PARAMETRIC STUDY OF VAPOUR COMPRESSION REFRIGERATION SYSTEM BY USING DIFFERENT CAPILLARY & REFRIGERANTS

R. M. Rathod, Omkar Pawar, Pravin Pawar, Gourav Ranaware, Yogesh Kakade

ABSTRACT

Refrigeration is the comfort for the a human being. A refrigerator is a system used for cooling of food products for the both domestic and commercial appliances utilizing mechanical vapour compression Cycle in its process. For the better performance optimization of the system becomes main issue and many researches are still ongoing to improve efficiency of the system. The main objective of this work is to enhance the performance of the domestic refrigerator by flooding the evaporator with liquid refrigerant. The performance of refrigerator is evaluated with and without low pressure receiver. To attain this objective a low pressure vessel is designed, developed, fabrication and incorporated between evaporator and compressor. Also analysis is carried using two different refrigerants (R134a, and R404a) & different dia. of capillary tube. From the results it is found that COP, refrigeration of the system improves with the installation of low pressure receiver. Also the system gets benefited in the form of decrease in compressor work with the installation of low pressure receiver. Comparing the performance parameters of the refrigeration system with different refrigerants & different capillary tube will get that R404a gives optimum performance over the R134a.

Index Terms—Refrigerator; vapor compression Cycle; R134a, and R404a; COP

Reference to this paper should be made as follows:


Biographical notes:

R. M. Rathod, Asst. Professor in Department of Mechanical Engineering, JSPM Narhe Technical Campus, Pune, India.

Omkar Pawar, Pravin Pawar, Gourav Ranaware, Yogesh Kakade are scholars in Department of Mechanical Engineering, JSPM Narhe Technical Campus, Pune, India.

Published by: International Associations of Professionals and Technical Teachers (IAPATT)
1. INTRODUCTION

Refrigeration: Refrigeration may be defined as the process of achieving and maintaining a temperature below that of the surroundings, the aim being to cool some product or space to the required temperature. One of the most important applications of refrigeration has been the preservation of perishable food products by storing them at low temperatures. Refrigeration systems are also used extensively for providing thermal comfort to human beings by means of air conditioning [1,2] Air Conditioning refers to the treatment of air so as to simultaneously control its temperature, moisture content, cleanliness, odor and circulation, as required by occupants, a process, or products in the space [3,4,5]. The subject of refrigeration and air conditioning has evolved out of human need for food and comfort, and its history dates back to centuries. The history of refrigeration is very interesting since every aspect of it, the availability of refrigerants, the prime movers and the developments in compressors and the methods of refrigeration all are a part of it [6,7].

A simple vapour compression refrigeration system consists of mainly five components namely compressor, condenser, expansion device, evaporator and a filter/drier. A capillary tube is a small diameter tube which is used for the expansion of the flowing fluid. The pressure difference between the entry and exit ends of the capillary tube is always equal to the pressure difference between the condenser and the evaporator. Background the first mechanically produced cooling system was developed in England in 1834. The system later became known as vapor compression. After availability of electricity automatic refrigeration system was developed in 1897. Air conditioning and refrigeration systems play an important role in industry, commercial infrastructure and households. The industrial sector includes the food industry, textiles, chemicals, printing, transport and others. Infrastructure includes banks, restaurants, schools, hotels and recreational facilities [8,9,10].

2. VAPOUR COMPRESSION REFRIGERATION SYSTEM

A. System: The most commonly used method of cooling is with vapor-compression cycles, because it is fairly easy to construct a cooling device employing this method and the cost is low. In fact, conventional refrigerators use this method of cooling to keep your leftovers and drinks chilled! Air conditioners also employ a vapor-compression cycle to cool the ambient air temperature in a room.

Basically, vapor-compression refrigeration employs a heat engine run backwards, so heat energy is taken from a cold reservoir and deposited into a hot reservoir. By the Second Law of Thermodynamics, heat energy does not spontaneously transfer from a cold to a hot reservoir. In order to have heat transfer in that direction (and not from hot to cold, as the system is naturally inclined to do), it is necessary to do work on the system.

B. Vapor-Compression Refrigeration Cycle: This refrigeration cycle is approximately a Rankine cycle run in reverse. A working fluid (often called the refrigerant) is pushed through the system and undergoes state changes (from liquid to gas and back). The latent heat of vaporization of the
refrigerant is used to transfer large amounts of heat energy, and changes in pressure are used to control when the refrigerant expels or absorbs heat energy. However, for a refrigeration cycle that has a hot reservoir at around room temperature (or a bit higher) and a cold reservoir that is desired to be at around 34°F, the boiling point of the refrigerant needs to be fairly low.

Fig. 1 Vapor-Compression Refrigeration Cycle

A. Stages of the Vapor-Compression Refrigeration Cycle

Stage 1: Compression
In this stage, the refrigerant enters the compressor as a gas under low pressure and having a low temperature. Then, the refrigerant is compressed adiabatically, so the fluid leaves the compressor under high pressure and with a high temperature.

Stage 2: Condensation
The high pressure, high temperature gas releases heat energy and condenses inside the "condenser" portion of the system. The condenser is in contact with the hot reservoir of the refrigeration system. (The gas releases heat into the hot reservoir because of the external work added to the gas.) The refrigerant leaves as a high pressure liquid.

Stage 3: Throttling
The liquid refrigerant is pushed through a throttling valve, which causes it to expand. As a result, the refrigerant now has low pressure and lower temperature, while still in the liquid phase. (The throttling valve can be either a thin slit or some sort of plug with holes in it. When the refrigerant is forced through the throttle, its pressure is reduced, causing the liquid to expand.)

Stage 4: Evaporation
The low pressure, low temperature refrigerant enters the evaporator, which is in contact with the cold reservoir. Because a low pressure is maintained, the refrigerant is able to boil at a low temperature. So, the liquid absorbs heat from the cold reservoir and evaporates. The refrigerant leaves the evaporator as a low temperature, low pressure gas and is taken into the compressor again, back at the beginning of the cycle.
3. COMPONENTS OF VAPOUR COMPRESSION REFRIGERATION SYSTEM

1. Compressor
2. Condenser
3. Throttling device
4. Evaporator

Reciprocating compressor is the workhorse of the refrigeration and air conditioning industry. It is the most widely used compressor with cooling capacities ranging from a few Watts to hundreds of kilowatts. Modern day reciprocating compressors are high speed (~3000 to 3600 rpm), single acting, single or multi-cylinder (up to 16 cylinders) type.

1. Condenser

Condenser is an important component of any refrigeration system. In a typical refrigerant condenser, the refrigerant enters the condenser in a superheated state. It is first de-superheated and then condensed by rejecting heat to an external medium. The refrigerant may leave the
condenser as a saturated or a sub-cooled liquid, depending upon the temperature of the external medium and design of the condenser.

2. Throttling device
The refrigerant leaving the throttling valve enters the evaporator at low pressure, low temperature and partially liquid and vapor state. The throttling valve also controls the amount of the refrigerant flowing through it and to the evaporator. A thermal expansion valve is a component in refrigeration and air conditioning systems that controls the amount of refrigerant released into the evaporator thereby controlling superheat.

Fig 5: Throttling device

3. Evaporator
The evaporator is main component of a refrigeration system in which heat is removed from air, water or any other body required to be cooled by the evaporating refrigerant. The refrigerant boils or evaporates in this component and absorbs heat from the substance being cooled which is the main purpose of a refrigeration system. The name evaporator refers to the evaporation process occurring in the heat.

4. REFRIGERANT
A refrigerant is the medium of heat transfer, which absorbs heat by evaporating at low temperatures and give out heat by condensing at high temperature and pressure conditions. A refrigerant must meet certain chemical, physical and thermodynamic properties so that it can be used suitably in the vapour compression cycle. A good refrigerant should have safe working properties apart from having economic aspects.
Desirable properties of good refrigerant:
A. Thermodynamic Properties
1. Boiling Point: It should have Low Boiling Point.
2. Freezing Point: It should be below the Evaporator temperature.
3. Evapourative Pressure: It should be above Atmospheric pressure.
4. Condensing Pressure: It should have LOW Condensing pressure.
5. Latent Heat of Vapourasion: It should have HIGH Latent heat of Vapourisation.
6. Critical Temperature & Pressure: It should be above the condensing Temperature & Pressure.
B. Chemical Properties
1. Toxicity: It should not be Poisonous or injurious. It should not be non-irritating to eyes.
2. Corrosiveness: It should not be corrosive & should not have any effect on materials used in equipment.
3. Leak Detection: It should have fewer tendencies to leak & if it is leaking it should be easily detectable.
4. Flammability: It should not be Inflammable.
5. Miscibility with Oil: It should be immiscible with oil & should not have any effect on the properties of Oil used for Lubrication.
6. Effect on Foodstuff: It should not affect on food articles or make them poisonous or unportable.
Stability: It should be capable of withstanding high pressure & temperature.

C. Physical Properties
1. Specific Volume: It should be LOW in Vapour state.
2. Viscosity: It should have LOW viscosity.
3. Thermal Conductivity: It should have HIGH Thermal Conductivity.
4. Di-Electric Strength: It should have High strength.

5. REFRIGERANT USED IN PROJECT

A. R134a: R134a is also known as Tetra-fluoro-ethane (CF3CH2F) from the family of HFC refrigerant. With the discovery of the damaging effect of CFCs and HCFCs refrigerants to the ozone layer, the HFC family of refrigerant has been widely used as their replacement.
It is now being used as a replacement for R-12 CFC refrigerant in the area of centrifugal, rotary screw, scroll and reciprocating compressors. It is safe for normal handling as it is non-toxic, non-flammable and non-corrosive.
It exists in gas form when expose to the environment as the boiling temperature is -14.9°F or -26.1°C.
This refrigerant is not 100% compatible with the lubricants and mineral-based refrigerant currently used in R-12. Design changes to the condenser and evaporator need to be done to use this refrigerant. The use of smaller hoses and 30% increase in control pressure regulations also have to be done to the system.

### TABLE 1. PROPERTIES OF R-134A

<table>
<thead>
<tr>
<th>No</th>
<th>Properties</th>
<th>R-134a</th>
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<tbody>
<tr>
<td>1</td>
<td>Boiling Point</td>
<td>-14.9°F or -26.1°C</td>
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<tr>
<td>2</td>
<td>Auto-Ignition Temperature</td>
<td>1418°F or 770°C</td>
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<tr>
<td>3</td>
<td>Ozone Depletion Level</td>
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<td>4</td>
<td>Solubility In Water</td>
<td>0.11% by weight at 77°F or 25°C</td>
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<td>5</td>
<td>Critical Temperature</td>
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<td>6</td>
<td>Cylinder Color Code</td>
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<tr>
<td>7</td>
<td>Global Warming Potential (GWP)</td>
<td>1200</td>
</tr>
</tbody>
</table>

B. R-404a: Application, Medium and low temperature commercial and industrial direct expansion refrigeration and ice machines.
<table>
<thead>
<tr>
<th>No</th>
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<th>R-404a</th>
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<tbody>
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<td>1</td>
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<td>-51.8°F</td>
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<td>2</td>
<td>Heat of Vaporization (bp, H)</td>
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<tr>
<td>3</td>
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<tr>
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<td>Molecular Weight</td>
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<td>Critical Temperature</td>
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<td>7</td>
<td>Global Warming Potential (GWP)</td>
<td>3920</td>
</tr>
</tbody>
</table>

6. COMPONENT SPECIFICATIONS

The experimental consists of compressor, fan cooled condenser, expansion device and an evaporator section. Capillary tube is used as an expansion device. The evaporator is of rectangular type which is loaded with water. Service ports are provided at the inlet of expansion device and compressor for charging the refrigerant.

The component specifications are given below:

Compressor : Reciprocating compressor
Condenser  : Fin type Air cooled condenser
Liquid filter : Micro filler
Evaporator volume: 43.5×12×25 cm³
Evaporator capacity: 13 liters’ flask capacity
Pressure gauge : 0-35 kg/cm²
Thermometer : Digital thermometer
Energy meter : Single phase AC
Voltmeter : AC (Range 0-300 Volt)
Ammeter : AC (Range 0-5 Amps)

D. Experimental procedure

The procedure for the conduction of experiments is as follows:

1. A performance test is made with the system loaded with pure R134a.
2. The data is treated as the basis for the comparison with the refrigerant mixtures.
3. Another performance test is made with the system loaded with pure R-404a.
4. This data is also treated as the basic for the compression with the blended refrigerants.

1. Mixture of R-404a and R-134a by mass in the proportion 30:70, 50:50 and 70:30 was charged in the compressor and the performance tests were conducted.
2. All the tests were taken out at ambient temperature of 32°C.
3. Half the volume of the evaporator is loaded with water throughout the experiment.
4. The required data are collected and tabulated to find out COP of the system.
7. CONCLUSION

The overall performance of vapour system was evaluated by the refrigerant blends and the operational parameters such as energy consumption (input to the compressor) of the system. The coefficient of performance was calculated using the experimental readings and used to compare the COPs of the blends with that of individual refrigerants. The variations in COP of individual refrigerant and blended refrigerant. The COP of R404a seems to be maximum. The discharge temperature of R404a is slightly similar to the R134a.
REFERENCES