TO IMPROVE COP OF A REFRIGERATOR USING DIFFUSER

Adityaswaroop[1] , S.C. Roy [2]

[1]PG Student , [2]Professor , Department of Mechanical Engineering

BIT Sindri , Dhanbad , Jharkhand , (India)

ABSTRACT

The goal of this project is to show that the COP of vapour compression refrigeration system can be increased by installing a diffuser between the condenser and the evaporator. In this space we are looking at opportunities to conserve energy by reducing its energy consumption and also by increasing its refrigeration effect. Experimental analysis on vapour compression refrigeration system with R134a refrigerant was completed and their results were recorded. The effects of the main parameters of performance analysis such as superheating on the refrigeration effect, power required to run the compressor for various evaporating temperatures, mass flow of refrigerant, percentage increase in COP , coefficient of performance. The results from vapour compression refrigerant set up (at Heat engine lab, BIT Sindri) was taken where the variables like suction pressure of compressor, delivery pressure of compressor, temperature of evaporator and condenser are noted down and COP of refrigerator is calculated. Initially the diffuser of increasing cross section area profile was designed, fabricated and introduced in our VCRS apparatus. The size of diffuser selected was of 15° divergence angle. By using diffuser power consumption is less for same refrigeration effect so performance is improved. The size of the evaporator can also be reduced due to more heat transfer. So cost of the evaporator will be reduced. The parameters pressure and temperature were measured. After in result analysis, we have found that the COP was enhanced from 1.877 to 2.07, in the case when conventional VCRS was used with diffuser.

Keyword: VCR system, COP, Diffuser, Divergence angle, Increasing efficiency.

I INTRODUCTION

Refrigeration can be defined as thescience of producing and maintaining temperatures below that of the surrounding atmosphere. This means the removing of heat from a substance to be cooled. Heat always passes downhill, from a warm body to a cooler one, until both bodies are at the same temperature. Maintaining food items and other required things at their required temperatures is done by refrigeration. Not only perishables but to-day many human work spaces in offices and factory buildings are air conditioned and a refrigeration unit is the heart of the system.

The basic of modern day refrigeration system is the ability of liquids to absorb a huge quantity of heat as they boil and evaporate. Prof.William Cullen of the University of Endinburgh demonstrated this in 1755 by placing some

water in thermal contact with ether under a receiver of a vacuum pump. The evaporation rate of ether increased due to the low pressure of vacuum pump and water could be frozen. This process deals with two thermodynamic concepts, the vapour pressure and the latent heat. Saturation pressure is the pressure in which liquid remains in the thermal equilibrium with its own vapor, this saturation pressure depends on the temperature alone. If the pressure is increased for example in a pressure cooker, the water starts boiling at higher temperature. The second concept of refrigeration is that the evaporation of liquid requires latent heat during evaporation. If latent heat is taken away from the liquid, the liquid gets cooled. The temperature of ether will remain constant as long as the vacuum pump maintains a pressure equal to saturation pressure at the desired temperature. This requires the removal of all the vapors formed due to vaporization of liquid. If a lower temperature is desired, then a lower saturation pressure will have to be maintained by the vacuum pump. The components of the modern day refrigeration system where cooling is produced by this method which is called as evaporator. If this process of cooling is to be made continuous then the vapors have to be condensed to the liquid state by recycling. The condensation process requires heat rejection to the surroundings. By increasing its pressure it can be condensed at atmospheric temperature. The process of condensation was learned in the second half of eighteenth century. U.F. Clouet and G.Monge liquefied SO_2 in 1780 while Van Marumand Van Troostwijk liquefied NH_3 in 1787. Hence, a compressor is required to maintain a high pressure so that the evaporating vapour can condense at a greater temperature than that of the surroundings. Oliver Evans in his book "Abortion of a young Steam Engineer's Guide" published in Philadelphia in 1805 described a closed refrigeration cycle to produce ice by ether under vacuum. Jacob Perkins, an American living in England actually designed such a system in1835. The apparatus described by Jacob Perkins in his patent specifications of 1834. In his manifest he said that "I am enabled to use volatile fluids for the purpose of producing the cooling or freezing of fluids, and yet at the same time constantly condensing such volatile fluids, and bringing them again into operation without wastage"

II RELATED WORK

In 1805, the American inventor Oliever Evans described a closed VCR cycle for the production of ice by ether under vacuum. Heat can be removed from the environment by recycling vaporized refrigerant, where it would move through a compressor and condenser and would eventually revert to a liquid form in order to repeat the refrigeration process over again.

Yuri etal. developed a new form of the ejector vapour compression refrigeration cycle, which used an internal heat exchanger and intercooler to enhance the performance of the cycle .Results obtained showed that there were increase of 8.6% and 8.15% in coefficient of performance and second law efficiency values respectively of the new ejector-vapour compression refrigeration cycle as compared to the conventional ejector-vapour compression refrigeration cycle with R125. It was also noted that there was an increment of 21% in the COP of the new ejector-vapour compression cycle compare to the conventional vapour compression system.

Selvaraju et al. analyzed an ejector with environment friendly refrigerants. Vapour ejector refrigeration is a heat operated system using low grade energy such as solar energy, waste heat from industrial processes, etc., and it could satisfactorily be operated at generator temperature as low as 650C. Results that were found had showed that among the selected working fluid, R134a given a better performance and higher critical entrainment ratio in comparison with other refrigerants.

Bergender investigated new regenerative cycle for vapour compression refrigeration cycle which described a novel approach to the Rankin vapour compression cycle for cooling and refrigeration. Results obtained had signified that the pressure on the ejector increased by 15-16% and prototype achieved energy saving of 16%.

Akintuinde obtained the validation of a design model for vapour compression refrigeration system developed by Akintuinde. This model was used to design a VCRS(vapour compression refrigeration system). The experimental set-up was made up of a compressor- reciprocating type, 0.746 kW capacity, using R134a as working fluid, with cylinder stroke volume of 32.7 cm2, evaporator and condenser, bare coil tube-in-tube serpentine copper coil. The analysis showed that the results that was obtained from the model were comparable to the actual system from both quantitative and qualitative points of view. Under the same operational conditions, maximum absolute deviations of the variable parameters – mass flow rate, coefficient of performance and circulating water temperature were within the range of 16%.

Jianlin Yu, Hua Zhao, Yanzhong Li Presented a novel auto cascade refrigeration cycle (NARC) with an ejector. In the novel auto cascade refrigeration cycle, the ejector is used to recover some available work to increase the compressor suction pressure. The novel auto cascade refrigeration cycle is the one which enables the compressor to operate at lower pressure ratio, which in turn improves the cycle performance.

Yinghai Zhu and Peicxue Jiang developed a refrigeration system which combines a basic vapor compression refrigeration cycle with an ejector cooling cycle. The ejector cooling cycle is driven by the waste heat from the condenser in the VCRS. The additional cooling capacity from the ejector cycle is directly input into the evaporator of the vapor compression refrigeration cycle the system analysis shows that this refrigeration system can effectively improve the coefficient of performance by the ejector cycle with the refrigerant which has high compressor discharge temperature.

N.D. Banker, P. Dutta, M. Prasad and K. Srinivasan present the results of an investigation on the efficiency of hybrid compression process for refrigerant R134a in cooling applications. The conventional mechanical compression is append by thermal compression using a string of adsorption compressors. It is shown that almost 40% of the energy saving is can be done by carrying out a part of the compression in a thermal compressor compared to the case when the entire compression is carried out in a single stage mechanical compressor. The hybrid compression is feasible even when the low grade heat is available. Some performance indicators, which are defined and evaluated for various configurations.

AndrewCheisi, Giovannia Ferrara, Lorenzo Ferrara and Fabio Tarani analyzed a complex system in which the solar powered ejection machine is used to increase the efficiency of a traditional vapor compression machine by

subtracting heat from the condenser. By means of a transient analysis, done with a reference building and with climate data corresponding to four different system locations worldwide, the year-round performance of such a system in a space cooling application is estimated in terms of energy balance and savings on power costs with respect to the traditional solutions

A. Selvaraju and A. Mani investigate the experimental analysis of the performance of a vapor ejector refrigeration system. The system utilizesR134a as working fluid and has a rated cooling capacity of 0.5 kW. The influence of generator temperature, evaporator and condenser temperatures on the system performance is studied. For anygiven ejector configuration, there is an optimum temperature of primary vapor at a particular condenser and evaporating temperatures, which yields maximum entrainment ratio and COP.

L. Kairouani, M. Elakhdar, E. Nehdi and N. Bouaziz presented an improved cooling cycle for a conventional multi-evaporators simple compression system utilizing ejector for vapour pre compression is analyzed. The ejector enhanceda refrigerationcycle consists of multi-evaporators that operate at different pressure and temperature levels. A 1-D mathematical model of the ejector was developed using the equations governing the flow and thermodynamics based on the constant-area ejector flow model. The theoretical results gives us an idea that the COP of the novel cycle is better than the conventional system.

Advances in condenser to increase coefficient of performance means to increase degree of sub cooling, F. W. Yu and K. T. Chan described use of direct evaporative coolers to improve the energy efficiency of air-cooled condenser. This evaporative cooler is installed in front of air-cooled condenser to pre-cool outdoor air before entering the condenser. With the help of results it was predicted that the use of the evaporative cooler results in an increase in the refrigeration effect.

III WORKING PRINCIPLE

As in the existing refrigeration cycle, cycle begins from the evaporator inlet, the low-pressure liquid expands, absorbs heat, and evaporates, changing to a low-pressure gas at the evaporator outlet. After this compressor pumps this gas from the evaporator through the accumulator increases its pressure, and discharges the high-pressure gas to the condenser. In the condenser, heat is removed from the gas, which then condenses and becomes a high pressure liquid. In some systems, this high-pressure liquid drains from the condenser into a liquid storage or receiver tank. On some other systems, both the receiver and the liquid line valve are omitted. Between the condenser and the evaporator and before an expansion device, a small Diffuser is located. Here, the pressure of the fluid gets increased and temperature is maintained in average manner. Hence flow of refrigerant into the evaporator is totally controlled by the pressure differential across the expansion device or, in the case of a thermal expansion valve, by the degree of superheat of the suction gas. As the high-pressure liquid refrigerant enters the evaporator; it is subjected to a much lower pressure due to the suction of the compressor and the pressure drop across the expansion device. Thus, the refrigerant tends to expand and evaporate. In order to evaporate, the liquid must absorb heat from the air passing

over the evaporator than the conventional refrigerators and cooling effect is attained quicker. Whenthe desired air temperature is reached and the thermostat or cold control will break the electrical circuit to the compressor motor and stop the compressor. As the air temperature passing through the evaporator rises, the thermostat or cold control remakes the electrical circuit. The compressor starts, and the cycle continues.

IV EXPERIMENTAL SET UP

A refrigeration system is a combination of different physical components that make up the total refrigeration unit. The different stages in the refrigeration cycle are undergone in these physical systems. These systems contains evaporator, a condenser, a compressor and an expansion valve. The evaporator is the space that needs to be cooled by the refrigerant; the compressor compresses the refrigerant from the low pressure of the evaporator to the pressure at the condenser. Now at the condenser heat gained by the refrigerant is rejected and the high pressure refrigerant is expanded into the low pressure evaporator by the expansion valve. This is a very simple representation of the various units in a vapour compression refrigeration system. The performance of refrigeration systems vary according to the purpose and the type of refrigerant used.

4.1   Description of equipment

a)   **Compressor:-**A compressor is the most valuable component of any vapour compression refrigeration system (VCRS). It consumes 30 to 40% of cost involved in VCRS.The function of a compressor in a VCRS is to continuously draw the refrigerant vapour from the evaporator, remove the vapour from the evaporator and also to raise its temperature and pressure to a point such that it (vapour) can be condensed with available condensing media,so that a low pressure and low temperature can be maintained in the evaporator, hence due to this refrigerant can boil extracting heat from the refrigerated space. Then the compressor has to raise the pressure of the refrigerant to a value at which it can condense by rejecting heat to the cooling medium in the condenser.

Fig-1: Compressor used in experiment

b) **Condenser**:- It is a device or unit which is used to condense a substance from its gaseous to its liquid state, by cooling it. In this process, the latent heat is given up by the substance, and will transfer to the condenser coolant. Condensers are a type of heat exchangers which have various designs and come in many sizes ranging from rather small (hand-held) to very large industrial scale units used in plant processes. For example, a condenser is used by a refrigerator to get rid of heat extracted from the interior of the unit to the outside air. Condensers are used in maximum of the air conditioning and industrial chemical processessuch as distillation, steam power plants and other heat-exchange systems. Use of cooling water or surrounding air as the coolant is common in this. A typical configuration of such a condenser unit is such that the heat exchanger section wraps around the sides of the unit with the compressor inside. In this heat exchanger section, the refrigerant goes through multiple tube passes, which are surrounded by heat transfer fins through which cooling air can move from outside to inside the unit. Sometimes in this a fan used inside the condenser unit near the top, which is covered by some grating to keep any objects from accidentally falling inside on the fan. The fan is sometimes also used to blow the outside cooling air in through the heat exchange section at the sides and out the top through the grating. Condensers are generally located on the outside of the building they are trying to cool, with tubing between the unit and building, one for vapor refrigerant entering and another for liquid refrigerant leaving the unit.

Fig-2: Condenser used in experiment

c) **Throttling Device**:-The throttling device obstructs the flow of liquid; cold liquid is reduced with the help of this device, in this case the throttling device is a capillary tube. The capillary tube has an length of 2m(approx.) and an inside diameter of around 0.6mm , so it offers considerable resistance to flow. The effective throttling at the inlet the refrigerant should be high pressure liquid. The throttling device restricts the flow of refrigerant which cause a tremendous pressure drop due to drop in pressure the boiling point of refrigerant is lowered and it start to evaporate.

d) **Evaporator:-** The evaporator is an important device used in low pressure side of a refrigeration system. The liquid refrigerant from the expansion valve enter into the evaporator where it boils and changes into vapour. The function of an evaporator is to absorb heat from the surrounding location or medium which is to be cooled, by means of a refrigerant. The temperature of the boiling refrigerant in the evaporator must always be less than that of the

surrounding medium so that the heat flows to the refrigerant. The evaporator becomes cold and remains cold due to two reasons :

i.   The temperature of the evaporator coil is low due to the low temperature of the refrigerant inside the coil.

ii.   The low temperature of the refrigerant remains unchanged because any heat absorbs is converted to latent heat as boiling proceeds

Fig-3: Throttling device used in experiment   Fig-4: Evaporator used in experiment

e)   **Diffuser**:-Diffuser is the static device of increasing cross-sectional area. It raises the pressure of flowing fluid by converting its kinetic energy of refrigerants into the pressure energy. Diffuser is making with the help of sheet metal operation and some process.To make the diffuser a metal plate is required. Then there are some steps of diffuser making which are given below :-

i.   Marking the metal plate with required size.

ii.   Scribing the metal plate at 60° angle.

iii. Cut the scribing plate with help of straight snip.

iv.   Work on sheet bending machine to bending the cutting plate.

v.   Work on edge folding machine to fold the edge of the shape.

vi.   Use round bottom stake to making round shape.

vii. Use funnel stake of hammering.

viii. Wooden mallet a wooden hammer to make desire shape.

ix.   Weld the bend section and cross section of final shape.

Fig-5: Diffuser used in experiment

f)   **Refrigerant(R134a):-** A refrigerant is a substance or mixture, usually a fluid, used in a heat pump and refrigeration cycle. In most cycles it undergoes phase transitions from a liquid to a gas and back again. Many working fluids have been used for such purposes. As according to our need we are taking R134a as my refrigerant and here, there are some properties of R134a which are given below:-

  i.   Boiling point : -21.6
 ii.   Auto ignition temp: 770
iii.   Ozone layer depletion : 0
 iv.   Critical temp : 122
  v.   Global warming potential : 1200
 vi.   Solubility in water : 0.11% by weight at 25° C
vii.   Cylinder colour code : Light blue

V METHODOLOGY

The schematic diagram of the vapour compression refrigeration system with diffuser at condenser outlet is shown in figure 6. The system consists of two flow lines one is simple vapour compression refrigeration system flow line without diffuser and other is flow line with diffuser. Three pressure gauges are installed at diffuser outlet, at compressor outlet and at capillary outlet to measure the pressure of the refrigerant at diffuser outlet and pressure in simple VCRS flow line. Thus we can calculate the pressure with and without diffuser. The both lines can be opened or closed with the help of flow control valves. A constant refrigeration effect is maintained throughout the experiment. The experiment is performed by taking with and without diffuser and compared with each other.
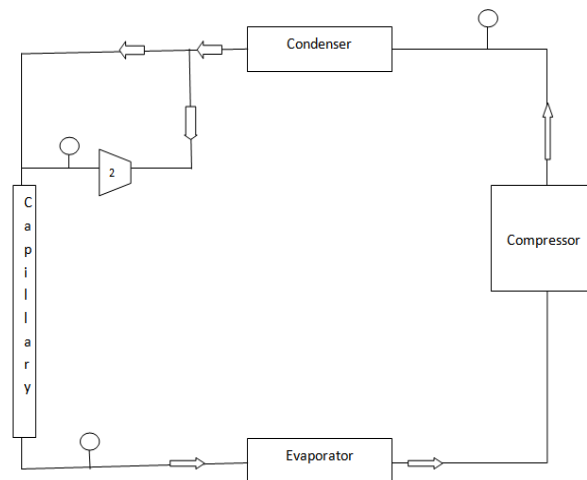

Fig-6: Schematic Diagram of Set Up

Fig-7: Image of the experimental set up installed at BIT Sindri, Heat engine lab
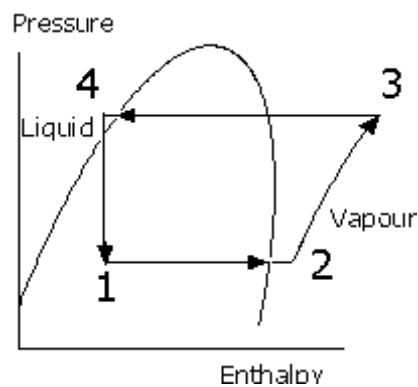
VI EXPERIMENTAL DATA

Fig-7:p-h diagram

6.1 Data for Existing system

P_1(psi)	P_2(psi)	P_3(psi)	P_4(psi)
13	13	200	200

1 psi = 6.895 kPa

So, P_1 = 13 psi = 89.635kPa

P_2 = 13 psi = 89.635 kPa

P_3 = 200 psi = 1379 kPa

P_4 = 200 psi = 1379 kPa

Using R134a property chart,

h_2 = 232 kj/kg

$S_2 = S_3$ = 0.956 kj/kg-k

h_3 = 289 kj/kg

$h_4 = h_1$ =125 kj/kg

hence, COP $= \dfrac{h_2 - h_1}{h_3 - h_2} = \dfrac{232 - 125}{289 - 232}$

$\qquad = 1.877$

6.2 COP of proposed system

P_1 (psi)	P_2 (psi)	P_3(psi)	P_4 (psi)
16	16	200	200

P_1 = 16 psi = 110.32 kPa

P_2 = 16 psi = 110.32 kPa

P_3 = 200 psi = 1379 kPa

P_4 = 200 psi = 1379 kPa

Using R134a property chart,

h_2 = 235.6 kj/kg

h_3 = 289 kj/kg

h_4 = 125 kj/kg

$h_1 = h_4$ = 125 kj/kg

hence, COP $= \dfrac{h_2 - h_1}{h_3 - h_2} = \dfrac{235.6 - 125}{289 - 235.6}$

$\qquad = 2.07$

Hence from above data we noticed that COP of a vapour compression refrigeration system increases when a diffuser is placed between throttling device and condenser.

VII MERITS

a)   Simple construction and efficient.

b)   Low power consumption.

c)   Simple Easy to operate.

d)   Maintenance cost low.

e)   High efficiency.

VIII APPLICATION

a) It is used to preserve food items, fruits, vegetables fresh for several days from being spoilt,

b) Gas Turbine Air Inlet Cooling,

c) Reflux chillers

d) Vent gas /solvent recovery chillers

e) Brine / Water chillers

f) It can be also used for preservation of dairy products, Blood plasma and antibiotics are manufactured using a method called freeze drying,

g) It can be used to "preserve fishes and meat" in ship containers for several days during travel in the sea

IX CONCLUSION

The project done by us will make an impressing mark in the field of Refrigeration .This project have also reduced the cost involved in the concern. The project has been designed to attain the cooling effect quicker than the prescribed time. Compared to other conventional refrigerators our project is very compact and able to save energy and it is also cost effective. So our project will play a major role in the field of engineering.

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