Evaluation of the Performance of Alternative Refrigerants with Low Global Warming Potential

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ABSTRACT

Global warming is the general increase in global temperature brought on by higher-than-normal concentrations of greenhouse gases. These gases trap heat waves as they approach the world and allow them to continue entering the atmosphere over time without being able to leave. This study used low-GWP alternative refrigerants to reduce greenhouse gas emissions, in line with global efforts to phase out chlorinated fluids in order to preserve the ozone layer as a result of the Montreal Protocol. A software program called Cycle-D-Hx, which has a graphical user interface and a thermodynamic model of the refrigeration system, was used to evaluate how well household refrigerators working with various types of refrigerants performed. The model was validated using data from a household refrigerator charged with R134A. The performance of several low-GWP alternative refrigerants, including R404A, R449A, R513A, and R452A, was then assessed using the model. It was demonstrated that the R452A has a high COP, a low potential for ozone depletion, a low temperature glide, and a low potential for global warming. In addition to these thermodynamic and environmental characteristics, R452A blend is non-flammable, non-corrosive, and will not corrode the metal components of the compressor and evaporator of the refrigeration system.

Keywords: Evaporator, Compressor, Ozone Depletion, Temperature glide, Refrigerants.

1. INTRODUCTION

Climate change is now proven to be driven by human-induced greenhouse gas emissions (IPCC 2013). The refrigeration, air conditioning and heat pump (RACHP) sector is one that contributes significantly to GHG emissions. In 2010, the RACHP industry was anticipated to be responsible for 349 MtCO2-eq., with this figure expected to climb to 1596 MtCO2-eq. by 2030. For 195 nations, 2015-2050 provides a logical and complete collection of historical and predicted estimates of emissions, as well as economic and technical mitigation assessments of non-CO_2 GHGs from human sources. The analysis gives data that may be utilized to analyze country contributions to greenhouse gases, and progress made on reducing the emissions together with mitigation prospects (USEPA 2019). The International Institute of Refrigeration (IIR) reported that indirect emissions from the power consumed from refrigeration devices accounted for thirty-seven percent of the overall of total greenhouse gas emissions, while direct emissions from the refrigerant leakage accounted for thirty-seven percent of total greenhouse gas emissions (IIR 2017, Yang et al. 2021). Global warming is defined as an increase in global temperature caused by greenhouse gas levels above normal, allowing heat coming into the planet earth to be captured and heat waves to continue accessing the airspace without escaping. Chlorofluorocarbons (CFC) cause chemical interactions with the Earth's protective ozone layer. These reactions, on the other hand, are exceedingly harmful and will deplete the ozone layer, which is a significant disadvantage. The ozone layer prevents ultraviolet (UV) radiation from entering the atmosphere, which is significant since UV rays are the leading cause of skin cancer, as well as impacting plant development and creating cataracts in people, which impair their vision. With the Montreal Protocol's international efforts to eradicate chlorinated fluids in order to protect the ozone layer (Newchurch 2003), it was time to concentrate on phasing out greenhouse gases in order to save the environment. The Kyoto Protocol was signed in 1997, setting off these efforts. It was further strengthened by the European Union's F-Gas Regulation in 2014 and the Kigali Amendment, which aims to cut HFC refrigerant usage by 80% by 2047 (UN 1998, EC 2014, UNEP 2016). Despite the inclusion of chlorinated compounds in the Montreal Protocol, the phase-out of CFC refrigerants, which are similar to chlorinated materials, lowered global warming by 25% (UNEP 2016). This is due to the fact that CFCs have a very high global warming potential (GWP). To minimize greenhouse gas emissions in the heat pump, refrigeration, and air conditioning sectors, substitute refrigerants with lower global warming potential have been introduced to replace currently utilized HFCs which has greater values of greenhouse gas. The HPRAC system emits both direct and indirect emissions that contribute to global warming. As a result, the global warming potential values of alternative refrigerants must be evaluated, including the energy efficiency of the equipment using the refrigerants (Goyal 2019, Mateu-Royo 2021). The similar environmental impact of HPRAC systems has been measured using a range of methods (Mota-Babiloni 2020). The Total Equivalent Warming Impact (TEWI) is a commonly used statistic for calculating the direct and indirect analogous CO_2 emissions from HPRAC systems (Sogut, Yalcn, Karakoc 2012). Several studies have been conducted to investigate the efficiency of refrigerator that uses refrigerants other than the typically used HFCs (Mateu-Royo et al. 2019, Mota-Babiloni et al. 2018). Mateu-Royo et al. conducted a comparison study to assess the impact of utilising R515B and R1234ze(E) as low-GWP R134a alternatives on heat pump system energy performance and environmental impact. Their research demonstrated that the refrigerants had the same coefficient of performance (COP) as R134a. The TEWI of R1234ze(E) and R515B was reduced by 18 and 15%, respectively, because they possess lesser GWP than R134a. The authors also investigated the properties of R1233zd(E), R1224yd(Z) and R1336mzz(Z) as low-GWP alternatives to R245fa in a high-temperature heat pump (HTHP), they discovered that the system's COP increased by 27, 21, and 17 percent, respectively. The system using alternative refrigerants lower-GWP values and higher energy performance resulted in a TEWI reduction of 59 to 61 percent when compared to R245fa. Makhnatch et al. evaluated the energy efficiency of refrigeration systems employing R134a and drop-in equivalents like R513A and R450A (Makhnatch et al. 2019). They observed that using R513A instead of R134a enhanced the COP of the system by 1.8 percent, whereas R450 had a 5.3 percent lower COP. Mota-Babiloni et al. examined the energy efficiency of an HTHP multistage vapour compression system with an IHX that used low-GWP HFC substitutes. They used R1234ze(E), isobutene, R1234yf, butane, and propane in the upper-stage cycle and pentane, R1233zd(E), R1336mzz(Z) and R1224yd(Z) in the lower-stage cycle. They discovered that pentane and R1336mzz(Z) offered the best system performance during the upper-stage cycle. When using butane/pentane instead of R134a/R245fa refrigerants, the system showed improvement, with a 13 % COP.

The purpose of this research is to compare four different refrigerants to R134a. Cycle-D-Hx software will be used to investigate characteristics such as COP, ozone depletion potential, global warming potential, and temperature glide of the alternative refrigerants.

2. LITERATURE REVIEW

2.1 Refrigerants

In a vapour compression refrigeration system, the refrigerant is the working fluid. Ammonia, sulphur dioxide, carbon dioxide and water were the first refrigerants employed. Some tragic mishaps caused by leaks in the 1920s paved the path for the introduction of the first synthetic refrigerants to the market in 1930. The primary goal was to provide performance and durability. The Freon refrigerants become the industry norm. Freon was widely utilized in a variety of purposes until the 1970s, when Mario Molina and F. Sherwood Rowland proposed that Freon possess ozone depleting characteristics. Their premise proved right, and the Montreal Protocol phased out Freon in 1987. The introduction of new refrigerants onto the market marked the beginning of the HFC era. Today, the goal is to lower the GWP while maintaining the safety and efficiency of the products. Figure 1 depicts a brief history of refrigerants. R410A is the most extensively used refrigerant nowadays (McLindena 2014).

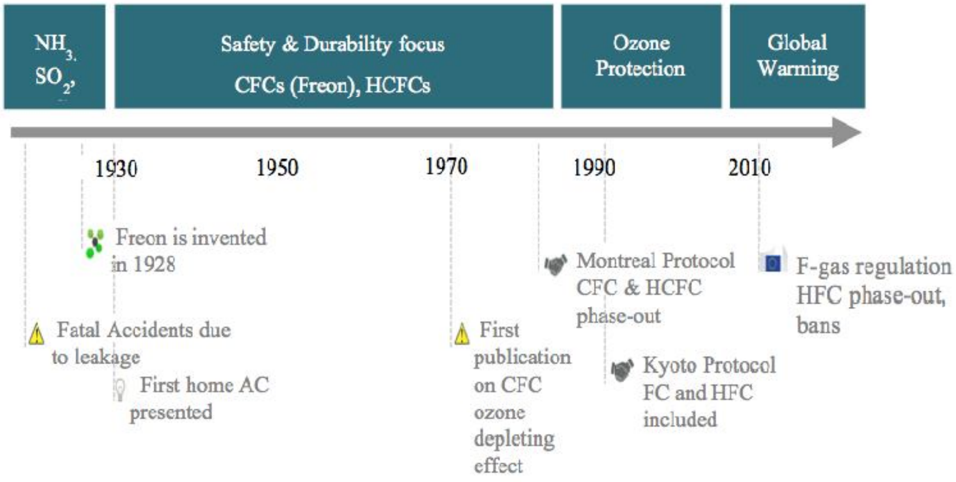


Figure 1. History time line of refrigerants (McLindena 2014)

2.2 Ozone Depletion and Global Warming

HFCs have been shown to be a well-researched and well-tested replacement to CFCs and HCFCs (hydrofluorocarbons). This was chosen since HFC is a natural chemical that already exists in small amounts in the atmosphere, posing no threat to the ozone layer or the environment. Natural refrigerants are required in an ever-expanding sector, where individuals prioritize their own well-being over environmental preservation for future generations. In addition to being an environmentally friendly option, the HFC is a longer-lasting refrigerant with favourable responses to all moving and metallic elements of the refrigeration unit. As a result, the shift from CFC and HCFC to HFC will cause no significant loss (Bolaji and Huan 2013).

Ammonia, water vapour, carbon dioxide, and hydrocarbon refrigerants were some of the alternative natural refrigerants. Ammonia is a frequently used refrigerant because it has better thermodynamic characteristics than CFCs, HCFCs, and HFCs. In addition, the efficiency is comparable to contemporary refrigerants with high compressor speeds. Furthermore, a leak may be quickly spotted, although this could be a drawback because the odour of ammonia is unpleasant.

Water is a suitable refrigerant since it is natural, non-flammable, non-toxic, does not deplete the ozone layer, and does not contribute to global warming. Water vapour is used as a refrigerant in a variety of processes, including compression chillers, dehumidification cooling and evaporative cooling. When compared to ammonia, the high coefficient of performance of water vapour refrigerants is the most desirable thermodynamic feature of a system. Carbon dioxide refrigerants are comparable to the natural refrigerants mentioned above. This refrigerant has been utilized in the automotive, domestic, commercial, and industrial refrigeration sectors as a suitable alternative.

As a result, the R744 (natural refrigerants) vapour compression cycle operates partially above the critical point and at significantly greater pressures than other halocarbons at ambient temperatures. As a result, instead of condensation, loss of heat is now primarily trans-critical fluid cooling with a significant decline in temperature of the gaseous refrigerant in the gas cooler.

Table 1: Environmental data collected on natural refrigerants

Data	**Refrigerants**		
	n-Butane R600	Iso-Butane R600A	Propane R290
Natural	yes	yes	yes
Ozone Depletion Potential	0	0	0
Global Warming Potential - 100 years	3	3	3
Density (25^{o}C) kg/m^3	532.5	550.7	492.7
Flammability limits (vol%)	1.7 to 10.3	1.9 to 10.0	2.1 to 11.4
Molar mass (kg/kmol)	58.1	58.1	44.1

Hydrocarbons are shown in Table 1 as a natural refrigerant. With several desired thermodynamic features such as a high COP, the ODP and GDP are both zero or near zero. The sole disadvantage is that hydrocarbons are not renewable, making them somewhat less environmentally beneficial than the other three refrigerants described earlier.

Table 2: ODP and GWP collected on CFC, HCFC and HFC

Group	**Refrigerants**	**ODP**	**GWP at 100 years' horizon**
CFCs	R11	1	3800
	R12	1	8100
	R113	0.8	4800
	R114	1	9000
	R115	0.6	9000
HFCs	R22	0.055	1500
	R123	0.02	90
	R124	0.022	470
	R141b	0.11	630
	R142b	0.065	2000

HFCs	R23 R32 R125 R134a R143a R152A	0 0 0 0 0 0	11700 650 2800 1300 3800 140
Natural Refrigerants	R290 R600a R717 R718 R744	0 0 0 0 0	3 3 0 0 1

Table 2 shows that, when their ozone depletion potential is combined with their global warming potential, HFCs are significantly less harmful to the environment than other refrigerants. This establishes a solid foundation for the claim that natural refrigerants and HFCs are far more environmentally friendly than CFCs and HCFCs. Table 3 shows the dominant installed refrigerants for vapor compression applications while Table 4 illustrates the global annual end uses of major refrigerants.

Table 3: Dominant Installed Refrigerants for Vapor Compression Applications

Application	United States	Rest of Americas	Europe	Asia	Middle East/Africa
Domestic Refrigeration	R-134a	R-134a R-600a	R-600a	R-600a R-134a	R-600a R-134a
Commercial Refrigeration	R-404A R-134a	R-404A R-134a	R-404A R-134a Hydrocarbons R-744	R-404A R-134a R-22	R-404A R-134a R-22
Industrial Refrigeration	R-717 R-22	R-717 R-22	R-717 R-744	R-717 R-22 R-744	R-717 R-22
Direct Expansion Air Conditioning	R-410A	R-410A R-22	R-410A	R-410A R-22 R-32	R-22 R-410A
Chillers	R-134a R-410A R-123	R-134a R-410A R-22 R-123	R-410A R-134a R-407A R-407C	R-134a R-410A R-407C R-22 R-123	R-410A R-22 R-134a R-123

Table 4: Global Annual End Uses of Major Refrigerants in ktons

Refrigerant	Polymer Precursor	Refrigeration & A/C	Foam Blowing Agents	Aerosols	Solvents	Fire Suppression
HCFC-22	360	248-400	34	-	-	-
HCFC-141b	-	-	60	-	5	-
HCFC-142b	106	6	11	-	-	-
HFC-32	-	10	-	-	-	-
HFC-125	-	83	-	-	-	0.4
HFC-134a	-	190-240	70	-	-	-
HFC-152a	50	17	16	38	-	-
HFC-245fa	-	-	28-62	-	-	-
HFC-143a	-	29	-	-	-	-
HFC-365mfc	-	1	8	-	-	-
HFC-227ea	-	-	-	-	-	0.6
HFO-1234yf	-	15-30	-	-	-	-
HFO-1234ze	-	<1	1-4.5	Unk	-	-
HFO-1233zdEk	-	<1	4	-	-	-
HFO-1336mzzl	-	Neg	Neg	-	-	-
Pentane (R-601c)	-	-	355	-	-	-
CO2 (R-744)	-	70-80	15d	52	-	-
Propane (R-290)	-	37-46	-	420	-	-
Ammonia (R-717)	-	9-26	-	-	-	-
Isobutane (R-600a)	-	6-11	-	420	-	-
n-butane (R-600)	-	-	-	420	-	-
Total	522	749-949	610-649	1510	14	13

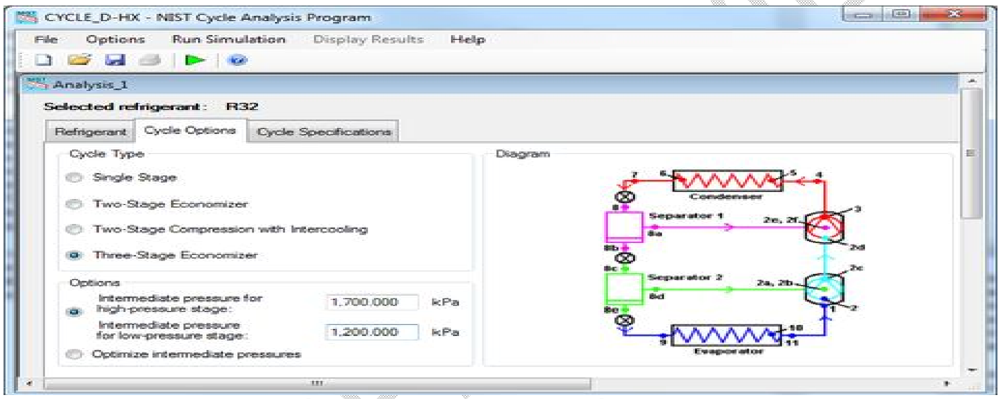
3. METHODOLOGY

3.1 Modeling Approach

The analysis involved the comparisons of R404A, R449A, R513A and R452A refrigerants with R134a. The COP of the alternative refrigerants was determined with the aid of a simulators. In each analysis, the P-v and T-s diagrams were displayed. To find a viable substitute, the COP of the refrigerants were compared to R134A.

3.2 Materials required for the Modeling

(i) A Carrier air conditioner (RAS-13N3KCV Indoor) specifications handbook
(ii) Cycle-D-HX simulation software: The user interface of the software offers a pull-down help menu and various choices for analyzing simulated results, such as (p-h) and (T-s) graphs. CYCLE D-HX replicates the performance of single-compound and refrigerant mixtures in a sub - critical refrigeration system (vapour compression). The basic CYCLE D-HX system, depicted in Figure 2, consists of a condenser, compressor, evaporator, expansion device, compressor suction line, discharge line and an optional suction-line/liquid-line heat exchanger.
The additional cycles might comprise one or two economizers, an intercooler or a second compressor. Unlike the simplified vapor - compression refrigeration cycle shown in Figure 3, which requires refrigerant saturation temperatures in the condenser and evaporator as input, CYCLE D-HX sets up saturation temperatures in the heat exchangers by using temperatures profiles of the heater and sink, as well as the average effective difference in temperature in the condenser and evaporator, as input to the software.



Selected refrigerant : R32

Cycle Type
○ Single Stage
○ Two-Stage Economizer
○ Two-Stage Compression with Intercooling
● Three-Stage Economizer

Options
● Intermediate pressure for high-pressure stage: 1,700.000 kPa
Intermediate pressure for low-pressure stage: 1,200.000 kPa
○ Optimize intermediate pressures

Figure 2. CYCLE_D-HX **simulator**

This heat exchanger representation makes it easier to include both thermodynamic and transport properties in cycle simulations, and it makes the software suitable for analyzing various refrigerants, the program gives the possibility of optimizing refrigerant circuits in heat exchangers to increase system COP. The software has seventy single-compound refrigerants as well as ninety-seven preconfigured mixtures. Blends of up to 5 components can be created by combining single-compound fluids.

3.3 Simulations Procedures

(i) The refrigerant which was being investigated was inputted into the **CYCLE_D-HX** simulator to determine the characteristics of the refrigerants as shown in Figure 2.
(ii) The cycle type was chosen to specify the settings under which the application should operate.
(iii) The cooling capacity was established by consulting the specification manual and then entering the value into the simulator.
(iv) The volumetric efficiency was calculated:

$$\text{Volumetric efficiency} = \frac{Q_f}{\text{Compressor displacement}} \times 100$$

Where compressor displacement is found by:

$$\text{Compressor Displacement} = \frac{\pi}{4} \times D^2 \times L \times N \times x \times n$$

Where, Q_f is Actual free air delivery, D is cylinder bore, L is cylinder stroke, N is compressor RPM, n is number of cylinders and X= 2.

(v) To depict these settings, the subsequent parameters were based on average household air conditioning system.

(vi) The simulation was carried out and the results can be seen in Figures 4 to 8.

(vii) These steps are repeated for refrigerants R404A, R449A, R513A and R452A.

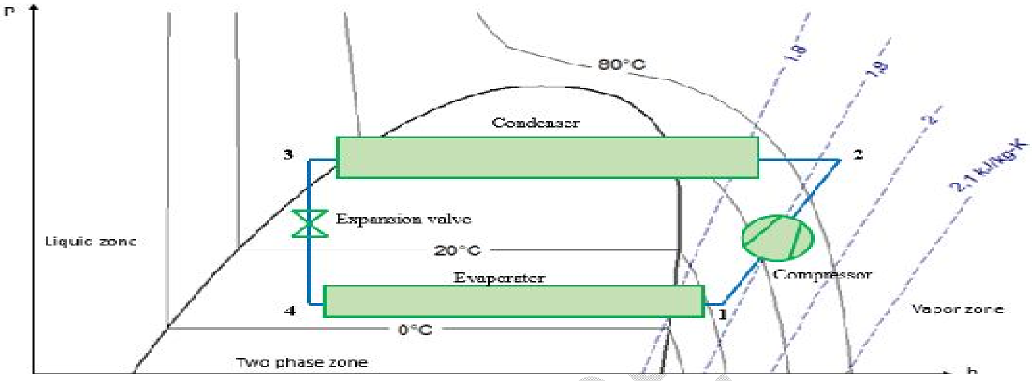


Figure 3. Vapour compression cycle

3.4 Thermodynamic Cycle of the refrigerant during simulation

The CYCLE D-HX model is based on the idea of using mean effective temperature differences (Thx) and temperature profiles of heat transfer fluids (HTFs) for the condenser and evaporator (Domanski and McLinden 1992), which makes it easier to account for the impacts of refrigerant pressure drop, thermophysical properties and heat transfer effectiveness on cycle performance (Brown, Kim and Domanski 2002a, Brown, Yana-Motta and Domanski 2002b). The simulated system, in its most basic version, consists of adiabatic expansion device, evaporator, compressor, and condenser. Figures 4 to 8 illustrate the T-s diagram of the cycle.

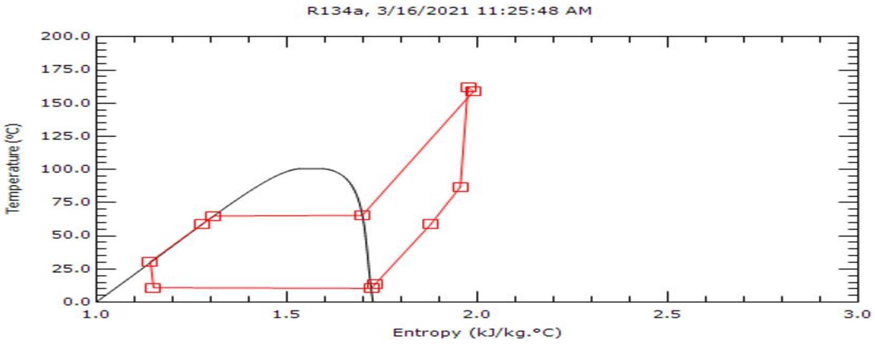


Figure 4. Simulation analysis of R134A refrigerants

The following specifications are required for the basic cycle simulation:

(i) The refrigerant

(ii) HTF temperature profiles

(iii) Thx (or UAhx, total heat transfer conductance) and refrigerant pressure drop in heat exchangers

(iv) Overall system cooling capacity

(v) Characteristics of hardware components, with the exception of the expansion device, which is characterized as isenthalpic (depend on the selected cycle configuration). The energy demands of the inside fan, outside fan, and system controls were specified.

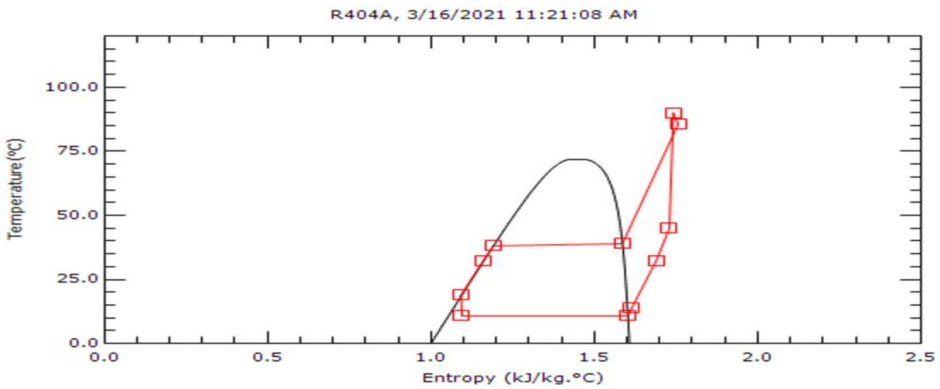


Figure 5: Simulation analysis of R404A refrigerants

For heat exchanger representations, CYCLE D-HX offers two options: 'Impose' or 'Simulate'; these phrases indicate whether Thx (or UAhx) and refrigerant pressure drop are provided (imposed) by the user or simulated. The 'Impose' option is the fundamental simulation mode of CYCLE D-HX and must be used first. At the operating conditions employed in the present cycle simulation, the values of Thx (or UAhx) and refrigerant pressure drop in the condenser and evaporator were provided.

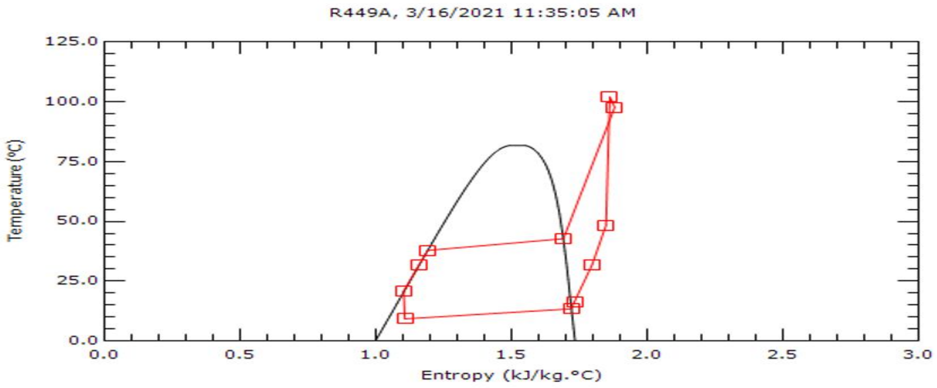


Figure 6. Simulation analysis of R449A refrigerants

Similar to the heat transfer process, the modelling of refrigerant pressure drop for evaporator and condenser is based on the same premise. The model calculates a pressure multiplication factor for smooth tubes based on the 'Impose' run by dividing the imposed refrigerant pressure drop by the value anticipated by related correlations (Eq. 1).

Factor Δp = ΔPimposed/ΔPpredicted ………………… (1)

The Muller-Steinhangen and Heck (MSH) correlation is used to determine ΔP expected for smooth tubes (Muller-Steinhangen and Heck 1986). According to Choi et al., the MSH value in improved tubes is adjusted (Choi, Kedzierski and Domanski 2001).

During calorimeter tests, compressor-map formulas are utilized to correlate the performance of the compressor at specified values of suction superheat and condenser sub-cooling.

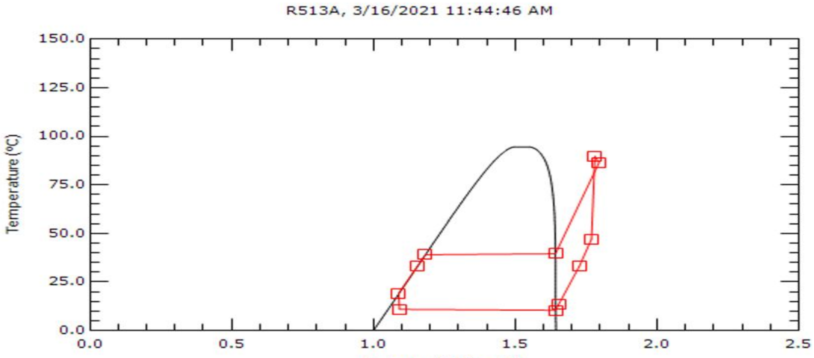


Figure 7. Simulation analysis of R513A refrigerants

The model employs the following stages and assumptions to allow simulations at user-specified conditions:

(i) I The compressor's isentropic efficiency is determined using compressor-map correlations at user-specified saturation temperatures (or pressures) and superheat and sub cooling levels utilized during calorimeter tests. The isentropic efficiency is considered to be unaffected by the degree of superheat, and the computed efficiency value is utilized in the cycle calculations.

(ii) The compressor volumetric efficiency and speed (RPM) are assumed to be unaffected by suction vapor superheat for computing the refrigerant mass flow rate. As a result, the refrigerant mass flow rate at the user-specified superheat matches the mass flow rate at the superheat established during the calorimeter testing, corrected for the difference in suction vapor specific volume produced by a different superheat.

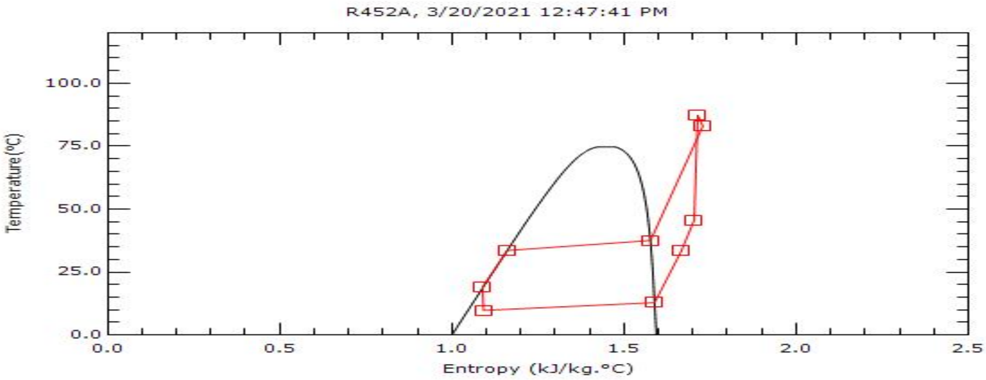


Figure 8. Simulation analysis of R452A refrigerants

4. RESULTS AND DISCUSSIONS

The outputs of the thermodynamic cycle, compressor, and system simulation are divided into two sections. In the cycle category, the results are given per unit mass of refrigerant cycled by the compressor. The ancillary power input to the interior fan, outdoor fan, and controls has no influence on these results, which are exclusively representative of refrigerant properties.

The refrigerant mass flow rate required to achieve the desired system capacity is calculated by CYCLE D-HX software utilizing the thermodynamic parameters identified during the cycle. R134A has a mass flow rate of 2.6479 x 10^{-2} kg/s, R404A 2.8521 x 10^{-2} kg/s, R449A 2.6479 x 10^{-2} kg/s, R513A 2.8521 x 10^{-2} kg/s, and R452A 3.3344 x 10^{-2} kg/s.

4.1 Chemical stability and composition

Each of these refrigerants is a combination of others. The blends were made up of two or more refrigerants that were chemically bound together to handle any form of environmental or safety risk. The base refrigerant of the mixtures is usually R134A, but the addition will minimize the harmful features of the R134A, but obviously these refrigerants will not be the most desirable, thus study on the individual refrigerants and an assessment of the constituent refrigerants was undertaken.

The more appealing refrigerants from Table 5 were R449A and R452A since they both diverge from the usage of the R134A refrigerant, thus the remainder will be less of a priority and less desired. R404A has already been ruled out because it is no longer permitted in any equipment, leaving just two refrigerants to be researched. R449A is a refrigerant mix comprising three refrigerants: hydrofluorocarbons, hydrofluoro-olefin molecules, R32, and R125.

Table 5 Composition of each refrigerant blend

Refrigerant	Refrigerants in that blend
R404A	R125a, R134a, R143a
R449A	R32,R125, R1234yf
R513A	R134a, R1234yf
R452A	R32,R125, R1234yf

This refrigerant is not poisonous or flammable, and ASHRAE has already granted it the A1 safety grade.

Because this refrigerant is not widely used and is still being explored, it was chosen based on its low popularity. This is an excellent refrigerant since it has no chlorine in its components, implying that it has no ozone depletion potential.

R452A is a mixture of hydrofluorocarbons, hydrofluoro-olefin molecules, R125 and R32. It is a non-toxic and non-flammable HFO combination. It has a zero percent of ODP, making it very desirable. It is frequently regarded as the future HFO refrigerant, capable of being employed in a vast scope of refrigeration applications ranging from big to small scale.

4.2 Coefficient of performance

Table 6 displays the coefficient of performance (COP) findings of the refrigerants generated from the simulator. The COP is the ratio of usable heating/cooling to work needed. The higher the performance coefficient, the more cost-effective the system.

Table 6 COP of the Refrigerants

Refrigerant	Coefficient of performance
R134a	1.455
R404a	1.567
R449a	1.560

R513a	1.572
R452a	1.578

The COP of the refrigerants are compared in Table 4. R452A has the greatest COP of 1.578, whilst R134A has the lowest.

Figure 9 illustrates that R452A has the highest COP. The greater the COP, the more efficient the system. As a result, R449A has the lowest coefficient of performance compared to R134A, while R452A has the greatest.

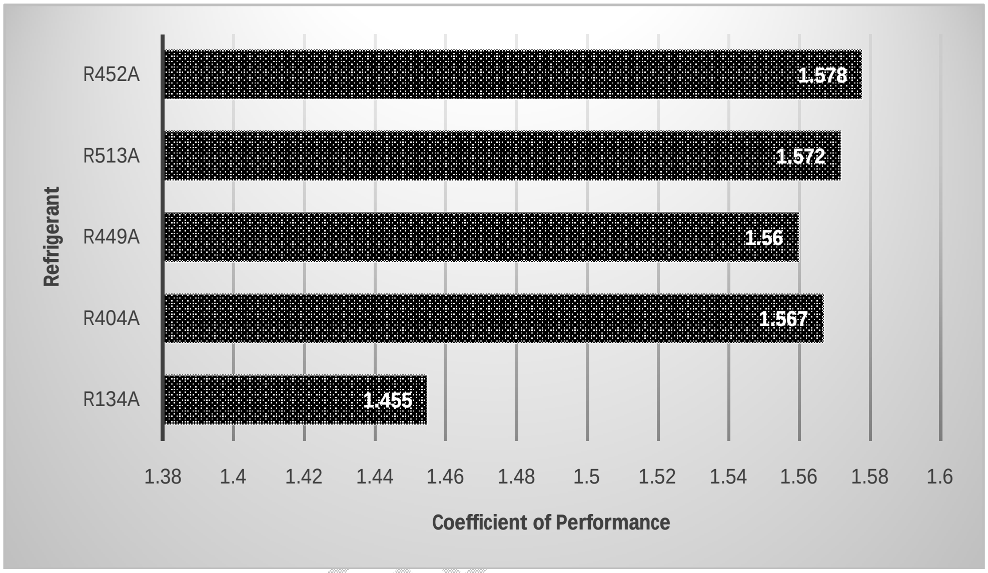


Figure 9. Coefficient of performance of the Refrigerants

This is critical when selecting a refrigerant since efficiency is essential to reduce energy consumption and be as cost-effective as possible while saving money on utility bills. As a result, when it comes to refrigerant selection, R452A stands out since it is 0.123 units higher than R134A, which is being replaced. The primary goal of this research was to find energy-efficient replacements for ozone-depleting refrigerants; however, in order to be both energy efficient and environmentally friendly, it was critical to include a criterion to ensure that the consumer gets their money's worth when using the refrigerant. As a result, the R452A is the best choice in terms of efficiency because it has the greatest COP. Furthermore, the counter flow evaporator and condensers were chosen because they produce a more consistent temperature differential between fluids along the whole length of the fluid route.

4.3 Global warming and ozone depletion potential

Table 7 demonstrates the potential for global warming and ozone depletion for each refrigerant. Global warming potential refers to the amount of heat absorbed by any greenhouse gas in the atmosphere. The greater the GWP of a gas, the more hazardous it is to the environment. However, ASHRAE authorizes a range of acceptable for GWP that ranges from 460 to 8600 units. As a result, a replacement refrigerant for R134A must be pretty near to that figure of 1430 units. R513A, on the other hand, has the lowest global warming potential as shown in Figure 10 but will not be employed because it is currently prohibited from manufacture as of 2020.

Table 7: Ozone depletion and Global warming potential of Refrigerant

Refrigerants	Global warming potential (Units)	Ozone depletion potential (Dobson Units)
R134a	1430	0.02
R404a	3922	0
R440a	3974	0
R513a	573	0
R452a	2140	0

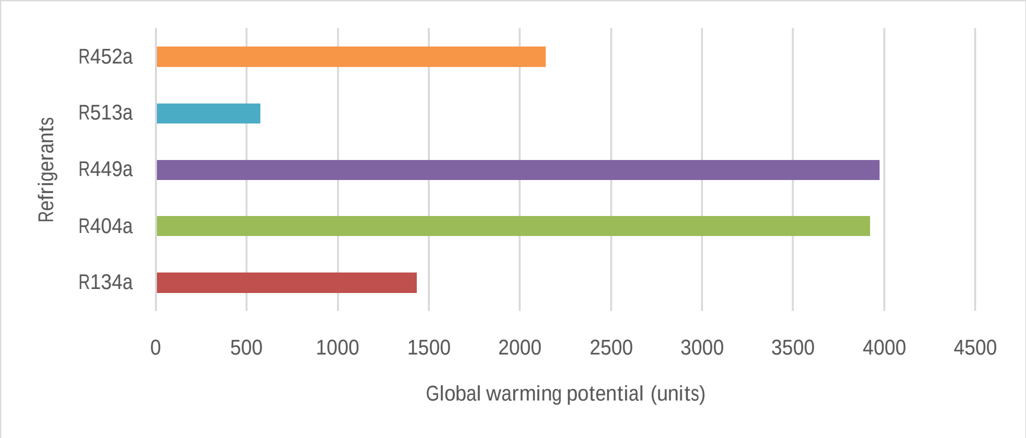


Figure 10. Global warming potential of the refrigerants

As a result, focus will shift to the next lowest bar, the R452A, which has a unit count of 2140. It is not less than R134A, but it is reasonably near, and it has other advantageous features that were previously stated, such as not being flammable or hazardous to human life as well as the environment, including being cost effective and low energy consumption due to its high performance coefficient. Furthermore, the other two refrigerants, R404A and R440A, are too expensive to be considered in contrast to R452A. As a result of this breakdown, R452A will be selected. Scientists in the present field of study and technology have discovered that CFCs have the property of depleting the ozone layer, which will lead to the entire global warming rise that is being avoided. As a result, R134A has the largest ozone depletion potential, whereas the rest of the refrigerants are all Zero or inconsequential due to their low values as shown in Figure 11. As a result, R452A is still the best option because of its advantages over other refrigerants.

4.4 Temperature glide

The temperature glide is the difference between the starting and finishing temperatures of a certain phase shift inside a constant pressure system. Temperature glide is defined as the difference between the saturated vapour temperature and the saturated liquid temperature at constant pressure in more sophisticated words.

Table 8 shows the respective temperature glides are shown below.

Figure 11. Ozone depletion potential of the refrigerants

Table 8. Temperature glide in the evaporator and condenser for each refrigerant

Refrigerant	Glide(evaporator) ^{o}C	Glide(condenser) ^{o}C
R134a	0.5	0.5
R404a	0.1	0.8
R449a	4.2	4.9
R513a	0.5	0.5
R452a	0.5	0.5

Table 8 shows that the results of the glide between R513A, R452A and R134A are the same. This indicates that the beginning temperature is 0.5 °C. lower than the end temperature during a phase shift.

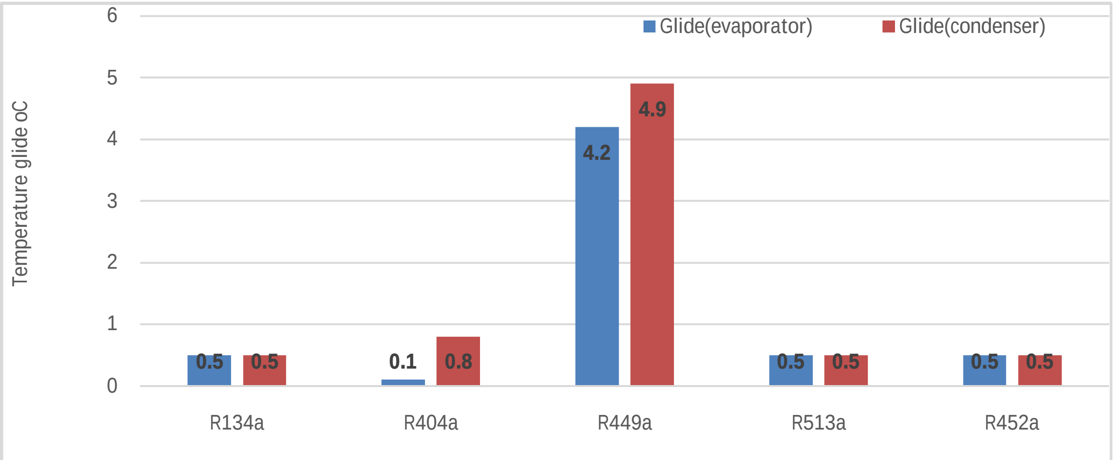


Figure 12. Temperature glide in the evaporator and condenser for each refrigerant

Temperature glide refers to the difference between the final and initial temperatures during a phase transition. This temperature variation was observed in both the condenser and the evaporator to provide a comprehensive view of the system's characteristics and specifications in order to appropriately analyse each situation.

The temperature glide, in essence, reflects the refrigerant's capacity to cool fast; hence, the smaller the difference, the better the refrigerant, because it can easily change phases. This will be useful in air conditioning systems, where rapid cooling/heating is necessary to achieve comfort criteria. This saves energy as the evaporator/condenser does not have to work as hard to achieve the required outcome. Figure 12 depicts the same values for R134A, R513A, and R452A. Because the evaporator and condenser are both balanced, the temperature differential for these refrigerants is favorable. As a result, when choosing a refrigerant, this criterion will be faulty. However, based on recent results, R452A will be the preferred refrigerant.

5. CONCLUSION

The purpose of this study was to look at the performance of a domestic refrigerator using various low-GWP refrigerants. R404A, R440A, R513A, and R452A were investigated as prospective R134A replacements. Data from an R134A-charged household refrigerator was used to verify the model. The model was then used to evaluate the performance characteristics of the alternative refrigerants, such as R404A, R449A, R513A, and R452A. The R452A was proven to have a high COP, a low ODP, a low GWP and a low temperature glide. R452A mix is non-corrosive, non-flammable, and will not cause corrosion of the metal parts of the refrigerating system's compressor and evaporator. The simulation accurately simulated a standard modern air conditioning system that is routinely used in the home. This air conditioner's model number is Carrier RAS-13N3KCV (indoor). This was chosen since it is a regularly marketed unit, so that a significant chunk of the population will be covered.

Since the refrigerants chosen are not popular and have not been extensively explored, the quantity of literature is limited when compared to dominant and widely used refrigerants such as R134A.

The parameters that were focused on are a crucial part of assessing system efficiency and hence determining which of these refrigerants may successfully replace R134A as a home refrigerant.

Aside from the temperature glide, the program featured an easy-to-use data entering structure as well as all of the necessary data outputs such as the COP and the accompanying graphs.

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