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Improving the COP of VCRS by use of heat exchanger and water cooling

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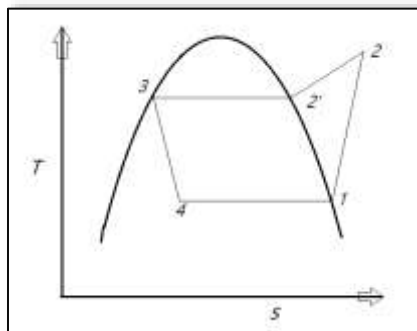
Abstract: This paper focus on the enhancement in the coefficient of performance of a vapour compression refrigeration system. There have been a lot of researches to enhance the coefficient of performance of VCR system, some of these were successful. After reading some of the latest researches over this topic, we found that more improvement could be done. With this aspect, we started working over this project and prepared another design that support my aim. And finally under the guidance of my faculty and some of the experienced worker in the refrigeration field I have reviewed and optimize the design and ultimately fabricated it and calculated the result.

Keywords: Coefficient of performance (COP), water cooled Condenser, heat exchanger, enthalpy (h), Refrigerant(R-134a)

I. Introduction

The Refrigeration system works on the second law of the thermodynamics i.e., Clausius statement, which says refrigeration system is a reverse heat engine that takes energy in the form of work to transfer heat from low temperature body to high temperature body.

Theoretical cycle:



1 - 2: Compressing of refrigerant from evaporator outlet to condenser inlet

2 - 2': Condensing of dry saturated vapor refrigerant to the state of liquid + vapor.

2' - 3: Condensing of refrigerant from liquid + vapor phase to saturated liquid phase.

3 - 4: Pressure drop from condenser outlet to evaporator inlet.

4 - 1: Evaporator coil provide cooling effect.

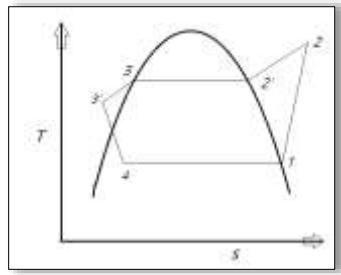
Coefficient of performance:

$$\text{COP} = \frac{\text{Refrigeration effect}}{\text{Net work done}} = \frac{h_1 - h_4}{h_2 - h_1}$$

II. Methodology used to improve COP

The coefficient of performance of an ideal vapor compression refrigeration cycle can be enhanced just by working over the temperature and pressure of the refrigerant flowing in the setup.

For a fixed compressor selection, one only can vary the temperature of the refrigerant. By cooling the refrigerant after the compressor discharge will be effective for improving the coefficient of performance of refrigeration system.



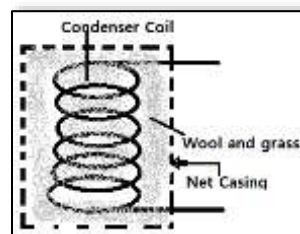
This is graph of refrigeration system, in which the refrigerant is being sub cooled.

Sub cooling in the refrigerant enhance the refrigeration effect whereas the work done is remain same for an ideal refrigeration cycle.

But in practical refrigeration cycle most common problem is that, there is a superheating occurs in the refrigerant entering the compressor suction, and this generally increases the work taken by the compressor and this phenomenon will affect the coefficient of performance of a refrigeration cycle.

III. Vapor Compression Refrigeration cycle with sub cooling

Sub cooling can be done before expansion of the refrigerant in the cycle. Here we tried to sub cool the refrigerant by installing heat exchanger and water cooling the condenser. There can be a slight change in the design of the condenser. The condenser can be made water cooled instead of air cooled. Water cooling in the condenser will provide force convection and thus cool the refrigerant and will be in the favor of COP improvement. The water used in cooling the condenser coil can be stored in the storage tank and can be reused again and again over the condenser pipe. The wool and the grass used in normal coolers for cooling purpose can be inserted in between the condenser coil and net shape casing of the condenser cooler, this can be useful in breaking the water drops into very small droplets thus enhancing the surface area of the droplets and such that these droplets will spread more over the condenser coil and thus take more heat from the coil and can be easily cooled in the atmosphere because of their size. Ultimately the water reach in the storing tank will be cooled as ambient temperature.



Design of Condenser cooler

The above diagram shows a method to make the condenser cooler, and same was adopted by us in designing the condenser. The next device for sub cooling is heat exchanger which can be used if the evaporator didn't transfer lot of heat in the cooling place, so heat exchanger can be used to utilize the cold refrigerant from the evaporator outlet to receive the heat from the condenser outlet.

This process will have two benefits, first is phase of refrigerant transferred to compressor suction will be in vapor and will improve the life of compressor. And next is sub cooling of the refrigerant.

This process will have one disadvantage that, if the refrigerant will be superheated it will increase the energy taken by the compressor thus reducing the COP.

There are many types of heat exchanger available, but pipe in pipe type or tube in tube annulus type or concentric tubes type heat exchanger can be beneficial for this purpose.

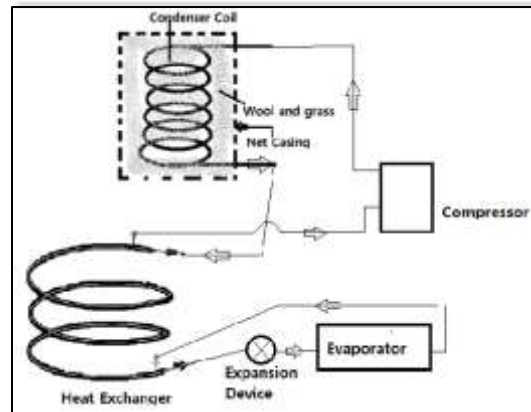
There are two methods to flow the refrigerant in the heat exchanger, first is parallel flow and next is counter flow. But in counter flow the effectiveness of the heat exchanger is more as compared to parallel flow.



Design of heat exchanger

IV. Complete Setup

The setup of a vapor compression refrigeration system consists of general components other than heat exchanger and the modified design of condenser.



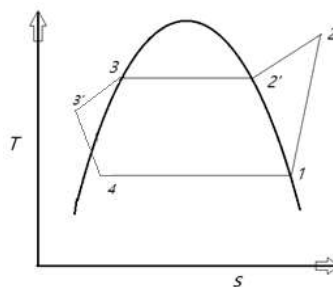
The above diagram shows the actual connections of all the components to form a complete setup of a vapor compression refrigeration system.

Working: In this setup pure vapor refrigerant is transferred to the compressor suction, compressor compresses the vapor refrigerant and transfers it to the condenser where the temperature of the refrigerant reduces due to cooling provided by the water and thus phase change becomes more easier and refrigerant is cooled to ambient temperature. After condenser, refrigerant enters the heat exchanger where heat is being exchanged between the condenser outlet and evaporator outlet, thus sub-cooling the refrigerant. And then after expansion, the temperature of the refrigerant drops immensely and then refrigerant is transferred to the evaporator coil for the refrigeration effect. After evaporator outlet, refrigerant is again transferred to the heat exchanger for exchanging heat with refrigerant from the condenser outlet, and ultimately the outlet is connected to the compressor, and this cycle repeats.

Refrigerant:

Refrigerant used here is R-134a which is a more reliable refrigerant and also does not have chlorine atoms which deplete the ozone. R-134a is non-corrosive and incombustible.

Result and discussion:



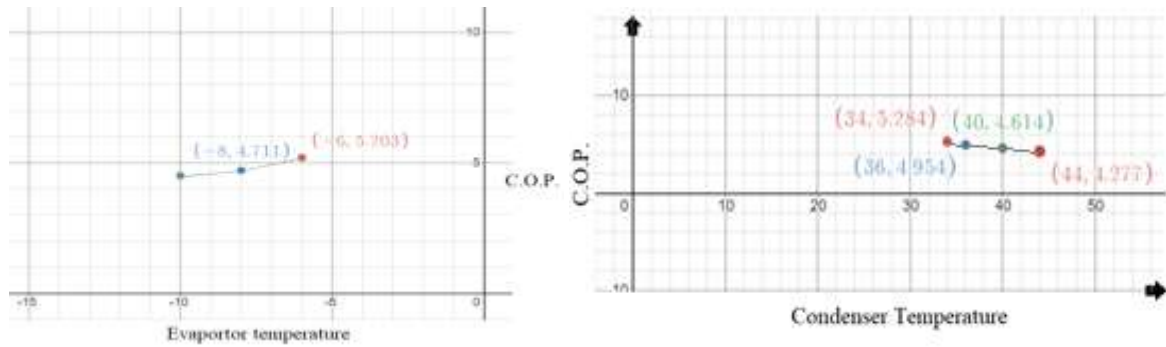
This is how the T-S graph of this VCRS design will be considered.

Experimental value for finding COP

$$\begin{aligned}
 T_1 &= -8^\circ\text{C} & h_1' &= 416.154 \text{ KJ/Kg} \\
 T_1' &= 18^\circ\text{C} & h_2 &= 445.821 \text{ KJ/Kg} \\
 T_2' &= 34^\circ\text{C} & h_4 = h_3' &= 237.201 \text{ KJ/Kg} \\
 T_3' &= 27^\circ\text{C} & h_1 = h_g(-8^\circ\text{C}) &= 293.95 \text{ KJ/Kg} \\
 T_2 &= 334.639 \text{ K}
 \end{aligned}$$

$$\text{C.O.P}_{\text{SUBCOOLING}} = 5.2836$$

$$\text{C.O.P}_{\text{WITHOUT WATER COOLING}} = 4.3475$$



V. Conclusion

Sub cooling in the VCRS cycle will improve to COP of the refrigeration system, and while using the heat exchanger there can be superheating in the refrigerant which in favor. If superheating is less and can be negligible so experiment in this setup will be successful. COP improvement also depends on the selection of proper refrigerant. The different components used in system should be selected according to the use, like compressor should be selected according to the requirement for cooling the room, the design of coils of condenser and evaporator should be pre analyzed according to the size of compressor.

VI. References

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