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Review on Comparative Analysis of COP of Vapour Compression Refrigeration System

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Abstract - *Literal meaning of refrigeration is the production of cold confinement relative to its surroundings. In this, temperature of the space under consideration maintained at a temperature lower than the surrounding atmosphere. This paper presents a theoretical performance study of a vapour compression refrigeration system with refrigerants R134a, R407c and R410a. R134a is the most commonly used refrigerant for vapour compression system but it has some harmful effect on environment like Ozone layer depletion and green house effect. R410a and R407c are eco friendly refrigerant and has no harmful effects. The variation of COP with respect to the evaporating temperature is shown in this report for systems using different refrigerant and in the result we will find the best option in terms of performance and environmental aspects.*

Key Words: Refrigerator, Vapour Compression, COP.

1. INTRODUCTION

A refrigerator is a cooling appliance comprising a thermally insulated compartment and a mechanism to transfer heat from it to the external environment, cooling the contents to a temperature below ambient. The refrigerator is one of the most innovative and important inventions of the twentieth century. Refrigerators are extensively used to store foods which deteriorate at ambient temperatures. Before the invention of the refrigerator, icehouses were used to provide cool storage for most of the year. After that, the first known artificial refrigeration was demonstrated by William Cullen at the University of Glasgow, Scotland in 1748. In 1805, Oliver Evans designed refrigerator based on a closed cycle of compressed ether, represented the first effort to use simple vapor instead of vaporizing a liquid. After that, in 1857, James Harrison introduced vapor-compression refrigeration to the brewing and meat packing industries.

Start of the 20th Century, all refrigerator use the vapor-compression refrigeration cycle until now. The design for contemporary refrigerator is based on two basic laws of physics: first, that heat flows from warmer material to cooler materials and never the reverse; second, which decreasing the pressure of a gas also decreases its temperature [1]. The refrigerator is a relatively modern invention amongst kitchen appliances. It replaced the common icebox which had been placed outside for almost a century and a half prior. In the refrigeration systems typically include a compressor, a condenser, an expansion valve (capillary tube), and an evaporator. All components interconnected to form a fluid circuit. Cooling is accomplished through evaporation of a liquid refrigerant under reduced temperature and pressure.

The raw material in refrigerators today consists of several basic components: the exterior cabinet and door, the inner cabinet or liner, the insulation inserted between the two, the cooling system, the refrigerant, and the fixtures. The cabinet and door are made of aluminum or steel sheet metal that is sometimes prepainted. The inner cabinet is made of sheet metal, like the outer cabinet, or of plastic. The insulation that fills the gap between the inner and outer cabinets consists of fiberglass or polyfoam [2]. The components of the cooling system (compressor, condenser, coils, and fins) are made of aluminum, copper, or an alloy. Freon is most commonly used refrigerant, and almost all of the large interior fixtures (door and cabinet liners) are made from vacuum-formed plastic.

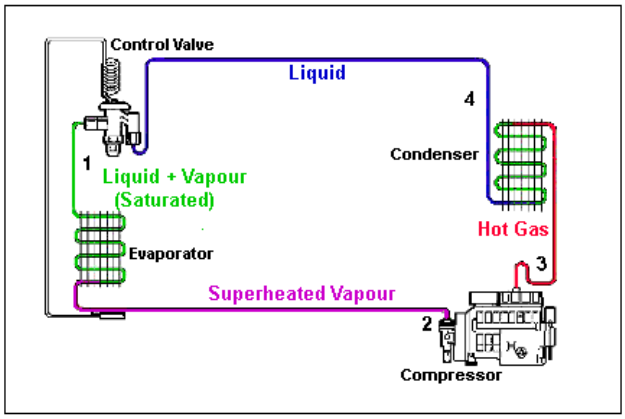


Fig. 1. Basic Refrigeration System

2. BASIC COMPONENT OF REFRIGERATOR

Refrigeration systems typically include a compressor, a condenser, an expansion valve, and an evaporator; all of these components are interconnected to form a fluid circuit [3].

2.1 Compressor

A refrigerant compressor as the name indicates is a machine used to compress the vapour refrigerant from the evaporator and to raise the pressure so that the corresponding saturation temperature is higher than that of

the cooling medium. The refrigeration process is, as implied, a closed circuit. It also continually circulates the refrigerant through the refrigerating system. Since the compression of refrigerant requires some work to be done on it, therefore a compressor are must be driven by some prime mover [4].

The refrigerant is not allowed to expand to free air. When the refrigerant coming from the evaporator is fed to a tank the pressure in the tank will rise until it equals the pressure in the evaporator. Therefore, refrigerant flow will cease and the temperature in both tank and evaporator will gradually rise to ambient[5]. To maintain a lower pressure, and, with it a lower temperature it is necessary to remove vapour [6][7]. This is done by the compressor, which sucks vapour away from the evaporator. In simple terms, the compressor can be compared to a pump that conveys vapour in the refrigeration circuit. Fig. 2 shows the basic compressor system [8][9].

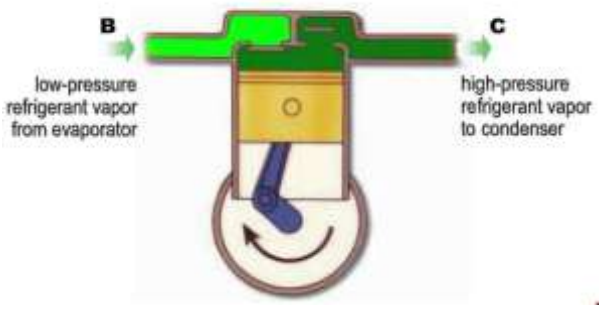


Fig -2: Basic Compressor System

In a closed circuit a condition of equilibrium will always prevail. To illustrate this, if the compressor sucks vapour away faster than it can be formed in the evaporator the pressure will fall and with it the temperature in the evaporator. Conversely, if the load on the evaporator rises and the refrigerant evaporates quicker, the pressure with it the temperature in the evaporator will rise.

2.2 Condenser

The condenser is an important device used in high pressure side of a refrigeration system. Its function is to remove heat of the hot vapor refrigerant discharge from the compressor. The heat from the hot vapour refrigerant in a condenser is removed first by transferring it to the walls of the condenser tubes and then from the tubes to the condensing or cooling medium [10]. The selection of a condenser depends upon the capacity of refrigeration system, and the type of refrigerant used and the type of cooling medium available. The refrigerant gives off heat in the condenser, and this heat is transferred to a medium having a lower temperature. Fig. 3 shows the basic condenser system.

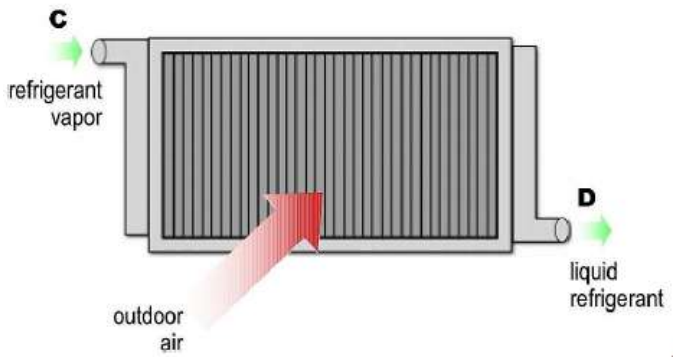


Fig -3: Basic Condenser System

The amount of heat given off is the heat absorbed by the refrigerant in the evaporator plus the heat created by compression input. The heat transfer medium can be air or water, the only requirement being that the temperature is lower than that which corresponds to the condensing pressure. The process in the condenser can otherwise be compared with the process in the evaporator except that it has the opposite "sign", i.e. the conditional change is from vapour to liquid[9].

2.3 Evaporator

The evaporator is used in the low vapour side of refrigeration system. The liquid refrigerant from the expansion valve enters in to the evaporator where it boils and changes in to vapour. The function of evaporator is absorbing heat from the surrounding location of medium which is cooled, by means of refrigerant. A simple refrigerant circuit is built up as shown in the sketch below. In what follows, the individual components are described to clarify a final overall picture[10]. A refrigerant in liquid form will absorb heat when it evaporates and it is this conditional change that produces cooling in a refrigerating process.

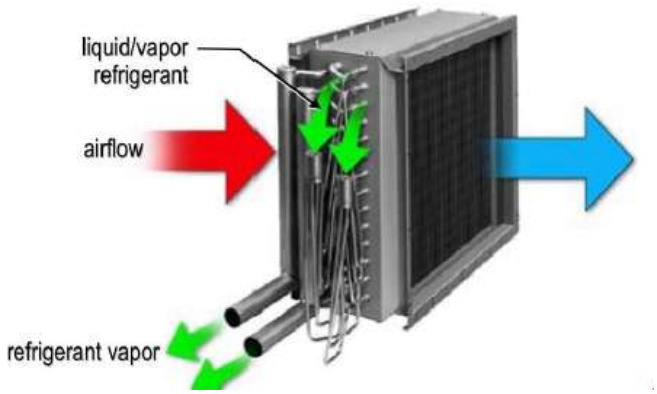


Fig -4: Basic Evaporator System

If a refrigerant at the same temperature as ambient is allowed to expand through a hose with an outlet to atmospheric pressure, heat will be taken up from the

surrounding air and evaporation will occur at a temperature corresponding to atmospheric pressure. If in a certain situation pressure on the outlet side (atmospheric pressure) is changed, a different temperature will be obtained since this is analogous to the original temperature - it is pressure dependent [11]. The component where this occurs is the evaporator, whose job it is to remove heat from the surroundings, i.e. to produce refrigeration. The evaporator becomes cold and remains cold due to following reason-

- The temperature of the evaporator coil is low due to the low temperature of the refrigerant inside the coil.
- The low temperature of the refrigerant remains unchanged because any heat it absorbs is converted in to latent heat as boiling proceeds.

2.4 Expansion Device

The expansion device also known as the metering device or throttling device it is an important device that divides the high pressure side and the low pressure side of refrigerating system. It is connecting between the receivers (containing liquid refrigerant at high pressure) and the evaporator (containing liquid refrigerant at low pressure). The expansion device performs following functions-

- It reduce high pressure liquid refrigerant to low pressure liquid refrigerant before being fed in to evaporator.
- It maintains the desired pressure difference between the high and low pressure sides of the system, so that liquid refrigerant vaporize at the designed pressure in the evaporator.

It controls the flow of refrigerant according to the load on the evaporator.

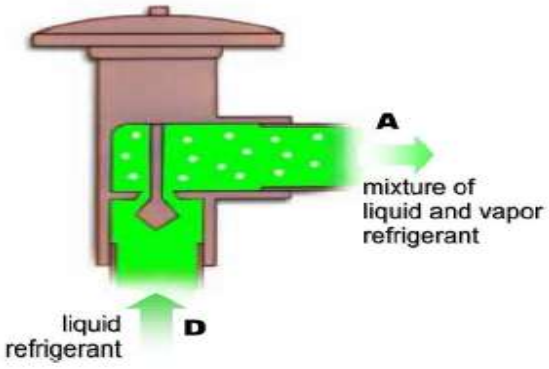


Fig -5: Basic Expansion Device System

Pressure in the receiver is much higher than the pressure in the evaporator because of the compression (pressure increase) that has occurred in the compressor. To reduce pressure to the same level as the evaporating pressure a device must be inserted to carry out this process, which is called throttling, or expansion [7]. Such a device is therefore known either as a throttling device or an expansion device. As a rule a valve is used a throttle or expansion valve. Ahead of the expansion valve the liquid will be a little under boiling point. By suddenly reducing pressure a conditional change will occur; the liquid begins to boil and evaporate. This evaporation takes place in the evaporator and the circuit is thus complete. Fig. 5 shows the expansion device system.

2.5 Refrigerant

Refrigerant is a heat transporting medium which during their cycle (compression, condensation, expansion and evaporation) in the refrigeration system absorbs heat from a low temperature system and discard the heat so absorbed to a to a higher temperature system.

3. VAPOUR COMPRESSION REFRIGERATION

A vapor compression cycle that is used in most household refrigerators, freezers and cold storages. The performance of a simple vapour compression refrigeration system, used in numerous of small refrigeration applications all over the world. In this cycle a circulating refrigerant enters a compressor as low pressure vapor at or slightly above the temperature of the refrigerator interior. The vapor is compressed and exits the compressor as high-pressure superheated vapor. The refrigerant, while passing through the condenser, gives up its latent heat to the surrounding condensing medium which is normally air or water. The condenser cools the refrigerant vapor, which then liquefies. This liquid refrigerant is forced through a metering or throttling device, also known as an expansion valve (essentially a pin-hole sized constriction in the tubing) to an area of much lower pressure [12].

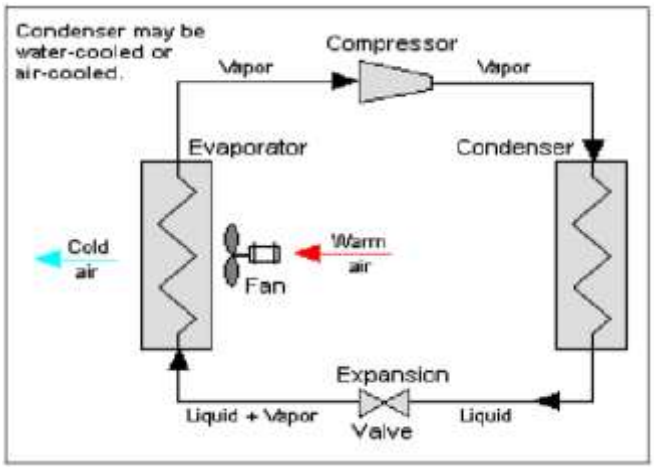


Fig -6: Schematic Vapour Compression Refrigeration

The sudden decrease in pressure results in explosive-like flash evaporation of a portion (typically about half) of the liquid. During evaporation, the liquid vapor refrigerant

absorbs its latent heat of vaporization from the product which is to be cooled. This phenomenon known as "auto-refrigeration"[9]. The typical lay out of the Vapour compression system in shown in Fig. 6. Refrigerant leaves the evaporator, now fully vaporized and slightly heated and returns to the compressor inlet to continue the cycle. In order for the vapour compression cycle to operate successfully each component must be present within the vapour compression system. Fig. 7 shows the basic vapour compression refrigeration system.

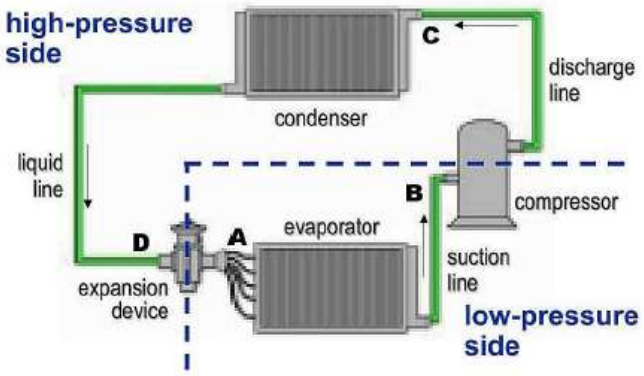


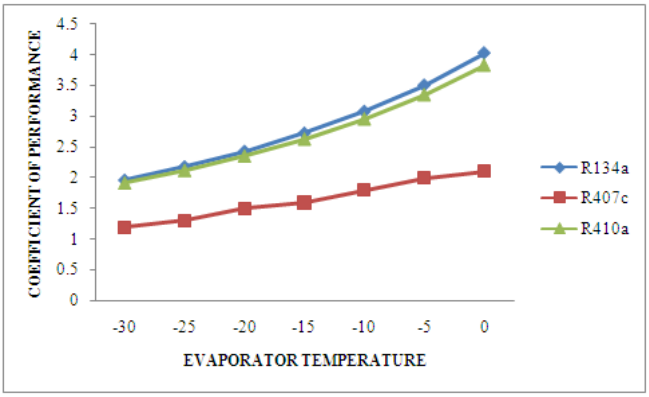
Fig -6: Basic Vapour Compression Refrigeration

4. COMPARATIVE ANALYSIS FOR COP

The COP is defined as the refrigerating effect over the net work input. Coefficient of performance is commonly used to calculate the performance of vapour compression system. The energy analysis based on first law of thermodynamic, the performance of vapour compression refrigeration system can be predicted in terms of Coefficient of Performance (COP), which is defined as the ratio of net refrigerating effect produced by the refrigerator to the work done by the compressor [8]. It is expressed as:

$$COP = \frac{\text{Cooling effect (kw)}}{\text{Power input to compressor (kw)}}$$

From the graphical representation & tabulation showing comparison of all configurations, it is observed that three refrigerants in vapour compression system – R134a, R410a, R407c, showing relationship in terms of coefficient of performance with respect to evapourated temperature. In this analysis refrigerant R134a having highest coefficient of performance (COP) than the other two refrigerants.



Refrigerant (Category)	Chemical formula	Boiling point(°C)	Critical Temperature(°C)
R134a(HFC)	CF3CH2F	-26.07	101.06
R407c	CH3CHF2	–43.56	86.74
R410a	C3F4H2	–51.6	72.5

Chart -1: Properties of all Refrigerants

5. CONCLUSION

The refrigerator is one of the most innovative and important inventions of the twentieth century. Refrigerators are extensively used to store foods which deteriorate at ambient temperatures. Before the invention of the refrigerator, icehouses were used to provide cool storage for most of the year. Refrigeration systems typically include a compressor, a condenser, an expansion valve, and an evaporator; all of these components are interconnected to form a fluid circuit. In this report a comparative analysis have been done for calculating COP in vapour compression refrigeration.

From the above study we can say that the COP of R134a is highest among R134a, R407c and R410a. However the COP of R410a is comparable to R134a so it can be a replacement for R134a as R410a has less ODP as compare to R134a. But R134a is the best option as refrigerant in case of vapour compression systems as the availibilty of R134a much higher than any other refrigerant.

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BIOGRAPHIES

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