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A Review on Vapor Compression Refrigeration Cycle for Refrigerant Mixture

[1]Saunak D.Modi, [2]Shivang N Ahir

[1]M.E. Student, [2]Assistant Professor, Mechanical Engineering, SRICT,
[1]Mechanical Engineering Department,
[1]Shroff S R Rotary Institute of Chemical Technology, Vataria,India

***Abstract*—This study presents thermodynamic analysis of vapor compression refrigeration cycle using refrigerant mixture. In developing country like India, most of the vapor compression based refrigeration, airconditioning and heat pump systems continue to run on halogenated refrigerants due to its excellent thermodynamic and thermo-physical properties apart from the low cost. However, the halogenated refrigerants have adverse environmental impacts such as ozone depletion potential (ODP) and global warming potential (GWP). Hence, it is necessary to look for alternative refrigerants to full fill the objectives of the international protocols (Montreal and Kyoto) and to satisfy the growing worldwide demand. This paper reviews the various experimental and theoretical studies carried out around the globe with environment friendly alternatives such as hydrocarbons (HC), hydrofluorocarbons (HFC) and their mixtures, which are going to be the promising long-term alternatives.**

***IndexTerms*- VCR System, GWP, ODP, CFC, HFC, HC, HC Mixture refrigerant.**

❖ INTRODUCTION

The quick industrialization has led to very high growth, development and technological progression across the world. It has given rise to a number of new concerns. Today, Global warming and Ozone layer depletion on one hand and spiraling oil prices on the other hand have become major challenges. More and more use of fossil fuels is leading to their sharp diminution and nuclear energy is not out of harm's way. In the face of fast approaching energy resource crunch there is need for developing thermal systems which are consume less energy than the conventional systems. Thermal systems like refrigerators and air conditioners consume large amount of energy in terms of electric power.

I. Refrigeration system

Refrigeration may be defined as the process of maintaining and also achieving a temperature below that of the surroundings. The oldest and most well-known among refrigerants are ice, water, and air. One of the most important applications of refrigeration has been the preservation of perishable food products by storing them at low temperatures as per the requirement. Refrigeration systems are also for to provide thermal comfort to human beings by means of air conditioning. Reversed heat engine is called Refrigerator, In other words heat pump which pumps heat from a sink (cold body) and delivers to a source (hot body). Refrigerant is a substance which works in a heat pump to extract heat from a cold body and to deliver it to a hot body.

The heat transfer is driven by mechanical work, but can also be happen by magnetism, electricity, laser, heat or other means. It has many applications, additives, but not restricted to: domestic refrigerators, air conditioning, industrial freezers, cryogenics etc. According to second law of thermodynamics, heat is pumped from a sink temperature to source temperature process can only be performed with the use of some additional work. Hence, supply of power (electrical motor) is continually required to run a refrigerator.

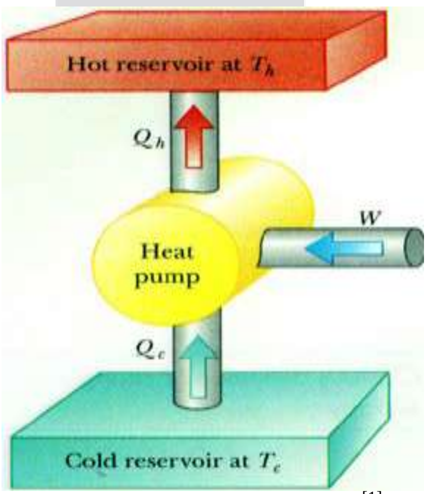

Fig1.1 Reversed Heat Engine [1]

There are wide range applications of refrigeration system which are shown below:

- Foodstuff conservation plants
- Process refrigeration
- Air conditioning plants
- Drying plants
- Fresh water installations plants
- Refrigerated containers
- Heat pumps
- Ice production
- Freeze-drying
- Transport refrigeration

There are different types of refrigeration, and they each have their own methods of working. One is industrial refrigeration. This type of refrigeration is usually used for food processing, cold storage and chemical processing.

II. Refrigerant

It is a substance or mixture, usually a fluid, used in a heat pump and refrigeration cycle. In most cycles it undergoes phase transitions from a liquid to a gas and back again. Many working fluids have been used for such purposes. Fluorocarbons, especially chlorofluorocarbons, became commonplace in the 20th century, but they are being phased out because of their ozone depletion effects. Other common refrigerants used in various applications are ammonia, sulfur dioxide, and non-halogenated hydrocarbons such as propane.

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 vapor compression refrigeration systems only.

III. Type of Refrigerant

The most common types of refrigerants in use nowadays are presented below:

A. Halocarbons or freons:

Halocarbons are generally synthetically produced. Depending on whether they include chemical elements hydrogen (H), carbon (C), chlorine (Cl) and florine (F)

Example:-

i. CFCs (Chlorofluorocarbons): R11, R12, R113, R114, R115
ii. HCFCs (Hydrochlorofluorocarbons): R22, R123
iii. HFCs (Hydrofluorocarbons): R134a, R404a, R407C, R410a

B. Azeotropic refrigerants:

An azeotropic or a constant boiling mixture is a mixture of two or more liquids whose proportions cannot be altered or changed by simple distillation. Because their composition is unchanged by distillation, azeotropic are also called (especially in older texts) constant boiling mixtures.

Example:-

i. R-502 : 8.8% R22 and 51.2% R115
ii. R-503 : 40.1% R23 and 59.9% R13

C. **Zeotropic refrigerants:**

A zeotropic mixture, or non-azeotropic mixture, is a mixture with components that have different boiling points. When a zeotropic mixture is boiled or condensed, the composition of the liquid and the vapor changes according to the mixture's temperature-composition diagram.

Example:-

i. R404a: R125/143a/134a (44%, 52%, 4%)

ii. R407c : R32/125/134a (23%, 25%)

iii. R410a: R32/125 (50%, 50%)

D. Hydrocarbon refrigerants:

Hydrocarbon Refrigerants are natural, nontoxic refrigerants that have no ozone depleting properties and absolutely minimal global warming potential. The most efficient and environmentally safe refrigerants in the world are the five natural refrigerants which are Air, Water, Carbon Dioxide, Ammonia and Hydrocarbons.

Example:-

i. R170 (ethane), R290 (propane), R600 (butane), R600a (isobutane)

E. Hydrofluoroolefins :

Hydrofluoroolefins (HFOs) are unsaturated organic compounds composed of hydrogen, fluorine and carbon. These organofluorine compound are of interest as refrigerants. Unlike traditional hydrofluorocarbons and chlorofluorocarbons which are saturated, HFOs are olefins, otherwise known as alkenes.

Example:-

i. R-1234yf (2,3,3,3-Tetrafluoropropene),R-1234ze(1,3,3,3-Tetrafluoropropene)

V. Blending refrigerants:

Refrigerant blends are mixtures of refrigerants that have been formulated to provide a match to certain properties of the refrigerants originally used. These blends have been researched and developed since the issue of the ODS phase-out emerged and are being produced by many chemical companies.

VI. Basic working of a Vapor Compression Refrigeration Cycle:

The vapor compression system uses a circulating liquid refrigerant as a working medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat to some other space. Fig. 2 shows a typical, VCRS (Vapor Compression Refrigeration System).

There are several mechanical components required for the refrigeration system. Among that several components there are four major components of a system and some auxiliary equipment associated with these four major components. These components include condenser, evaporators, compressor, and refrigerant lines and piping, refrigerant capacity controls, receivers, and accumulators.

Major components of a vapor-compression refrigeration system are as follows:

a) Compressor,
b) Condenser,
c) Evaporator,
d) Expansion devices.

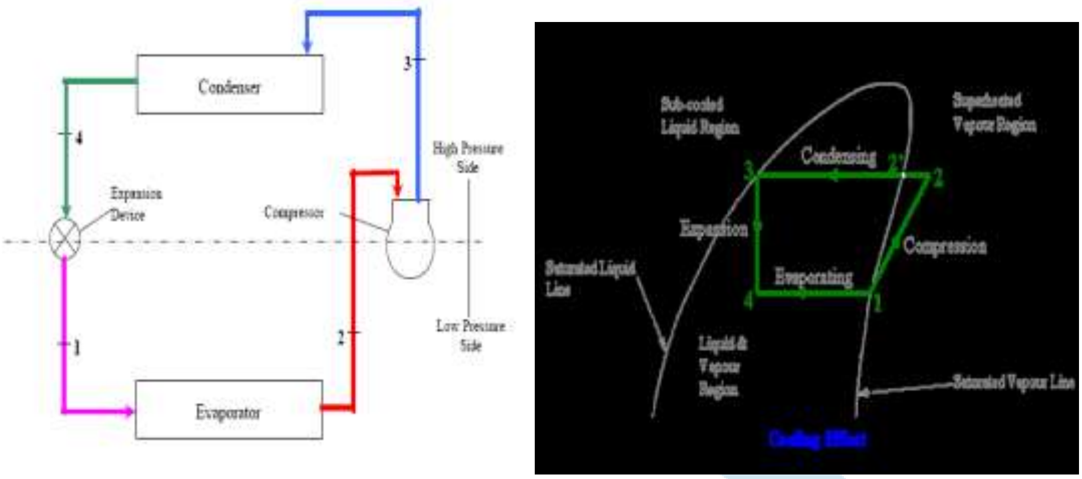

Fig1.2 Working of VCRS [2]

Circulating refrigerant first enters in to the compressor in the thermodynamic state known as a saturated vapor state and is compressed to a higher pressure, resulting in a higher temperature as well. The hot vapor goes through a condenser where it is condensed into a liquid state by flowing through a coil or tubes with cool air flowing across the coil or tubes.

The condensed liquid refrigerant, in the thermodynamic state known as a saturated liquid state, next goes through an expansion device where it undergoes sudden reduction in pressure. That sudden pressure reduction results in the adiabatic flash evaporation of a part of the liquid refrigerant. The cold mixture is then routed through the coil or tubes in the evaporator. A fan circulates the warm air in the enclosed space across the coil or tubes which carrying the cold refrigerant liquid and vapor mixture. That warm air evaporates the liquid part of the cold refrigerant mixture. At the same time, the circulating air is cooled and thus lowers the temperature of the enclosed space to require desired temperature.

VII. Environmental Impacts

Green House gas emissions from fossil fuel combustion for generation of power and emission of halogenated refrigerants from vapor compression based refrigeration, air conditioning and heat pump systems contribute significantly to global warming. A reduction in Green House gas (GHG) emissions can only be achieved by using environmental friendly and energy efficient refrigerants. The high environmental impacts due to halogenated refrigerant emissions lead to identifying a long-term alternative to meet all the system requirements including system performance, refrigerant –lubricant interaction, energy efficiency, safety and service point of view. Halogenated refrigerants are extensively used in the refrigeration and air conditioning industries over many years due to their very excellent thermodynamic and thermo-physical properties. Because of that it required to phase out all ChloroFluro Carbons (CFCs) by 2010 and all Hydro ChloroFluro carbons (HCFCs) by 2040. HFC refrigerants are considered as one among the six targeted greenhouse gas under Kyoto protocol of United Nations Framework Convention on Climate Change (UNFCCC) in 1997.

VIII. Ozone Layer Depletion

The very first major environmental impact that struck the refrigeration based industries is Ozone Depletion Potential (ODP) into the atmosphere due to manmade chemicals. About 90% of the ozone exists in the stratosphere which is in between 10 and 50 km above the earth surface. Molena and Rowland (1974) give in detail that chlorine based refrigerants are stable enough to reach the stratosphere, where the chlorine atoms which are act as catalyst to destroy the stratospheric ozone layer which protects the earth surface from direct ultra violet sun rays.

IX. Global Warming Potential (GWP)

The second major impact on environmental is Global Warming Potential (GWP), which is due to the absorption of infrared emissions from the earth, causing an increase in global earth surface temperature. While solar radiation at 5800 K and 1360 W/m2 arrives the earth , more than 30% is reflected back into space and most of the remaining radiation passes through the atmosphere and reaches the ground level. This solar radiation heats up the earth surface, which is approximately as a black body radiating energy with a spectral peak in the infrared wavelength range. This infrared radiation cannot pass through the atmosphere because of absorption by Global Warming Potential (GWP) including the halogenated refrigerants.

❖ Literature Study

B.O. Bolaji et al. 2012[1]the environmentally friendly refrigerants and the ultimate solution to the problems of ozone depletion and global warming. The halocarbon refrigerants used in the refrigeration and air-conditioning systems have become a subject of great concern for the last few decades. The problem is not with refrigerants inside the system, but with their release to the environment. CFCs and HCFCs were found harmful to the earth's protective ozone layer Therefore; their production has been prohibited by the Montreal Protocol and other international agreements. Now a day to use for HFC refrigerant to be currently the leading replacement for CFC and HCFC refrigerants in refrigeration and air-conditioning systems. It is obvious and much preferable to use natural compounds. Natural refrigerants especially hydrocarbons and their mixtures are miscible with both mineral oil used in CFC and polyesters oils used in HFC system and Also, with exception of ammonia, they are fully compatible with all material striation ally used in refrigeration systems that natural refrigerants are the most suitable long time alternatives in refrigeration and air-conditioning systems.

M. Mohanraj et al.2009 [2]presented the Environment friendly refrigerants alternatives used to halogenated refrigerants but now the in developing country like India used in the vapor compression based refrigeration, air conditioning and heat pump systems continue to run on halogenated refrigerants due to its excellent thermodynamic and thermo-physical properties apart from the low cost. But halogenated refrigerants have environmental impacts such as ozone depletion potential (ODP) and global warming potential (GWP). The very limited number of pure fluids has suitable properties to provide alternatives to the halogenated refrigerants. This is problem solved by used refrigerant mixtures .but there are three different types refrigerant mixture as alternative working fluids like azeotropic, near azeotropic and zoetrope.

Hydrocarbon blends are the zeotropic substances which have greater potential for improvements in energy efficiency and capacity modulation. That HC mixtures and R152a are found to be better substitutes for R12 and R134a in domestic refrigeration sector. R290, R1270, R290/R152a, R744 and HC/HFC mixtures are found to be the best long-term alternatives for R22 in air conditioning and heat pump applications. The use of low environmental impact refrigerants like the natural refrigerants (R290, R1270 and R744) and HC/HFC refrigerants in air conditioning and heat pump applications play a vital role in the developing countries India for reducing the environmental impact of halogenated refrigerants.

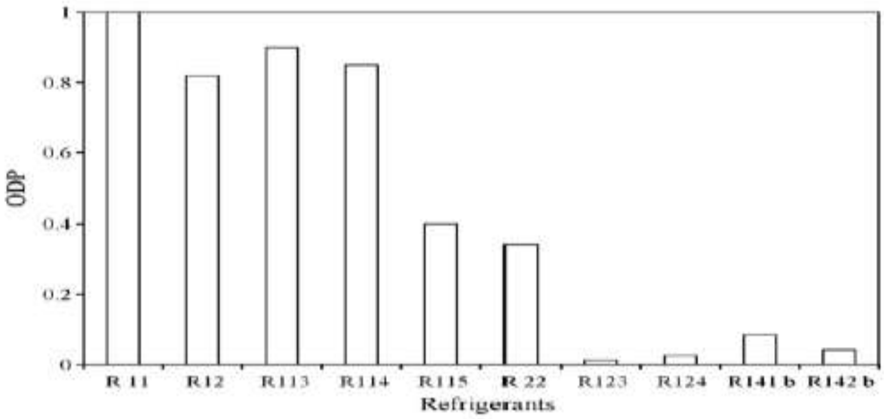

Fig 2.1 Ozone depletion potential of pure CFC and HCFC refrigerants [2]

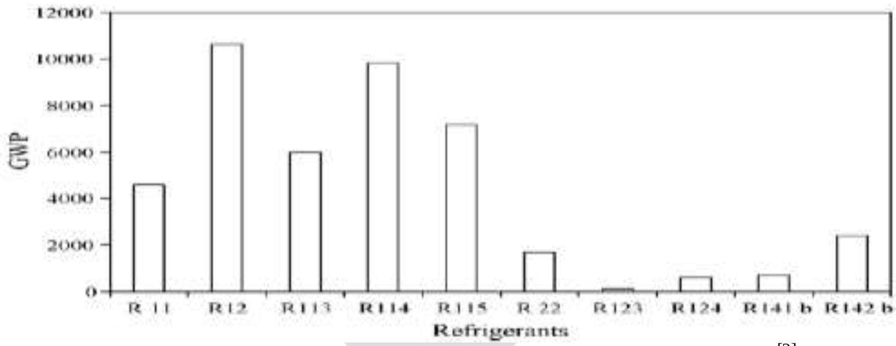

Fig 2.2 Global warming of pure CFC and HCFC refrigerants [2]

K. Harby et al 2017 [3]In this presented study for carried out with hydrocarbons as alternative refrigerants in refrigeration, air conditioning and heat pump, and automobile air conditioning systems. The study contains also a useful amount of information about the refrigerant properties, environmental impacts, and replacement strategy of conventional refrigerants. The Conclusions is use of hydrocarbons as refrigerants are not just good for the environment but also it can reduce the energy consumption and offer good drop-in replacements for the existing halogenated refrigerants. The hydrocarbons refrigerants are short atmospheric lifetime of make their GWP near to zero.

Due to flammability properties related to hydrocarbons, most of the researches have been carried out on the low refrigerant charge in large-capacity systems. HC and HFC/HC mixtures are found to be the good substitutes for replacing R12 and R134a in domestic and commercial refrigeration systems. R290 has been successfully commercialized to replace R22 in low charge, room and portable air conditioner. HC mixtures such as R432A and R433A and HC/HFC mixtures (like R470c/R600a/ R290) are accepted as an environment-friendly option for replacing R22 in air conditioning and heat pump applications. R290/R600/R600a and HC/HFC mixtures (R134a/R290:R600a) were found to be an attractive alternative to R143 and R12 in automobile air conditioners.

Somchai Wongwises et al 2005 [4]experimental study on the application of hydrocarbon mixtures to replace HFC- 134a in a domestic refrigerator. The refrigerant mixtures used are divided into three groups: the mixture of three hydrocarbons, the mixture of two hydrocarbons and the mixture of two hydrocarbons and HFC-134a. Comparison of Pure & mixture refrigerate like HFC-134a, Pure propane, Propane/butane (60%/40%), Propane/Isobutane (60%/40%) Propane/butane/Isobutane (70%/25%/5%), Propane/butane/Isobutane (50%/40%/10%), Propane/butane/HFC-134a (40%/30%/30%), Propane/Isobutane/HFC-134a (40%/30%/30%).Then conclusion of this experiment results show the fig 2.1 & 2.2 that propane/butane (60%/40%) is the most appropriate alternative refrigerant to HFC-134a.

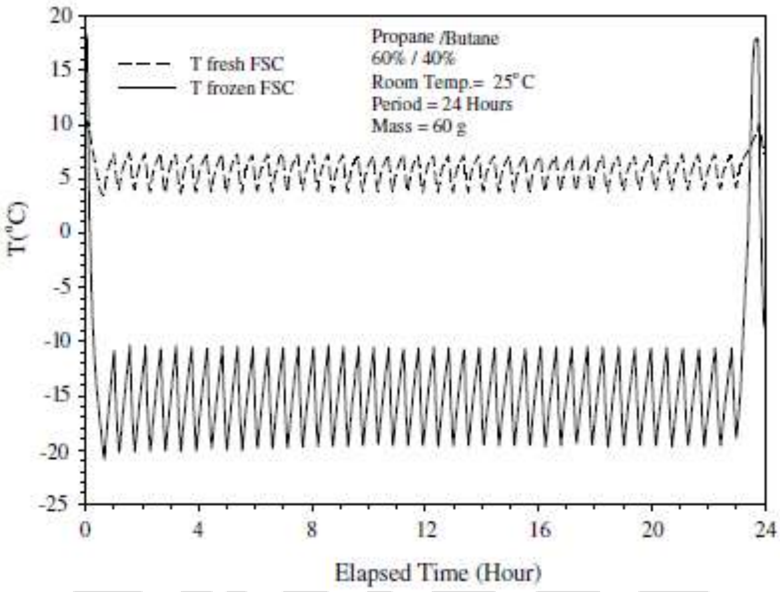

Fig 2.3 Temperature profiles during 24 h in the fresh food storage compartment and in the frozen food storage compartment [4]

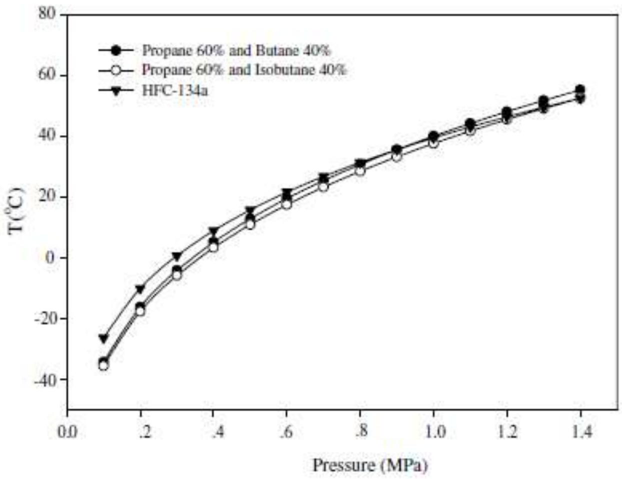

Fig 2.4 Comparison of saturated pressure and temperature for various refrigerants [4]

Mehmet Yilmaz et al 2003[5]this is performance analysis of an air-to-water vapor compression heat pump system using pure refrigerants and zeotropic refrigerant mixtures. The comparisons are pure refrigerants and refrigerant mixtures on the basis of the COP and second law efficiency. Conclusion that for performance analysis results show they have refrigerant mixtures ratio affected on COP & second law efficiency of heat pump. The COP and second law efficiency of pure refrigerants can be improved by using appropriate mixtures of the refrigerants.

Dongsoo Jung et al 2000[6]the performance of a R290/R600a mixture was examined for domestic refrigerators in the composition rang of 0.2 to 0.6 mass fraction of R290 refrigerant with compared to CFC12 refrigerant. They are conclusion this experiment is COP as increase of up to 2.3% for compared to CFC12. The reduction in the charge, almost a 50% reduction from the CFC12 charge, is mainly due to the lower density of the mixture.

Sharmas Vali Shaik et al 2017[7]the theoretical thermodynamic performance of a 0.8 TR window air conditioner with ten binary refrigerant mixtures consists of propylene (R1270) and propane (R290) was investigated based on actual vapour compression refrigeration cycle. They are conclusion of this theoretical thermodynamic performance COP of refrigerant mixture M8 (3.566) showed the nearest to that of COP of R22 (3.601) among ten investigated refrigerant mixtures. Percentage variation in COP of the mixture M8 was least by 0.97% among the ten studied refrigerant mixtures when compared to R22 and power per ton of refrigeration for the refrigerant mixture M8 (0.986 kW/TR) showed the nearest to that of power per ton of refrigeration of R22 (0.976 kW/TR) among the ten studied refrigerant mixtures.

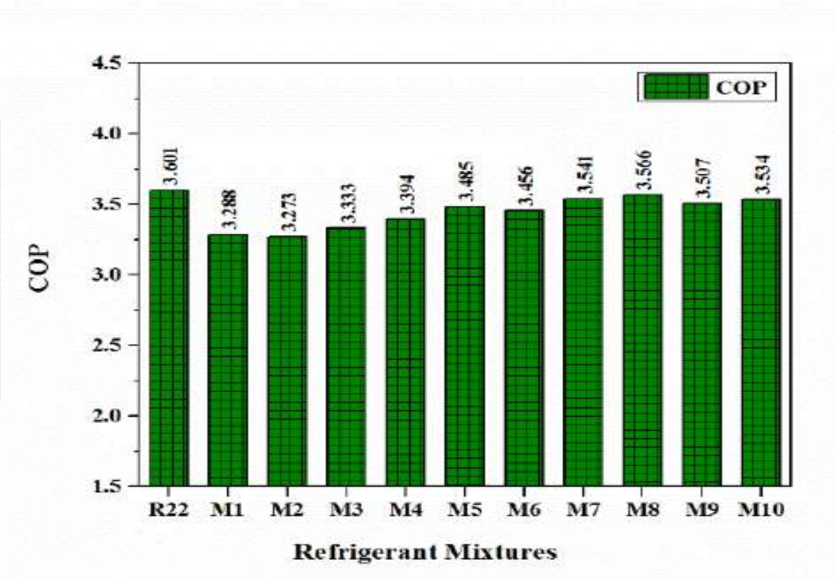

Fig 2.5 COP of various refrigerant mixtures [4]

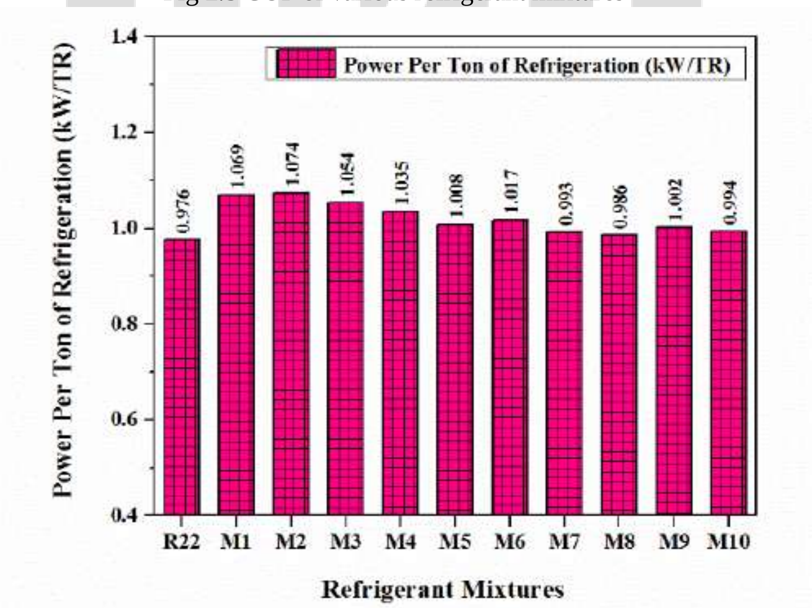

Fig 2.6 Power per ton of refrigeration for various refrigerant mixtures [4]

M. Fatouh et al 2006 [8] Experimental evaluation of a domestic refrigerator working with LPG (60 propane and 40 commercial butane) has been tested as drop in substitute in for R134 refrigerant. Consideration is Continuous running cycling that R134a with a capillary tube length of 4 m, charge of 100 g or LPG with capillary tube lengths from 4.0 to 6.0 and charge of 50 g or more satisfy the required freezer air temperature of -12 0C .The conclusion for this experimental work for Pull-down time, pressure ratio, power consumption, energy consumption of LPG refrigerator were lower than those of R134a refrigerator by about 7.6%, 5.5%, 4.3% and 10.8 respectively. Then LPG seems to be an appropriate long-term candidate to replace R134a in the existing refrigerator.

Junjiang Bao et al 2016[9] Experimental research on the influence of system parameters on the composition shift for zeotropic mixture (Isobutane/pentane) in a system occurring phase change. Another characteristic of zeotropic mixture is composition shift. Composition shift means that the circulating composition and charge composition is different and is mainly caused by the two-phase hold-up and different solubility in lubricating oil. The existence of composition shift will affect the design and operation of thermodynamic system. They are different four working condition used in experimental setup shown in table 1

Working condition	Hot water Inlet tempr ℃	Hot water pump level	Frequency of feed pump (Hz)	Cold water temper ℃	Evaporator length (m)
WC1	55	2	40	30	3
WC2	60	2	40	30	3
WC3	65	2	40	30	3
WC4	70	2	40	30	3

For mass fraction of R290/R600(48.5/51.5) & R600a/R601(67.8/32.2) for the Conclusion of Composition shift is an important characteristic for zeotropic mixture. When the hot water temperature, flow rate of hot water and evaporator length increase and cold water temperature decreases, circulating composition will increase. For feed pump frequency, when the evaporator outlet is in two phase region, and circulating composition will decrease with the increase of feed pump frequency.

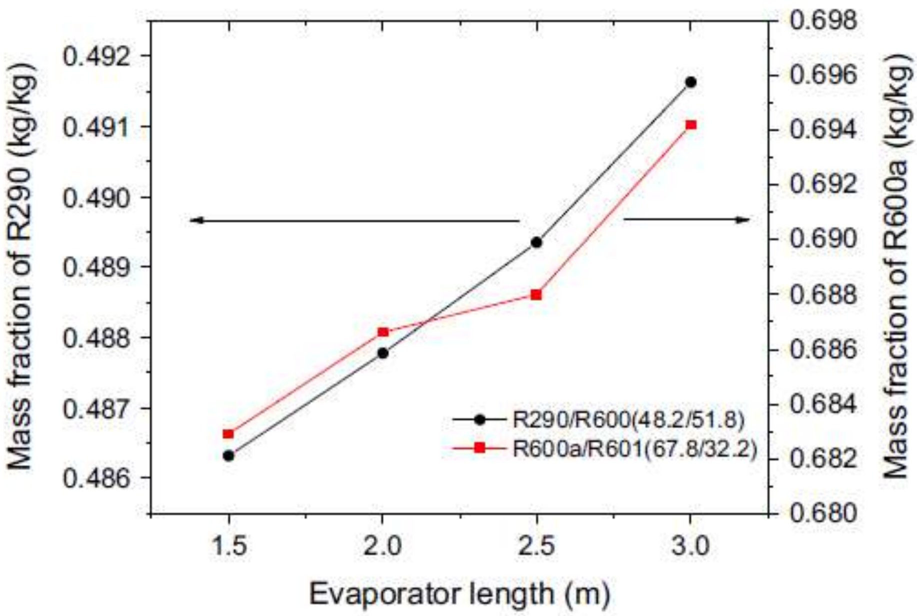

Fig 2.7 Evaporator length vs Mass fraction of R290/R600, R600a/R601 [9]

Yicai Liu et al 2011[10] that has experiment for prototype diffuser pipes in refrigeration system. The diffuser pipe has been used exhaust and suction-pressure and energy-saving. The diffuser pipes have been installed behind the exhaust port and in front of the suction port. The experimental data were presented supports the theoretical findings. This novel refrigeration system is more reliable and has higher COP, and lower energy costs, making it more attractive than conventional ejector refrigeration cycles. The conclusion of this experiment have been ,These diffuser pipes improved the COP of the entire refrigeration system .In this experiment have energy savings ranged from 3.36% to 4.09%. The system with the pressurized and energy-saving diffuser pipe consumed 0.575 kWh, compared with 0.625 kWh without it. This represents an 8.0% reduction in power consumption. Adding the vapor-pressurized and energy-saving diffuser pipe improved the COP of the system and reduced power consumption. The system with an exhaust-pressurized and energy-saving diffuser pipe is also more efficient than the suction system.

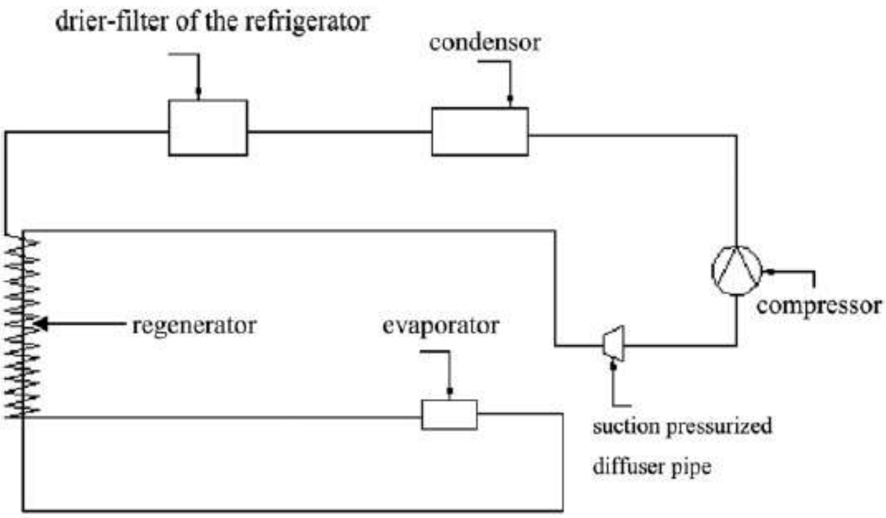

Fig 2.8 Refrigeration system with suction-pressurized and energy-saving diffuser pipe [10]

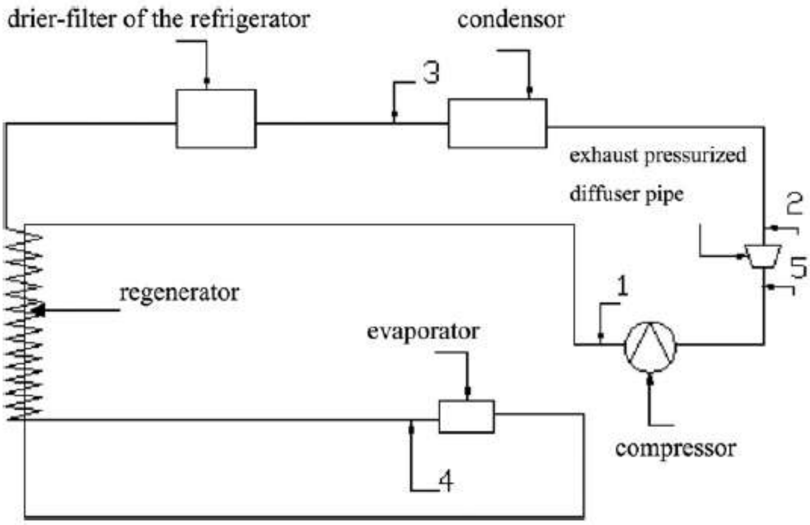

Fig 2.9 Refrigeration system with exhaust-pressurized and energy-saving diffuser pipe [10]

Won Jae Yoon et al 2012[11]; the performance analysis & optimization of a Lorenze-Meutzner cycle with hydrocarbon mixtures use for domestic refrigerator-freezer. The cycle is energy saving potential because of lower entropy generation in the fresh food compartment (R)-evaporator and lower compression ratio due to higher mean evaporating temperature, compared to a conventional cycle using pure refrigerant. The effects of the refrigerant charge, capillary tube, compressor capacity, and mixture composition on the performance of the LM cycle using R290/R600 were investigated experimentally.

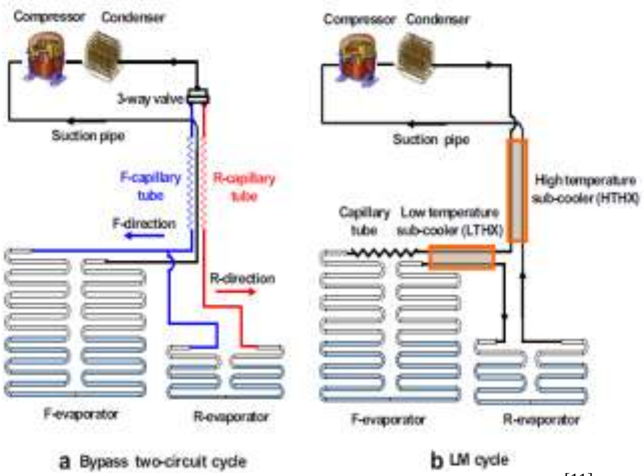

Fig 2. 10 (a) bypass two circuit cycle (b) LM cycle [11]

Then conclusions of this performance is optimized the energy consumption for LM cycle using R290/R600 in mass friction (40:60%) was 11.2% lower than that bypass two circuit cycle.

Won Jae Yoon et al 2012[12] A dual-loop cycle for a domestic refrigerator-freezer (RF) has a large energy saving potential because it has a lower compression ratio due to a higher evaporating temperature in the fresh food compartment (R)-operation compared to a conventional refrigeration cycle, as well as individual optimization flexibility for each loop. In this study, optimizations of dual-loop cycles using R-600a and hydrocarbon (HC) mixtures were individually carried out. Each optimization process included both a theoretical analysis and an experimental investigation.

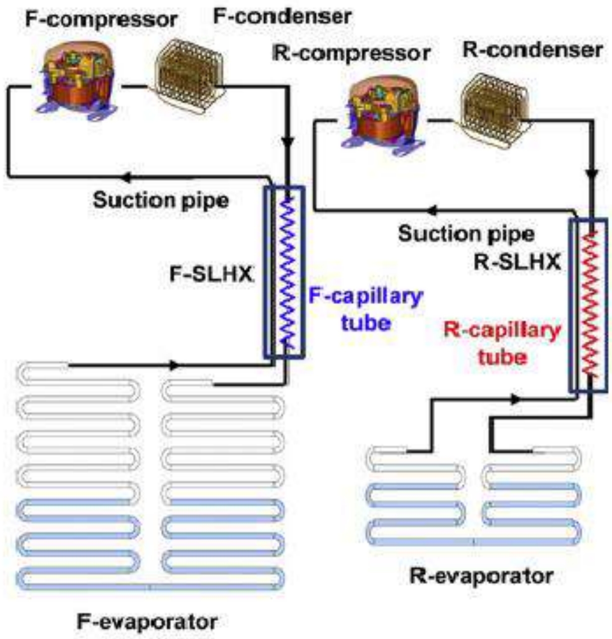

Fig 2.11 schematic diagram of a the dual-loop cycle [12]

Then conclusion of this use of HC mixtures R290/R600 (20/80) in the dual-loop cycle, an additional energy saving of 5.4% was obtained as compared to the dual-loop cycle using R-600a. The dual-loop cycle for use R600a saving 13.96% higher than bypass two circuit cycle.

A.S. Dalkilic et al 2010[13] the theoretical performance study on a vapour compression refrigeration system with mixtures based on R134a, R152a,R32, R290, R1270, R600, and R600aDone for various ratio and compared with R12, R22, R134a as possible alternative replacement. They have Consideration of condensation temperature of 50 °C and evaporating temperatures ranging between −30℃ and 10℃ This is study above conclusion for refrigerant blends of R290a/R600a (40/60 wt. %) and R290/R1270 (20/80 wt. %) are found to be the most suitable alternatives among refrigerants tested for R12 and R22 respectively. The refrigeration efficiency, the performance coefficient (COP) of the system, increases with increasing evaporating temperature for a constant condensing temperature in the analysis. All systems including various refrigerant blends were improved by analysing the effect of the superheating/subcooling case.

K. Mani et al 2013[14] this is preformation of hydrocarbon refrigerant mixture R290/R600 (79/21%) to use for analysed as an alternative refrigerant R12 & R134a. Experiments are conducted with R12, R134a and R290/R600 mixture refrigerant at different condensing and evaporating temperatures and at various compressor speeds. They are conclusion for this experiment for The RC of R290/R600 (79/21 by wt. %) is 49% higher for lower temperatures and 30% higher for higher than that with R12 and R134a and COP is 19.3%-27.9% higher than that of R12 and R134a for the range of evaporating temperatures ,The RC of refrigerant mixture is 29.7% higher for the lower and 28% higher for the higher than that with R12 and R134a. and 15.3-16.7% higher COP than that with R12 and R134a for the range of condensing temperature and the investigated hydrocarbon mixture R290/R600 (79/21%) can be used as a possible alternative refrigerant for R12 and R134a.

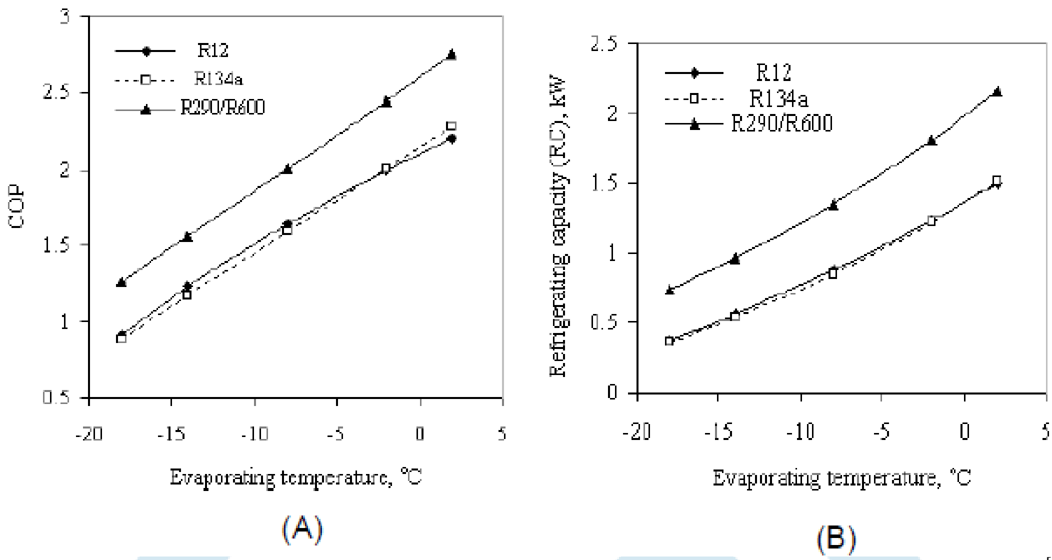

Fig 2.12 (A) Effect of condensing temperature on COP (B) Effect of condensing temperature on RC [14]

Qi Chen et al 2017[15] performance analysis of an ejector enhanced refrigeration cycle withR290/R600a for application in domestic refrigeration/freezers. Energetic and exergetic analysis methods are utilized to theoretically investigate the system operating performance of EVRC and compared with the traditional vapor compression refrigeration cycle (TVRC). They are conclusion the system performance improvement of EVRC over TVRC in the aspect of COP, volumetric cooling capacity and exergy efficiency can reach up to 14.2%, 37% and 17.7%, respectively.

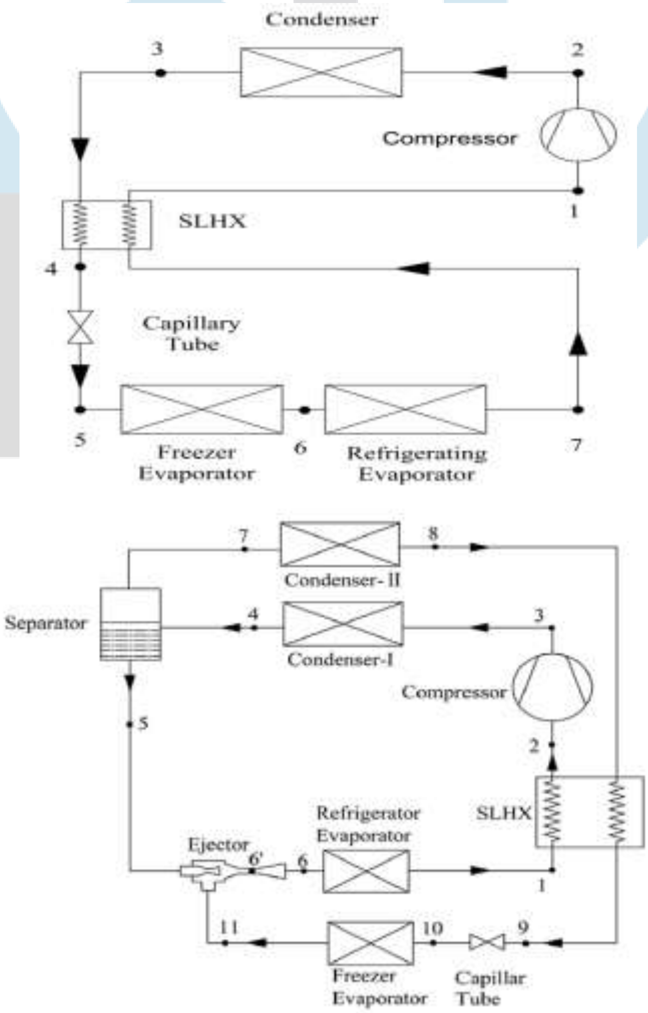

Fig 2.13 (A) Schematic diagram for the TVRC cycle (B) Schematic diagram for the MVRC cycle [15]

Mohamed El-Morsi et al 2015[16] Energy and exergy analysis of pure HC refrigerant as a drop in replacement for R134a in domestic refrigerators. In this study, three different pure HCs refrigerants- R290, R600, commercial LPG is used in theoretical analysis. The evaporator temperature ranges from 30 to 0 0C while the condenser ranges from 30 to 50 0C.They are conclusion for this result of using HC refrigerant in domestic refrigerator showed that the R290 could not be used as a refrigerant replacement due to its high operating pressure in comparison with R134a R600 has the higher COP and Exergetic efficiency, while LPG has the lowest when compared to R134a.

❖ CONCLUSION

Literatures related to A pure HC refrigerant has zero ODP and GWP near to zero.HC mixtures refrigerant are used for domestic refrigerator-freezer for reducing charge, higher COP and Exergetic efficiency. HC and HC mixtures are found to be the good substitutes for replacing R12 and R134a in domestic and commercial refrigeration systems. Due to flammability properties related to hydrocarbons, most of the researches have carried out research work on the low refrigerant charge in large-capacity systems. Refrigerant blends of R290a/R600a (40/60 wt. %) and R290/R1270 (20/80 wt. %) are found to be the most suitable alternatives among refrigerants tested for R12 and R22 respectively. Adding energy-saving diffuser pipe improves the COP of the system and reduced power consumption. The energy consumption of the LM cycle was lower than that of the bypass two-circuit cycle. The use of HC mixtures in the dual-loop cycle, an additional energy saving of 5.4% was obtained as compared to the dual-loop cycle using R-600a.

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