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Verification of Multi Evaporator VCR System with Micro channel Condenser

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Abstract—*This paper presents a proposal for a multi evaporative refrigeration and air conditioning system with microchannel condenser. In order to improve refrigerant distribution and reduce pressure drop in microchannel evaporator and thus increase system efficiency. Introduction to the microchannnel condenser in conventional refrigerating system gives positive effect on the performance of system and that is observed in previous literatures. In multi evaporative system in this proposal it is considered the system consists of three different applications of refrigeration, a refrigerator, a water cooler and an air conditioner. Each space is cooled by its own evaporator in order to obtain the required conditions. Multi evaporator systems yields the higher value of coefficient of performance compared to single evaporator system meant for different temperatures. There is easy control of fluctuations in loads by controlling individual evaporator. Also saving in initial cost and space required are the additional advantages with single compressor multi evaporator systems. Considering the above advantages of multi evaporator system over single evaporator system one can easily recommend its use in similar situations. But generally multi evaporator systems are overlooked by assuming it as complex system and hence a problem arises in maintaining specific temperature conditions. It is proposed to develop a multi evaporator system (2evaporators) to maintain the different operating temperature in evaporators with a single compressor, an individual expansion valve and an air cooled condenser. An air conditioner compressor of 1 ton is used. Refrigerant R134a will be used as it is required for compressor model.*

Index Terms—. Multi evaporator VCR System, Micro channel Condenser, Compressor, Expansion valve, COP.

1 Introduction

THERE are many applications where refrigeration plant is required to meet the various refrigerating loads at different temperatures. For example, systems for hotels, large restaurant, institutions and food preservation industries. In these cases, it is necessary that each location is cooled by separate evaporators to maintain the particular temperature and produce the required refrigeration load. Hence it requires different refrigerating units with single evaporator for each location. Instead it will be beneficial to use a refrigerating unit with multiple evaporators working at different temperatures. Therefore, it is the purpose of this paper to introduce vapor compression system which uses a single compressor and individual expansion devices to provide the concurrent testing.

Classification of complex air conditioning system can be done in the various ways. The evaporators can be arranged in series or parallel. There can be just a single expansion valve catering to all the evaporators or there can be an individual expansion valve for each evaporator. In the similar way, a single compressor (staged or non-staged) can cater to all the evaporators or there can be multiple compressors in the system too.

In certain cases, the system can have different outdoor units also, depending on the condensing requirements. The choice of the system arrangement depends on application, initial and operational costs.

The most common of these arrangements is one with multiple evaporators connected in parallel, each with an individual expansion device, a variable speed compressor or a staged set of compressors and a single outdoor or condensing unit.

In other arrangements, more commonly available in residential units, there are two air conditioning circuits, a primary and a secondary. In the primary circuit a high performance refrigerant is used to produce a certain base line cooling effort which is transferred to the secondary circuit through the other refrigerant, usually water which is circulated to the air conditioned spaces.The flow rate for secondary refrigerant is controlled separately for each of the space rather than controlling the primary cycle. Many times, it is advantageous to use dual or higher stage compressor stacks where initial cost of a variable speed / variable displacement compressor is not tolerable. It is however not particularly evident, whether, in a new design, one big compressor should serve all evaporators or there should be an individual compressor for each evaporator or there should be an intermediate number of compressors.

One basic disadvantage of a single compressor catering to all evaporators is that maintenance shut down affects all refrigerated spaces. However, there are some advantages of single compressor systems that more than shadow this disadvantage. In a residential air conditioning system, a big capacity compressor can cater to large number of rooms, each having its own evaporator, thus avoiding complex

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high voltage electrical circuitry for more than one compressor. Also, a multi-evaporator system with single compressor can be designed to work more efficiently than a number of single evaporator systems.

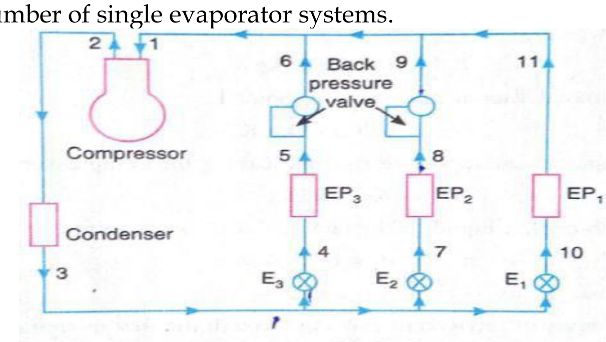

Figure.1MultiEvaporatorSystem VCRS

Figure 1 shows single stage compression multi-evaporator systems

2. LITERATURE REVIEW

Kumbhar A. D. developed the multi evaporative system to maintain the design temperatures in three evaporators at -3˚C, 2˚C, 7˚C. They conducted tests to evaluate the system by varying the condensing temperature from 37˚C to 42˚C with a step of 1˚C. Also the system was evaluated by varying the evaporator operating combinations. They shown that the multi evaporative system.[1]. **Silvia Minettoet. al** studied Experimental analysis of a new method for overfeeding multiple evaporators in refrigeration Systems .In this study, An innovative method for feeding flooded evaporators, arranged in parallel in R744 plants, is presented. In order to promote evaporators overfeeding, an ejector circulates liquid from the low pressure receiver back to the intermediate pressure receiver. **Kairouani et al** studied Use of ejectors in a multi-evaporator refrigeration system for performance enhancement. In this study, an improved cooling cycle for a conventional multi-evaporators simple compression system utilizing ejector for vapour pre compression is analysed. The ejector enhanced refrigeration cycle consists of multi-evaporators that operate at different pressure and temperature levels.[3]

F. Lontsi et al studied Development and performance analysis of a multi-temperature combined compression/ejection refrigeration cycle using environment friendly refrigerants. In this study, a combined compression/ejection refrigeration cycle intended for the simultaneous production of cold for refrigeration and freezing, and operating based on environment friendly refrigerants is proposed and analysed in this study. This makes it possible to vaporize the low-temperature heat sources in the ejector cycle, thereby reducing the share of mechanical energy otherwise required to operate the conventional two-stage vapour compression system. **Chen Lin a et al. [5]** investigation was carried out for the performance of adjustable ejector used in a multi evaporator refrigeration system. The adaptability of the adjustable ejector for the system was first evaluated by the tests and the results show the adjustable ejector can efficiently deal the problem of variable primary cooling load in the system. The tests for the performance of pressure recovery were subsequently carried out. In this study, the ejector tests for a novel multi-evaporator refrigeration system with adjustable ejector were carried out in order to study the adaptability and pressure recovery performance of the adjustable ejector. The adjustable ejector can be efficient to keep the primary inlet pressure in design value when the primary flow rate varies.

WenjianCai et al studied Numerical investigation of geometry parameters for pressure recovery of an adjustable ejector in multi-evaporator refrigeration system. In this study, Computational Fluid Dynamics (CFD) technique is used to investigate the optimum geometry parameters of the adjustable ejector, which is used in variable cooling loads conditions, for the performance of pressure recovery in a multi- evaporator refrigeration system (EMERS) using R134a as the refrigerant. **D. W. Gerlach et al.** S performance of dual evaporator household refrigerators was studied experimentally and by numerical simulation. A serial connection where the refrigerant flows through the fresh food evaporator and then through the freezer evaporator without a pressure drop between the evaporator is considered. However, it also includes the development and validation of a complex computer model of the serial evaporator configuration.

JiYan et al studied Experimental study on a multi-evaporator refrigeration system with variable area ratio ejector. In this study, an experimental study on a multi-evaporator refrigeration system (MERS) with conventional pressure regulating valve (PRV) and variable area ratio ejector. Some key performance indicators such as cooling capacity, power consumption and ejector entrainment ratio were evaluated by switching operating modes, adjusting superheat and tuning ejector spindle and so on. The results indicated that the energy efficiency of the MERS can be improved by up to 12% by replacing the conventional pressure regulating valve with the variable area ratio ejector, sufficient superheat or superheat degree greater than 2 is conducive to high entrainment performance of the ejector, large cooling capacity of the low-temperature evaporator and low power consumption of the system, and the effect of nozzle spindle position on the performance of the system is evident.

J. Sarkar studied Performance analyses of novel two-phase ejector enhanced multi-evaporator refrigeration systems. In this paper, Study shows that for typical combination of air conditioning (5°C), refrigeration (.20°C) and freezing (.40°C) applications, proposed refrigeration cycles yield COP enhancement of about 20% compared to basic valve expansion two-stage compression, 67% compared to ejector enhanced single-stage compression and 117% compared to basic valve expansion single-stage compression system. Volumetric cooling capacity also improves significantly [9].

P.G. Lohote et al. contributed by using spiral and micro channel condenser to raise COP of refrigerator to the value that was never before. The geometry, enhanced surface area of such micro channels are found adding positive results in the enhancement of COP value and work is elaborate through research work drafted in the paper. The Experimental work centric about performance study of spiral and micro channel shaped condenser used in refrigerator holding 165 litters' capacity. For spiral and micro channel shape condensers, COP value found increased by 5.06 % and 13.82 % respectively over the conventional refrigeration system. When spiral condenser is replaced by micro channel there is increase in refrigeration effect and compressor work by 12.02 % and 6.25 % respectively with increase in rate of heat rejection considerably. The summarized observations from the performance of Micro channel shape base condenser and so the refrigeration System has better performance over conventional refrigeration system supported with regular shape condenser[12] . **B. Santosh Kumar et al.** performed the experimental investigation of vapour compression refrigeration system with spiral shaped condenser. The work is centric about COP of refrigeration system using conventional condenser made of MS with cu coating and the verifying effect of performance using conventional condenser made of copper material. Experiment was done on kelvinator refrigerator of 165 liters and hermitic compressor is used. Result obtained from the conventional shape of condenser are compared with spiral shaped condenser with varying pitch from 1.5 inch to 2.25 inch. The optimum COP is 4.25and it is obtained at 2 inch pitch of the coil. After experimental investigation of various condensers final result comes as spiral shaped condenser coil (cu) of diameter 6.35 mm, 8500mm length and 2 inch pitch is recommended for VCR system of domestic refrigerator of 165 liters capacity with R134a as refrigerant. [13]. **VivekSahu et al.** presented experimental analysis of domestic refrigeration system by using wire-on-tube condenser with different spacing of wire. Operating parameters like heat transfer rate, condenser pressure and condenser temperature are considered. Refrigerating effect is increased by using wire-on-tube condenser comparatively power consumption remain same as with air cooled condenser in a domestic refrigeration system. Therefore wire-on-tube condenser can replace the ordinary air cooled condenser in a domestic refrigeration system. The conclusion of this paper is that Discharge pressure of 9mm fins spacing is about the same with that of 6mm fins spacing with average percentage reduction of 5.7%. The discharge pressure of 3mm fins spacing was the highest with average value of 4.7% and 10.2% higher than those of 6mm fins spacing and 9mm fins spacing respectively. At steady-state conditions the discharge pressures for 3 mm, 6 mm, 9 mm were 34.41, 32.00 and 30.56 bar, respectively [14]. **Wang zhiyuan et al** described comparative Performance Assessment of water cooling condenser, air cooling condenser and evaporation condenser. Collected various performance parameters to evaluate the performance of different condenser system on the same condition. Refrigerating capacity and COP of water cooled condenser. The refrigerating capacity of water cooling condenser system increases 2.9 - 14.4% than evaporative condenser system and also COP of water cooling condenser system increases 1.5 - 10.2% than evaporative condenser system; The refrigerating capacity and COP of evaporating condenser system is more by 31% and 14.3% than air cooled condenser. At the same evaporating temperature and condensing temperature, the refrigerating capacity, heat rejection and COP of the water-cooling condensing system are better than that of evaporative cooling system and air cooling system. When temperature is 40°C, the evaporating temperature range from -24 to 13°C, an evaporative condenser system can performance is same as the water-cooling condenser system, and evaporative condenser system is much better than the air cooling condenser system, here the advantages of water saving and energy saving of evaporative condenser is most obvious.[15]**Mohan M. Tayde et al.** Designed Mini-Scale Refrigerator. The performance analysis is centric about design of mini scale refrigerator by using Spiral micro-tube evaporator and miniature compressor. A mini-scale scale vapour compression refrigeration system of 300 Watt cooling capacity using R134a as a refrigerant was designed, built and tested. This test indicates that the actual COP of the developed system is 1.6 and second law efficiency is 19%. The experiments also show that the system was able to dissipate heat fluxes of 48 W/cm2 and keep the junction (chip) temperature below 82˚C. The refrigeration cycle is designed for this mini refrigerator using Cool pack software.[16]

V. W. Bhatkar et al. experimental performance of R134a and R152a using Spiral micro-tube Condenser was done. The performance analysis is centric about comparison of performance between conventional refrigerator and Spiral micro-tube refrigerator with R134a and R152a refrigerant. The author can conclude that Refrigerant charge was reduced by 40% with the use of micro-channel condenser over the conventional condenser. Discharge temperature of R152a was more than R134a by around 6 to 10°C. The condensation temperature drops by 2 to 2.5°C by using micro-channel condenser over the conventional condenser for same ambient temperature. The compressor energy consumed by R152a is slightly less than R134a from -10 to 15°C. COP with R152a refrigerant was more than R134a for all evaporator temperatures. Condenser capacity for R152a was higher than R134a because of large latent heat.[17].**Bilal A. Qureshi etal.**studied experimental observation on the impact of fouling on the condenser of a vapor compression refrigeration system. An experimental study of condenser fouling factor on some performance characteristics and properties of a simple vapor compression system is presented. It can be conclude that due to fouling heat transfer rate of condenser was decreases. Robert [18] **J. Kee et al.** performed design, fabrication, and evaluation of a ceramic counter-flow Spiral micro-tube heat exchanger. In a refrigeration system compressor absorb more power due to pressure drop in condenser. In Spiral micro-tube condenser to optimize the pressure drop various design parameter is consider. Pressure drop is depending upon shear stress, wetted perimeter and cross sectional area. To analyze pressure drop shear stress is represented as frictional factor, Reynolds number. Pressure drop is inversely proportional to cube of channel height. After caring out so much literature it is felt that further work can possible on multi evaporative system and micro channel condenser.

OBJECTIVES

1) To design multi-evaporator system for domestic use.
2) To fabricate multi-evaporator system which consist of refrigerator, water cooler and air conditioning unit.
3) To investigate performance of the system at different evaporative temperature.
4) To make the system user friendly, cost effective and energy efficient

3. EXPERIMENTAL SETUP

The setup consists of three systems operating on a single compressor. The three systems are namely a Refrigerator, a water cooler and an air conditioner. They are connected as shown in the figure 2 by direction control valves. The flow of the Refrigerant can be directed in any desired direction to get the required effect by the direction control valve. Temperature and Pressure sensors are used at inlet and outlet of each evaporator to study the effects.

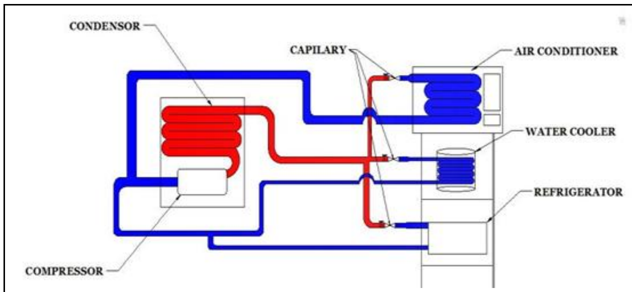

Figure.2 Multi evaporative VCRS system

4. SYSTEM SPECIFICATIONS

1. Compressor: 1 T
Refrigerant- R134-a, Type –Reciprocating, Current- 2.1 Amp Voltage- 230 volt, Relay- 10 Amp, Capacitor – 40-80 MFD

2. Condenser Capacity - 1TR
Type – Air cooled Micro tube condenser with fan. Condenser tube – ¼ inch copper tube

Figure: 3. Micro channel condenser

For the analysis of refrigeration system using spiral micro-tube condenser set up is built considering various parameters. The measured parameters are actual coefficient of performance, theoretical coefficient of performance, mass flow rate of refrigerant, heat rejection ratio, heat rejected by condenser and heat transfer coefficient. From various operating conditions data obtained from refrigeration system using spiral micro-tube condenser.

2. Capillary: Air conditioner capillary – 1.6256 mm Water cooler capillary – 1.27 mm Refrigerator capillary – 0.9144 mm

3. Evaporator
Air conditioner capacity – 2200 watt
Water cooler capacity – 800 watt
Refrigerator capacity – 600 watt

RESULTS

An experiment is conducted with the change in load of the evaporators various heat inputs at the simulator to test the performance of the system to maintain the temperature of evaporators.

1) When all valves are open
2) The following temperatures are obtained
3) Refrigerator =17°C
4) Air conditioner =19°C
5) Water cooler = 7°C

6) When one valve is closed (water cooler)
7) the following temperatures are obtained
8) Refrigerator =2°C
9) Air conditioner =19°C
Water cooler = 9.5°C

3) When all valves are open (after 10min) the following temperatures are obtained
Refrigerator =5°C

Air conditioner =19°C
Water cooler = 8°C
Observations for a time interval of 10 minute

The heat inputs are tuned down from 3000 W to 500 W in steps of 500 W and each test is given a time interval of 10 minutes to reach steady state conditions. Figure 1 shows the response of the power consumed by compressor at the various heat loads supplied. It is observed that increase in load increases the mass flow rate of refrigerant Hence compressor requires more power for suction of refrigerant.

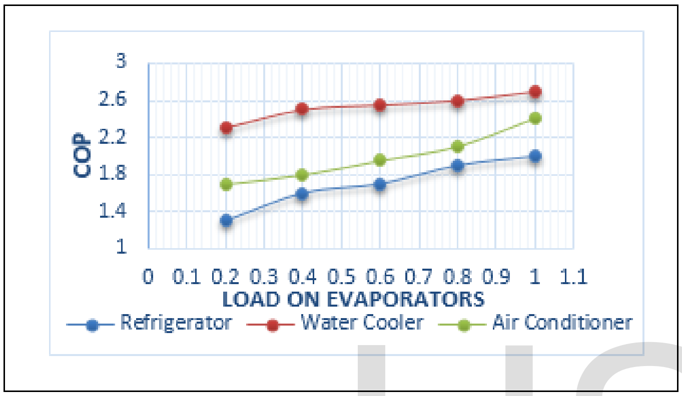

Figure: 4. COP Vs Load on Evaporator

It is observed that as load increases power consumed by compressor also increases .But comparatively increase in power consumed is less than increase in load. Hence coefficient of performance of the system increases with increase in load.

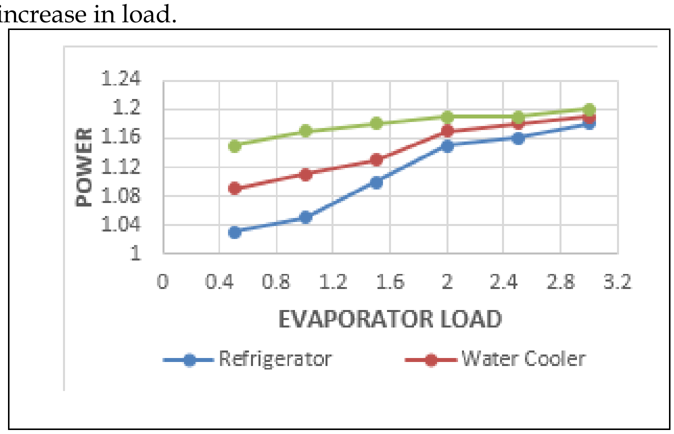

Figure: 5. PowerVs Load on Evaporator

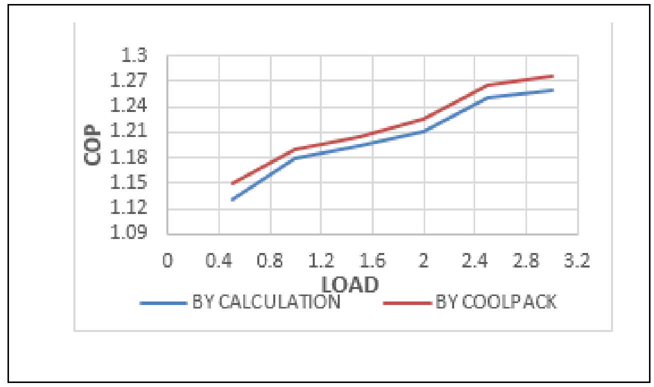

Figure: 6. COP Vs Load on Evaporator (overall)

CONCLUSIONS

It is concluded that by using multi-evaporator system there can be reduction of energy used for separate evaporators as well sufficient and required temperature and cooling can be maintained at the same periods, cost saving is the another benefit by utilizing multi-evaporator system.

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