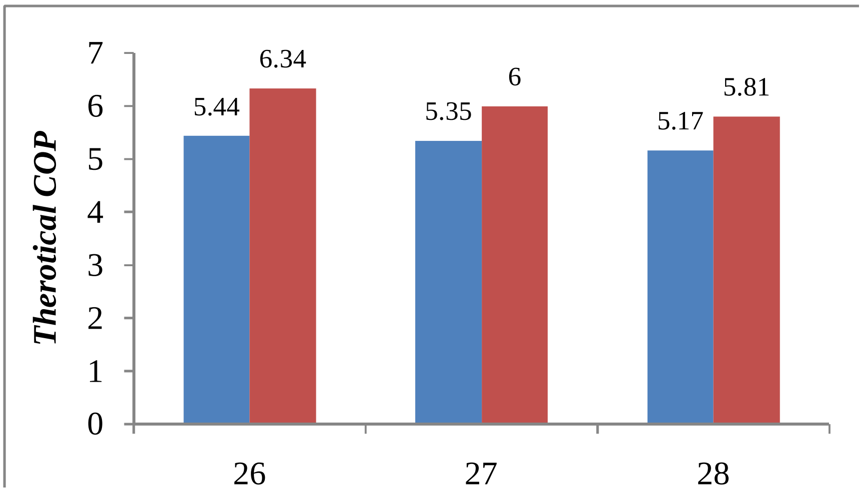

Figure 3. Ambient temperature VS Theoretical C.O.P

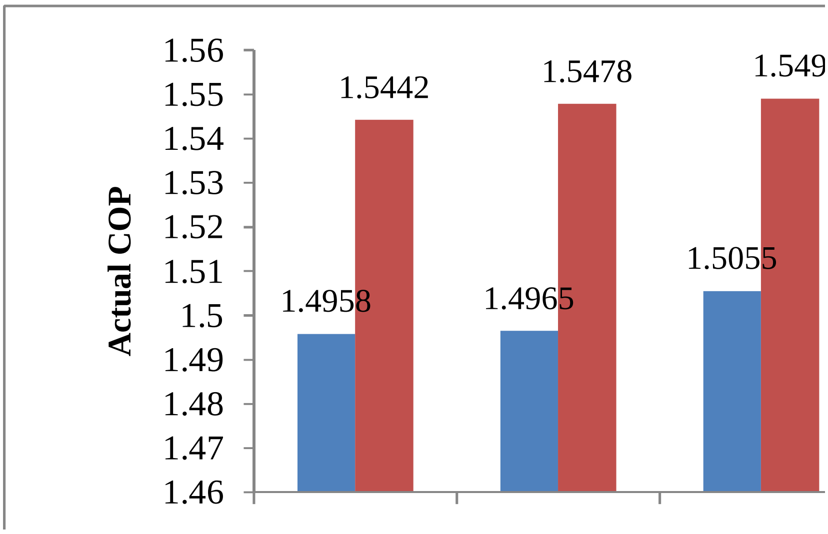

Figure 4. Ambient temperature VS Actual C.O.P

From this graph it is clear that Actual C.O.P of the system increased by using matrix heat exchanger. Blue bar indicate Actual C.O.P of the Vapour compression refrigeration system. Red bar indicate actual C.O.P of the vapour compression refrigeration system with and without matrix heat exchanger. At 26˚C actual C.O.P of the system without matrix heat exchanger is 1.4985 and with matrix heat exchanger is 1.5422. At 27˚C actual C.O.P of the system without matrix heat exchanger is 1.4965 and with matrix heat exchanger is 1.5478.At 28˚C theoretical C.O.P of the system without matrix heat exchanger is 1.5055 and with matrix heat exchanger is 1.549.

5.2 Comparison of Results of V.C.R System with and without Matrix Heat Exchanger for 200w Load

The results from below graph show that as the ambient temperature increases the theoretical C.O.P of system goes on decreases. By using matrix heat exchanger theoretical C.O.P of the system is increased. Blue bar indicate theoretical C.O.P of the Vapour compression refrigeration system. Red bar indicate theoretical C.O.P of the vapour compression refrigeration system with and without matrix heat exchanger. At 27˚C theoretical C.O.P of the system without matrix heat exchanger is 5.5 and with matrix heat exchanger is 6.15. At 28˚C theoretical C.O.P of the system without matrix heat exchanger is 5.5 and with matrix heat exchanger is 6.15.At 29˚C theoretical C.O.P of the system without matrix heat exchanger is 5.13 and with matrix heat exchanger is 5.78.

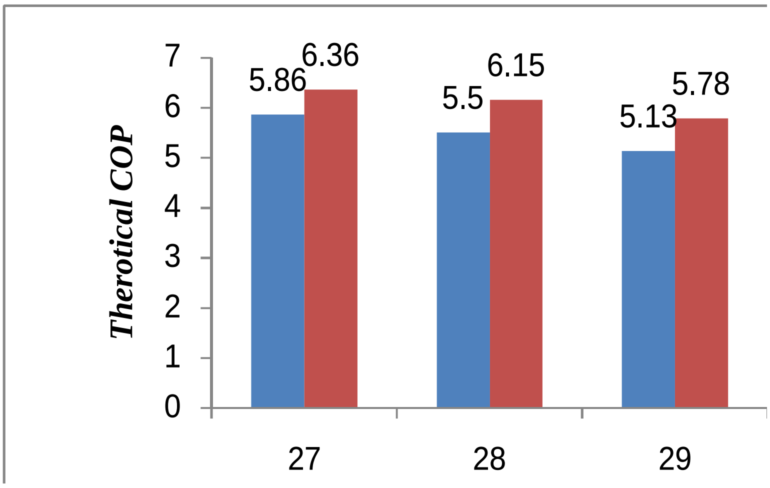

Figure 5. Ambient temperature VS Theoretical C.O.P

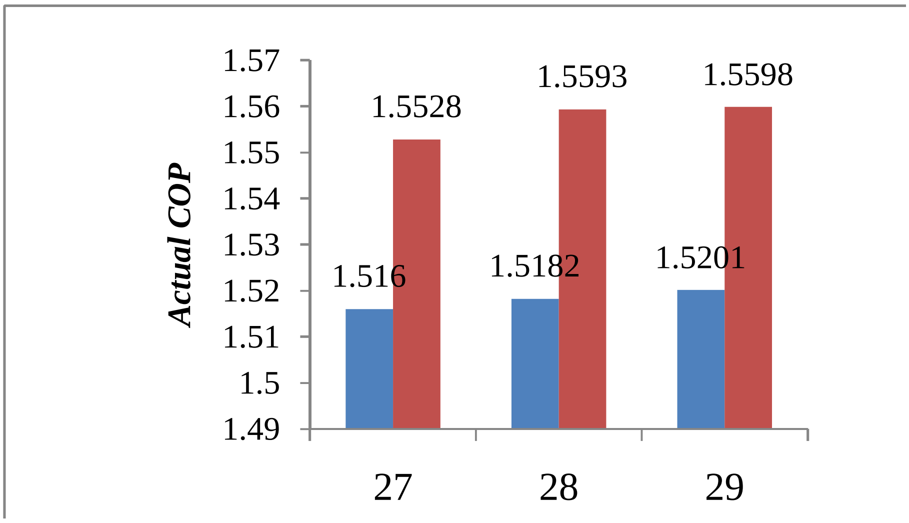

Figure 6. Ambient Temperature VS Actual C.O.P

The above figure 6 shows comparison of actual C.O.P for the vapour compression system with and without matrix heat exchanger. From this graph it is clear that Actual C.O.P of the system increased by using matrix heat exchanger. Blue bar indicate Actual C.O.P of the Vapour compression refrigeration system. Red bar indicate actual C.O.P of the vapour compression refrigeration system with and without matrix heat exchanger. At 27˚C Actual C.O.P of the system without matrix heat exchanger is 1.516 and with matrix heat exchanger is 1.5528. At 28˚C actual C.O.P of the system without matrix heat exchanger is 1.5182 and with matrix heat exchanger is 1.5593.At 29˚C actual C.O.P of the system without matrix heat exchanger is 1.5201 and with matrix heat exchanger is 1.5598.

6.CONCLUSION

From this research it is observed that theoretical C.O.P of the system is decreases as ambient temperature increases it means that theoretical C.O.P of the system is inversely propotional to the ambient temperature of the system. And actual C.O.P of the system also increases as ambient temperature enhance. Therefore it has been concluded that actual C.O.P of the system are directly proportional to the ambient temperature of the system. The power consumption of system is increases as the ambient temperature increases because for higher temperature cooling load on system increases. Therefore by using of base fluid as refrigerant the actual C.O.P of system decreases and power consumption increases.

The results are enhanced when subcooling of vapour compression refrigeration system is done by with matrix heat exchanger. It is observed that therotical C.O.P of the system using matrix heat exchanger increases nearly equal to 13.68%.It is observed that actual C.O.P of the system increases by approximately 3.14 % when vapour compression refrigeration system is implemented with matrix heat exchanger.

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