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STUDY THE PERFORMANCE OF VAPOUR COMPRESSION REFRIGERATION SYSTEM WITH DIFFUSER AT COMPRESSOR OUTLET BY USING ECO-FRIENDLY REFRIGERANT R134A

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Abstract

Aim of this paper is to improve Coefficient of performance of VCRS system with diffuser at compressor outlet by using eco friendly Refrigerant R134a. In VCRS vaporised R134a leaves the compressor with relatively high velocity which directly strikes on the tubing of condenser which may cause damage to it by vibration, pitting or erosion. So It is required to convert this kinetic energy of vaporised R134a at condenser inlet to pressure energy by using diffuser of a fixed divergence angle .This arrangement saves the power consumption for same refrigerating effect hence coefficient of performance is improved.

Index Terms: Condenser, Diffuser, Vapour compression refrigeration system, R134a

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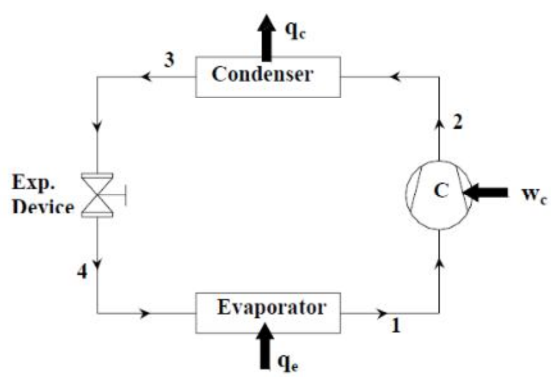
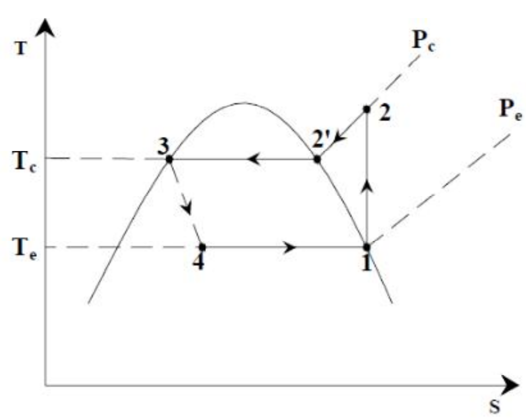
1. INTRODUCTION

VCRS is based on vapour compression cycle. It is also used in domestic and commercial refrigerators, large-scale warehouses for chilled or frozen storage of foods and meats, refrigerated trucks and railroad cars, and a host of other commercial industrial services. A simple analysis of standard vapour compression refrigeration system can be carried out by assuming;

a) Steady flow.
b) Negligible kinetic and potential energy changes across each component.
c) No heat transfer in connecting pipe lines. The steady flow energy equation is applied to each of the four components.

In a vapour compression refrigeration system refrigeration is obtained as a refrigerant evaporates at low temperatures. The system input is in the form of mechanical energy required to run the compressor. Hence these systems are also known as mechanical refrigeration systems. Vapour compression refrigeration systems are available to suit almost all applications with refrigeration capacities ranging from few watts to few megawatts. That means this is one of the most versatile refrigeration system.





Improvement of performance of system is too important for higher refrigerating effect or reduced power consumption for same refrigerating effect. Many efforts have to be done to improve the performance of VC refrigeration system.

Selvaraju et al. [1] analyzed an ejector with environment friendly refrigerants. Vapour ejector refrigeration is a heat-operated system utilizing 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. Investigations were carried out for analyzing the performance of the system and its components with few selected organic and inorganic refrigerants. Results obtained were showed that among the working fluids selected, R134a given a better performance and higher critical entrainment ratio in comparison with other refrigerants.

Yinhai Zhu and Peixue Jiang [2] developed a refrigeration system which combines a basic vapour compression refrigeration cycle with an ejector cooling cycle. The ejector cooling cycle is driven by the waste heat from the condenser in the vapour compression refrigeration cycle. 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 COP by the ejector cycle with the refrigerant which has high compressor discharge temperature.

Banker et al., [3] present the results of an investigation on the efficacy of hybrid compression process for refrigerant HFC 134a in cooling applications. The conventional mechanical compression is supplemented by thermal compression using a string of adsorption compressors. It is shown that almost 40% energy saving is realizable 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 low grade heat is available. Some performance indicators are defined and evaluated for various configurations.

Andrea Chesi, Giovanni Ferrara, Lorenzo Ferrari and Fabio Tarani [4] analyze 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, performed 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.

Selvaraju and Mani [5] investigate the experimental analysis of the performance of a vapor ejector refrigeration system. The system uses R134a as working fluid and has a rated cooling capacity of 0.5 kW. The influence of generator, evaporator and condenser temperatures on the system performance is studied. For a given ejector configuration, there exists an optimum temperature of primary vapor at a particular condenser and vaporising temperatures, which yields maximum entrainment ratio and COP.

Kairouani et al., [6] presented an improved cooling cycle for a conventional multi-evaporators simple compression system utilizing ejector for vapour pre-compression is analyzed. The ejector enhanced refrigeration cycle consists of multi-evaporators that operate at different pressure and temperature levels. A one-dimensional 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 show 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[7].

Yu and K. T. Chan [7] 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. Results were predicted that the use of the evaporative cooler results in an increase in the refrigeration effect.

1.1 Tetrafluoroethane-R134a

Synthetic refrigerants that were commonly used for refrigeration, cold storage and air conditioning applications are: R 11 (CFC 11), R 12 (CFC 12), R 22 (HCFC 22), R 502 (CFC 12+HCFC 22) etc. However, these refrigerants have to be phased out due to their Ozone Depletion Potential (ODP). The synthetic replacements for the older refrigerants are: R-134a (HFC-134a) and blends of HFCs. Generally, synthetic refrigerants are non-toxic and non-flammable. However, compared to the natural refrigerants the synthetic refrigerants offer lower performance and they also have higher Global Warming Potential (GWP).

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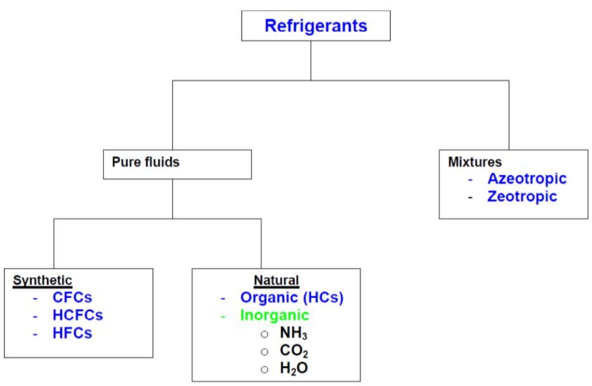
1.2 Environmental and safety properties of refrigerants

At present the environment friendliness of the refrigerant is a major factor in deciding the usefulness of a particular refrigerant. The important environmental and safety Properties are:

a) *Ozone Depletion Potential (ODP*): According to the Montreal protocol, the ODP of refrigerants should be zero, i.e., they should be non-ozone depleting substances.

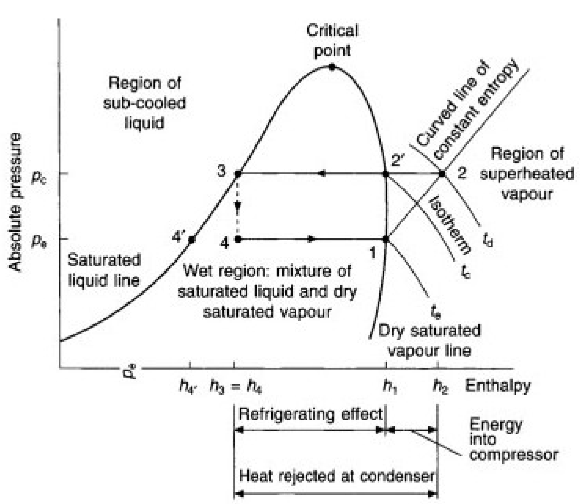


Refrigerants having non-zero ODP have either already been phased-out (e.g. R 11, R 12) or will be phased-out refrigerants such as CFCs and HCFCs are non-toxic when

Mixed with air in normal condition.

2. Theoretical analysis

Simple vapour compression cycle:



COP (Coefficient of Performance)**-** it is a performance parameter of simple VC Cycle. If refrigerating effect is increases or work input is decreases than performance of simple VC Compression cycle are increases.

in near-future(e.g. R22). Since ODP depends mainly on the presence of chlorine or bromine in the molecules, refrigerants having either chlorine (i.e., CFCs and CFCs) or bromine cannot be used under the new regulations

b) *Global Warming Potential (GWP):* Refrigerants should have as low a GWP value as possible to minimize the problem of global warming. Refrigerants with zero ODP but a high value of GWP (e.g. R134a) are likely to be regulated in future.

c) *Total Equivalent Warming Index (TEWI):* The factor EWI considers both direct and indirect (through energy consumption) contributions of refrigerants to global warming. aturally, refrigerants with as a low a value of TEWI are preferable from global warming
point of view.

d) *Toxicity:* Ideally, refrigerants used in a refrigeration system should be nontoxic.However, all fluids other than air canbe called as toxic as they will cause suffocation when their concentration is large enough. Thus toxicity is a relative term,which becomes meaningful only when the degree of concentration and time of exposure required to produce harmful effects are specified. Some fluids are toxic even in small concentrations. Some fluids are mildly toxic, i.e., they are dangerous only when the concentration is large and duration of exposure is long.Some

This work, diffuser is installed at condenser inlet. In vapour compression refrigeration system, condenser is used to remove heat from high pressure vapour refrigerant and converts it into high pressure liquid refrigerant. The refrigerant flows inside the coils of condenser and cooling fluid flows over the condenser coils. Condenser used in domestic vapour compression refrigeration system is air cooled condenser, which may be naturally or forced air cooled. Heat transfer occurs from the refrigerant to the cooling fluid. High pressure liquid refrigerant flows through an expansion device to obtain low pressure refrigerant. Low pressure refrigerant flows through the evaporator. Liquid refrigerant in the evaporator absorbs latent heat and get converted into vapour refrigerant which returns to compressor. Compressor raises the pressure and temperature of the vapour refrigerant and discharges it into the condenser to complete the cycle [9,10].

Diffuser is the static device. It raises the pressure of flowing fluid by converting its kinetic energy. In vapour compression refrigeration system, to avoid the problems of high velocity refrigerant, one of the ways is to use diffuser at condenser inlet. It smoothly decelerates the incoming refrigerant flow achieving minimum stagnation pressure losses and maximizes static pressure recovery [11]. Due to pressure recovery, at same refrigerating

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effect, compressor has to do less work. Hence, power consumption of the compressor will be reduced which results improvement in system efficiency. As the refrigerant flow passes through the diffuser, pressure as well as temperature will be increased. In air cooled condenser, for constant air temperature, temperature difference between hot and cold fluid will be increased. Amount of heat rejected from condenser will be rise. To remove the same amount of heat, less heat transfer area will be required. Using the diffuser at condenser inlet will provide an opportunity to use a smaller condenser to achieve the same system efficiency. Use of diffuser will also provide an advantage of reducing the effect of starvation in vapour compression refrigeration systems [12].The cross-sectional area of diffuser should reduce in the flow direction for supersonic flows and should increase for. The velocity of refrigerant leaving the compressor is sub-sonic. Hence, cross-sectional area of diffuser should be increasing.

Vapor compression cycle using diffuser:

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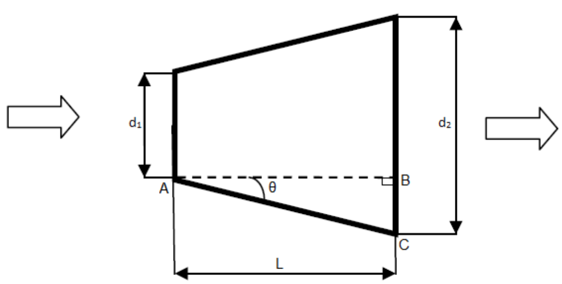
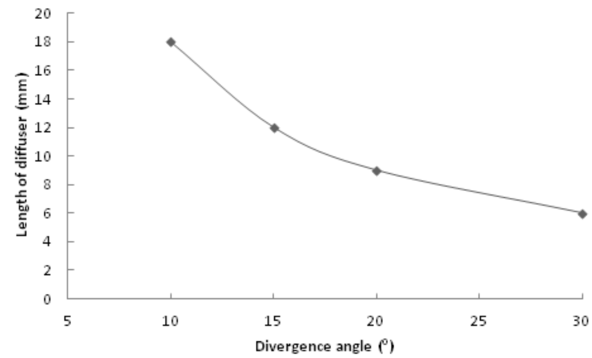


Geometry of Diffuser

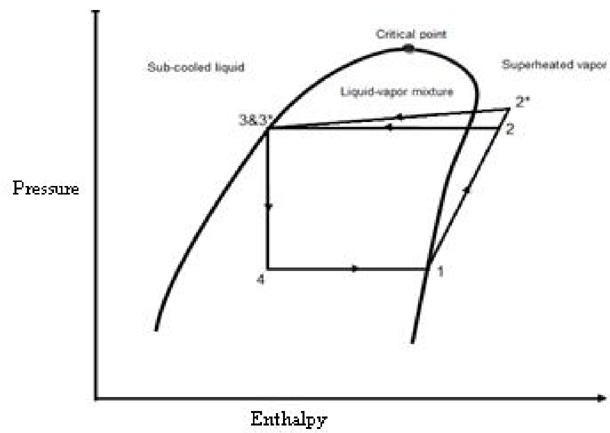
Diffuser's inlet and outlet diameters were designed. To design length of diffuser equation 1 is developed from figure1:

$L = AB = (d_2 - d_1/2)/\tan\theta$

Relation between length and divergence angle of diffuser plotted as shown in Figure 2. With increase in divergence angle of diffuser, its length is reduced for same inlet and outlet diameters.



Relation between length and divergence angle of diffuser(13)



ph diagram- VCRS with diffuser at outlet of compressor

In above Figure , points 1, 2, 3, 4, 2*, and 3* represent states of refrigerant at compressor inlet, compressor outlet, condenser outlet, evaporator inlet, diffuser inlet and diffuser outlet respectively. Cycle 1-2-3-4-1 is for simple vapour compression refrigeration system and cycle 1-2*-3*-4-1 is for vapour compression refrigeration system with diffuser at condenser inlet.

3. CONCLUSION

By using diffuser after compressor, velocity of vaporised R134a is converted into pressure energy. Some part of required pressure increases in diffuser and some part of pressure increases in compressor so compressor work is decreases or power consumption is decreases. As COP is the ratio of Refrigeration effect to work input. Thus performance or COP is increases.

COP of Vapor Compression Cycle is increased by lowering the power consumption /work input or increasing the refrigerating effect. By using diffuser with divergence angle 15 deg[13] at compressor outlet refrigerating effect increases and power consumption or work input decreases for domestic refrigerant R134a. Thus performance of cycle is improved.

High velocity refrigerant has various serious affect on vapor compression refrigeration system such as liquid turbulence ,undesirable splashing of the liquid refrigerant in the condenser and damage to the condenser tubes by vibration,pitting and erosion. Diffuser is such a device to reduce velocity of refrigerant is the conversion of some amount of kinetic energy into pressure energy without work consumption.

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