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Analysis of R410A and R404A in Domestic Refrigerator

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ABSTRACT:

In this work, an experimental work was investigated on the R-410A and R-404A which are eco friendly refrigerants and have zero ozone depletion potential and low global warming potential than R-134a used in a domestic refrigerator without any system reconstruction. The refrigerator performance was then investigated using energy consumption test and freeze capacity test. The results indicatethat R-410A and R-404A work normally and safely in the refrigerator. The refrigerator performance was better than the pure R404A, thus R-410A refrigerant in domestic refrigerators is feasible and can replace the R-134a. To do experiment some parameters like food compartment temperature, freezer compartment temperature, operating pressure, compressor temperature, condenser temperature are taken and performance analyzed.

1. INTRODUCTION

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. Air Conditioning refers to the treatment of air so as to simultaneously control its temperature, moisture content, cleanliness, odour and circulation, as required by occupants, a process, or products in the space. 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.

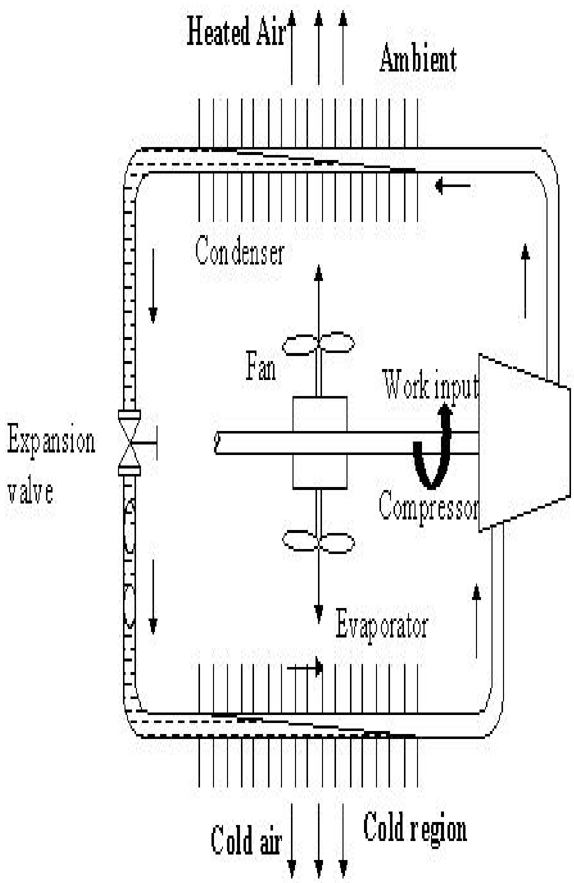


Fig 1.1 Layout of Air Conditioning System

VAPOUR ABSORPTION REFRIGERATION SYSTEMS:

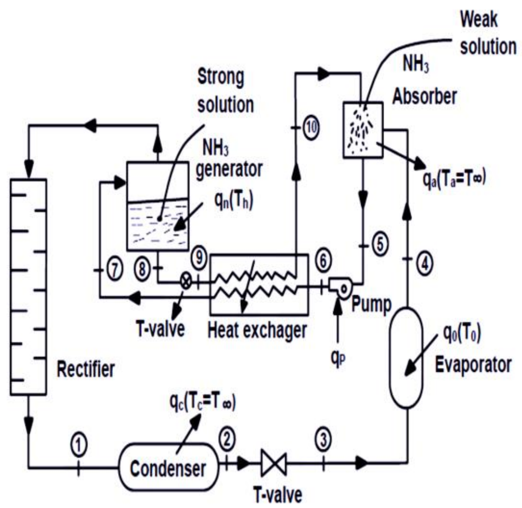


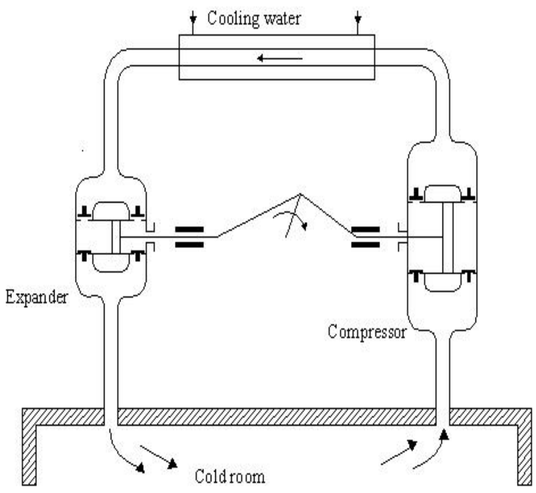
Fig: 1.2 General Layout of Vapour Absorption Refrigeration System

Some liquids like water have great affinity for absorbing large quantities of certainvapors (NH3) and reduce the total volume greatly. The absorption refrigeration systemdiffers fundamentally from vapor compression system only in the method ofcompressing the refrigerant. An absorber, generator and pump in the absorptionrefrigerating system replace the compressor of a vapor compression system.Figure 6.7 shows the schematic diagram of a vapor absorption system. Ammonia vaporis produced in the generator at high pressure from the strong solution of NH3 by anexternal heating source. The water vapor carried with ammonia is removed in therectifier and only the dehydrated ammonia gas enters into the condenser. High pressureNH3 vapor is condensed in the condenser. The cooled NH3 solution is passed through athrottle valve and the pressure and temperature of the refrigerant are reduced below thetemperature to be maintained in the evaporator. The low temperature refrigerant entersthe evaporator and absorbs the required heat from the evaporator and leaves theevaporator as saturated vapor. Slightly superheated, low pressure NH3 vapor isabsorbed by the weak solution of NH3 which is sprayed in the absorber as shown inFig..Weak NH3 solution (aqua–ammonia) entering the absorber becomes strong solutionafter absorbing NH3 vapor and then it is pumped to the generator through the heatexchanger. The pump increases the pressure of the strong solution to generatorpressure. The strong NH3 solution coming from the absorber absorbs heat form hightemperature weak NH3 solution in the heat exchanger. The solution in the generatorbecomes weak as NH3 vapor comes out of it. The weak high temperature ammoniasolution from the generator is passed to the heat exchanger through the throttle valve.The pressure of the liquid is reduced to the absorber pressure by the throttle valve.

GAS CYCLE REFRIGERATION:

If air at high pressure expands and does work (say moves a piston or rotates a turbine), its temperature will decrease. This fact is known to man as early as the 18th century. Dalton and Gay Lusaac studied this in 1807. Sadi Carnot mentioned this as a well-known phenomenon in 1824. However, Dr. John Gorrie a physician in Florida developed one such machine in 1844 to produce ice for the relief of his patients suffering from fever. This machine used compressed air at 2 atm. pressure and produced brine at a temperature of –7o C, which was then used to produce ice. Alexander Carnegie Kirk in 1862 made an air cycle cooling machine. This system used steam engine to run its compressor. Using a compression ratio of 6 to 8, Kirk could produce temperatures as low as 40o C. Paul Gifford in 1875 perfected the open type of machine. This machine was further improved by T B Lightfoot, A Haslam, Henry Bell and James Coleman.

This was the main method of marine refrigeration for quite some time. Frank Allen in New York developed a closed cycle machine employing high pressures to reduce the volume flow rates. This was named dense air machine. These days air cycle refrigeration is used only in aircrafts whose turbo compressor can handle large volume flow rates. Figure 1.6 shows the schematic of an open type air cycle refrigeration system. The basic system shown here consists of a compressor, an expander and a heat exchanger. Air from the cold room is compressed in the compressor. The hot and high pressure air rejects heat to the heat sink (cooling water) in the heat exchanger. The warm but high pressure air expands in the expander. The cold air after expansion is sent to the cold room for providing cooling. The work of expansion partly compensates the work of compression; hence both the expander and the compressor are mounted on a common shaft.



Schematic diagram of the cold air system

Fig 1.3 Gas Refrigeration Cycle

STEAM JET REFRIGERATION SYSTEM:

If water is sprayed into a chamber where a low pressure is maintained, a part of the water will evaporate. The enthalpy of evaporation will cool the remaining water to its saturation temperature at the pressure in the chamber. Obviously lower temperature will require lower pressure. Water freezes at 0^{o}C hence temperature lower than 4^{o}C cannot be obtained with water. In this system, high velocity steam is used to entrain the evaporating water vapour. High-pressure motive steam passes through either convergent or convergent-divergent nozzle where it acquires either sonic or supersonic velocity and low pressure of the order of 0.009 kPa corresponding to an evaporator temperature of 4^{o}C. The high momentum of motive steam entrains or carries along with it the water vapour evaporating from the flash chamber. Because of its high velocity it moves the vapours against the pressure gradient up to the condenser where the pressure is 5.6-7.4 kPa corresponding to condenser temperature of 35-45^{o}C. The motive vapour and the evaporated vapour both are condensed and recycled.

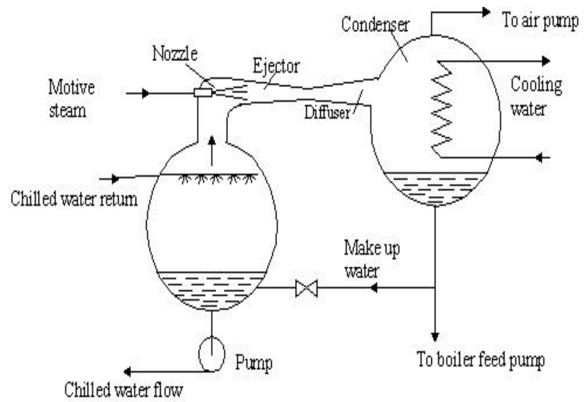


Fig 1.4: Steam Jet Refrigeration System

REFRIGERANT:

The thermodynamic efficiency of a refrigeration system depends mainly on its operating temperatures. However, important practical issues such as the system design, size, initial and operating costs, safety, reliability, and serviceability etc. depend very much on the type of refrigerant selected for a given application. Due to several environmental issues such as ozone layer depletion and global warming and their relation to the various refrigerants used, the selection of suitable refrigerant has become one of the most important issues in recent times. Replacement of an existing refrigerant by a completely new refrigerant, for whatever reason, is an expensive proposition as it may call for several changes in the design and manufacturing of refrigeration systems. Hence it is very important to understand the issues related to the selection and use of refrigerants. In principle, any fluid can be used as a refrigerant. Air used in an air cycle refrigeration system can also be considered as a refrigerant. However, in this lecture the attention is mainly focused on those fluids that can be used as refrigerants in vapour compression refrigeration systems only.

EXPERIMENTAL SETUP:

To perform the experiment 185L LG refrigerator is selected which was designed to work with R-134a it is consist of an evaporator, air cooled condenser, reciprocating compressor. The refrigerator was instrumented with two pressure gauges with inlet and outlet of the compressor the temperature at four different points are taken by 8 digital sensors for measuring temperatures at food and freezer compartment temperature five sensors are fitted current and volt of the volt is measured by digital clamp meter.

SPECIFICATION OF REFRIGERATOR:

1.	Manufactured By	LG Electronics India Pvt.Ltd.
2.	Model	Gl-195RL4
3.	Net Weight	35 Kg.
4.	Gross Capacity	185L
5.	Net Dimensions (In Mm) (WxDxH)	538x634x1147
6.	Voltage	220V-240V
7.	Frequency	50Hz
8.	Compressor	Reciprocating
9.	Condenser	Air-Cooled
10.	Working Refrigerant	R-134a

Table 1.1: Specification of domestic refrigerator

METHODOLOGY

1. Firstly cleaning is done with the help of nitrogen gas then evacuation is carried out with the help of vacuum pump and refrigerant is charged with the help of charging system.

2. The refrigerator was first charged with 60 gm. of R-410A and tested at various conditions. Same test were repeated with 80 and 100 gm. of R-410A, test were carried out the same way with R-134a refrigerant by following the same procedure.

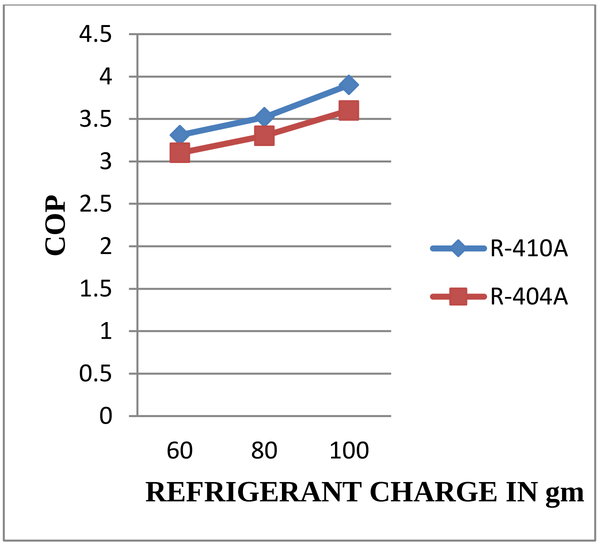
PARAMETERS SELECTED

1. Freezer compartment temperature.
2. Food compartment temperature.
3. Discharge pressure.
4. Power consumption.
5. COP.

INSTRUMENTS AND REFRIGERATOR USED

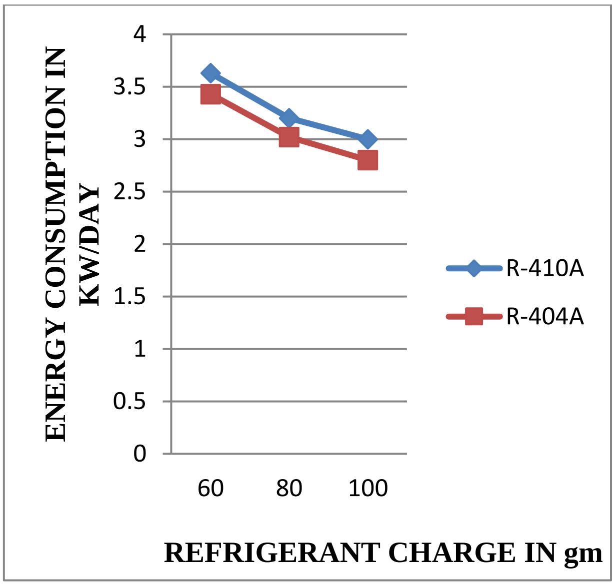
1. SINGLE DOOR LG REFRIGERATOR OF 185L.
2. TWO PRESSURE GAUGES .
3. DIGITAL CLAMP METER.
4. 14 DIGITAL SENSORS .
5. REFRIGERANTS (R-410A AND R-404A)
6. FILTER AND INSULATING TAPE.

GRAPH 1.1 EFFECTS OF REFRIGERANTS CHARGES ON THE SYSTEM (COP).



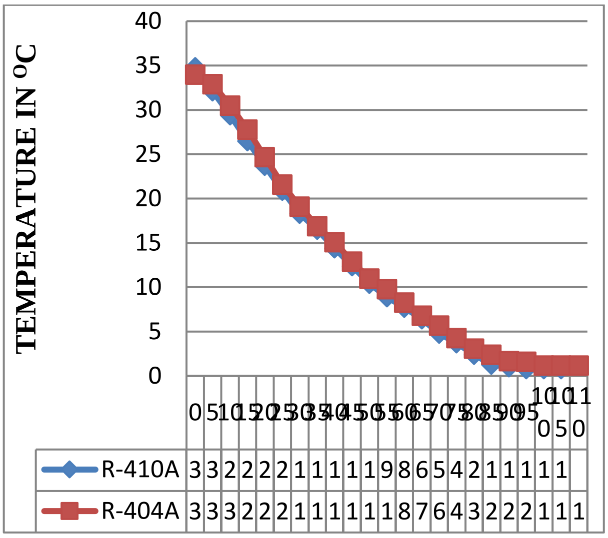
Graph1.1 shows the effect of refrigerant charges on the system COP. The COP increases with refrigerant charge for all the refrigerants. Increase in refrigerant charge increases the quantity of refrigerant in the system, which increased the cooling capacity and also the COP of the system. COPs of 3.31 and 3.1 were obtained with 60 gm charge for R410A and R404A, respectively, While COPs of 3.52 and 3.3 were obtained with 80 gm charge for R410A and R404A, respectively. Highest COPs of 3.9 and 3.6 were obtained with 100 gm charge for R410A and R404A respectively.

GRAPH 1.2 EFFECT OF REFRIGERANT CHARGES ON THE ENERGY ON THE CONSUMPTION.



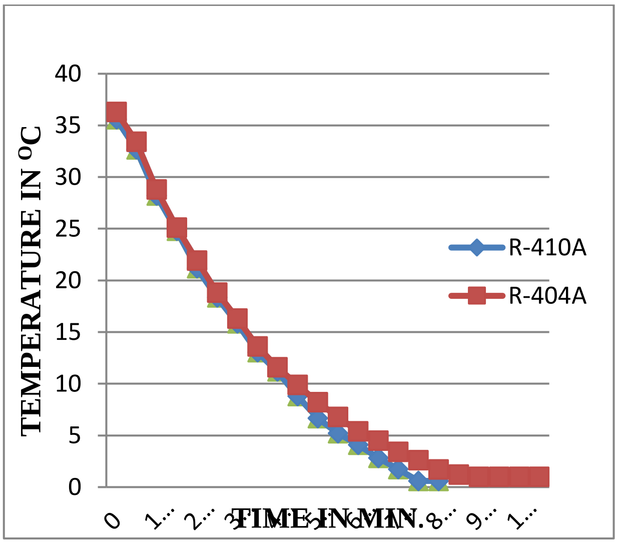
Graph 1.2 shows the effect of the refrigerant charge on the energy consumption. The graph shows that the power consumption reduces as the refrigerant charge increases until it reached the minimum power consumption. As shown in the figure, the average optimal refrigerant charge, which corresponds to the minimum power consumption, for the two refrigerants, was 100 gm. The power consumptions of 3.63, 3.2 and 3.0, 3.43 and 3.02, 2.8 KWh/day were obtained during the test at 60,80 and 100 gm for R410A and, R404A, respectively.

GRAPH 1.3 FOOD STORAGE COMPARTMENT TEMPERATURES AT 60 gm.



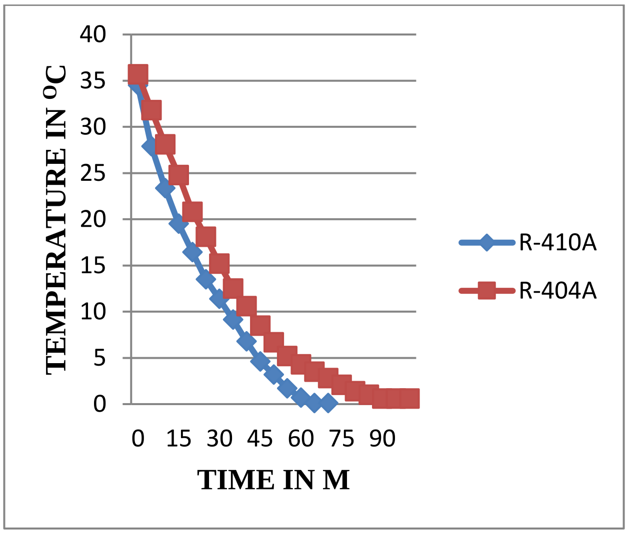
ME IN MIN.**Graph 1.3** is plotted between time and temperature, where graph shows that at 60 gm refrigerant R-410A achieved up to 0.8°c temperature in 95 minute, while R-404A achieved up to 1.2 °c in 100 minute. While using R-410A, Food compartment temperatures of refrigerator get stable earlier than R-404A.

GRAPH 1.4 FOOD STORAGE COMPARTMENT TEMPERATURES AT 80 gm.



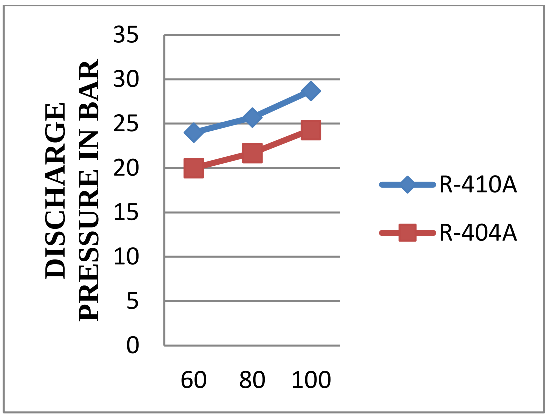
Graph 1.4 is plotted between time and temperature, where graph shows that at 80 gm refrigerant R-410A achieved up to 0.6°c temperature in 75 minute and R-404A achieved up to 1.0 °c in 90 minute. While using R-410A, Food compartment temperatures of refrigerator get stable earlier than R-404A.

GRAPH 1.5 FOOD STORAGE COMPARTMENT TEMPERATURES AT 100 gm.



Graph 1.5 is plotted between time and temperature, where graph shows that at 80 gm refrigerant R-410A achieved up to 0.1°c temperature in 65 minute, while R-404A achieved up to 0.6°c in 90 minute. While using R-410A, Food compartment temperatures of refrigerator for R-410A get stable earlier than for R-404A.

GRAPH 1.6 EFFECT OF REFRIGERANT CHARGES ON THE COMPRESSOR DISCHARGE PRESSURE.



REFRIGERANT CHARGE IN gm

Fig.1.6 shows the effect of refrigerant charges on the compressor discharge pressure. The discharge pressure is an important parameter that affects the performance of a refrigerating system. It influences the stability of the lubricants and compressor components. Fig. 8 shows that increase in refrigerant charge increases the discharge pressure. As shown in the figure, the value of discharge pressures at 60 gm were obtained 20 and 24 bar for two refrigerants R-404A and R-410A respectively, while value of discharge pressures at 80 gm were obtained 21.7 and 25.7 bar for two refrigerants R-404A and R-410A respectively, highest value achieved at 100 gm which were 24.3 and 28.7 for refrigerants R-404A and R-410A respectively

CONCLUSION:

After the successful investigation on the performances of R-410A and R-404A, the following conclusions can be drawn based on the results obtained:

❖ **Pull down time of refrigerator.**

- Pull down time of R-410A at 60 gm was 10.52% (10) minute earlier than R-404A
- Pull down time of R-410A at 80 gm was 16.66% (15) minute earlier than R-404A
- Pull down time of R-410A at 100 gm was 23.52% (20) minute earlier than R-404A.

❖ **Food compartment temperature of refrigerator.**

- Food compartment temperature of R-410A at 60 gm was 0.4ºc lover than R-404A
- Food compartment temperature of R-410A at 80 gm was 0.4ºc lover than R-404A
- Food compartment temperature of R-410A at 100 gm was 0.5ºc lover than R-404A

❖ **Energy consumption of refrigerator.**

- R404A offers lowest energy consumption. The compressor Consumes 4.13% less energy when R404A was used than when R410A was used in the system, respectively.

❖ **COP of refrigerator.**

- Overall average COP of R-404A was 5.38% higher than the R-410A.

❖ **Discharge pressure of refrigerator.**

- Discharge pressure of R404A was less with that of R410A with average percentage reduction of 15.80%.

Thus, it can be concluded that R410A could be ozone friendly, and safe viable alternative to R-134a for domestic and small commercial refrigeration systems with the main advantage that it can be replaced directly without the need to replace or modify any system component.

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