

Performance Assessment of Low Global Warming Potential Alternative Refrigerants

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 **global warming potential** 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 **global warming potential** alternative refrigerants, including R404A, R449A, R513A, and R452A, was then assessed using the model.

The hydrofluoroolefin based R452A refrigerant is an alternative to R404A and R507 that is non-ozone depleting and has a low global warming potential. An azeotropic blend, R-513A is a drop-in replacement for R-134a in existing systems. Common hydrofluorocarbons and the new hydrofluoro-olefin molecule R1234yf are combined to form R449a, which is made up of R32 (24%), R125 (25%), R134a (26%), and R1234yf (25%). R513A, an azeotropic blend with no temperature glide, is composed of 44% R134a and 56% R1234yf.

The simulation's findings demonstrate that R452A has a coefficient of performance 1.578, a zero potential for ozone depletion, a 0.5°C temperature glide for the evaporator and condenser and also a low potential for global warming unit count of 2140. Along with these thermodynamic and environmental qualities, R452A blend can take the place of R134A as a refrigerant because it is non-flammable and noncorrosive and will not corrode the metal parts 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-CO₂ 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).

28 Global warming is defined as an increase in global temperature caused by greenhouse gas
29 levels above normal, allowing heat coming into the planet earth to be captured and heat
30 waves to continue accessing the airspace without escaping. Chlorofluorocarbons (CFC)
31 cause chemical interactions with the Earth's protective ozone layer. These reactions, on the
32 other hand, are exceedingly harmful and will deplete the ozone layer, which is a significant
33 disadvantage. The ozone layer prevents ultraviolet (UV) radiation from entering the
34 atmosphere, which is significant since UV rays are the leading cause of skin cancer, as well
35 as impacting plant development and creating cataracts in people, which impair their vision.
36 With the Montreal Protocol's international efforts to eradicate chlorinated fluids in order to
37 protect the ozone layer ([Newchurch 2003](#)), it was time to concentrate on phasing out
38 greenhouse gases in order to save the environment. The Kyoto Protocol was signed in 1997,
39 setting off these efforts. It was further strengthened by the European Union's F-Gas
40 Regulation in 2014 and the Kigali Amendment, which aims to cut HFC refrigerant usage by
41 80% by 2047 ([UN 1998](#), [EC 2014](#), [UNEP 2016](#)). Despite the inclusion of chlorinated
42 compounds in the Montreal Protocol, the phase-out of CFC refrigerants, which are similar to
43 chlorinated materials, lowered global warming by 25% ([UNEP 2016](#)). This is due to the fact
44 that CFCs have a very high global warming potential (GWP). To minimize greenhouse gas
45 emissions in the heat pump, refrigeration, and air conditioning sectors, substitute refrigerants
46 with lower global warming potential have been introduced to replace currently utilized HFCs
47 which has greater values of greenhouse gas. The HPRAC system emits both direct and
48 indirect emissions that contribute to global warming. As a result, the global warming potential
49 values of alternative refrigerants must be evaluated, including the energy efficiency of the
50 equipment using the refrigerants ([Goyal 2019](#), [Mateu-Royo 2021](#)). The similar environmental
51 impact of HPRAC systems has been measured using a range of methods ([Mota-Babiloni](#)
52 [2020](#)). The Total Equivalent Warming Impact (TEWI) is a commonly used statistic for
53 calculating the direct and indirect analogous CO₂ emissions from HPRAC systems ([Sogut](#),
54 [Yalcin](#), [Karakoc 2012](#)). Several studies have been conducted to investigate the efficiency of
55 refrigerator that uses refrigerants other than the typically used HFCs ([Mateu-Royo et al.](#)
56 [2019](#), [Mota-Babiloni et al. 2018](#)). [Mateu-Royo et al.](#) conducted a comparison study to assess
57 the impact of utilising R515B and R1234ze(E) as low-GWP R134a alternatives on heat
58 pump system energy performance and environmental impact. Their research demonstrated
59 that the refrigerants had the same coefficient of performance (COP) as R134a. The TEWI of
60 R1234ze(E) and R515B was reduced by 18 and 15%, respectively, because they possess
61 lesser GWP than R134a. The authors also investigated the properties of R1233zd(E),
62 R1224yd(Z) and R1336mzz(Z) as low-GWP alternatives to R245fa in a high-temperature
63 heat pump (HTHP), they discovered that the system's COP increased by 27, 21, and 17
64 percent, respectively. The system using alternative refrigerants lower-GWP values and
65 higher energy performance resulted in a TEWI reduction of 59 to 61 percent when compared
66 to R245fa. [Makhnatch et al.](#) evaluated the energy efficiency of refrigeration systems
67 employing R134a and drop-in equivalents like R513A and R450A ([Makhnatch et al. 2019](#)).
68 They observed that using R513A instead of R134a enhanced the COP of the system by 1.8
69 percent, whereas R450 had a 5.3 percent lower COP. [Mota-Babiloni et al.](#) examined the
70 energy efficiency of an HTHP multistage vapour compression system with an IHX that used
71 low-GWP HFC substitutes. They used R1234ze(E), isobutene, R1234yf, butane, and
72 propane in the upper-stage cycle and pentane, R1233zd(E), R1336mzz(Z)
73 and R1224yd(Z) in the lower-stage cycle. They discovered that pentane
74 and R1336mzz(Z) offered the best system performance during the upper-stage cycle. When
75 using butane/pentane instead of R134a/R245fa refrigerants, the system showed
76 improvement, with a 13 % COP.

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

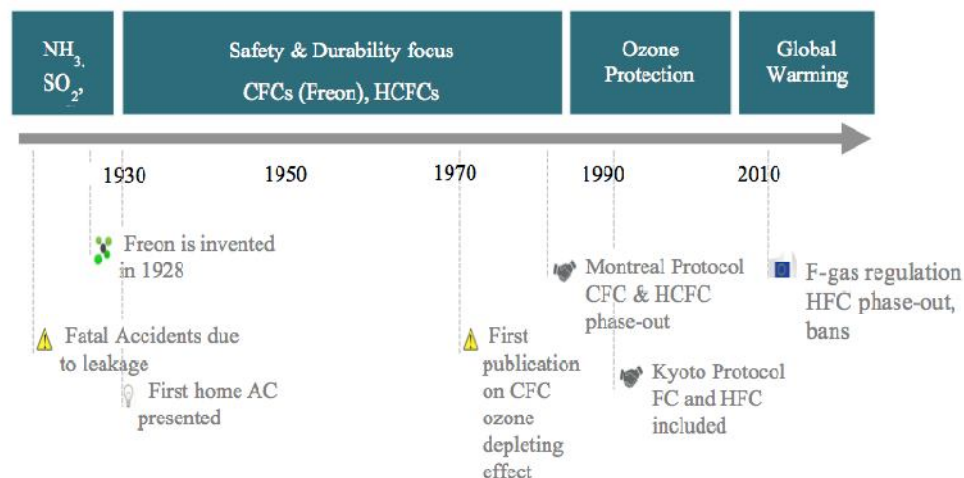
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82 2. LITERATURE REVIEW

83 2.1 Refrigerants

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



95

96

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

97 2.2 Ozone Depletion and Global Warming

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

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

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

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

126 **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°C) kg/m³	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

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

131 **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	0	11700
	R32	0	650
	R125	0	2800
	R134a	0	1300
	R143a	0	3800
	R152A	0	140
Natural Refrigerants	R290	0	3
	R600a	0	3
	R717	0	0
	R718	0	0
	R744	0	1

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

138
139

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 ktoms

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

141 3. METHODOLOGY

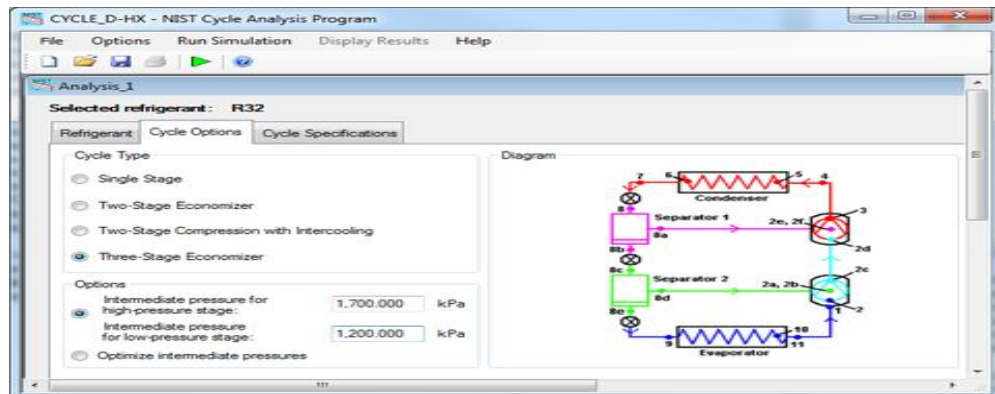
142 3.1 Modeling Approach

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

147

148 3.2 Materials required for the Modeling

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



163
 164 **Figure 2. CYCLE_D-HX simulator**
 165

166 This heat exchanger representation makes it easier to include both thermodynamic and
 167 transport properties in cycle simulations, and it makes the software suitable for analyzing
 168 various refrigerants, the program gives the possibility of optimizing refrigerant circuits in heat
 169 exchangers to increase system COP. The software has seventy single-compound
 170 refrigerants as well as ninety-seven preconfigured mixtures. Blends of up to 5 components
 171 can be created by combining single-compound fluids.
 172

173 3.3 Simulations Procedures

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

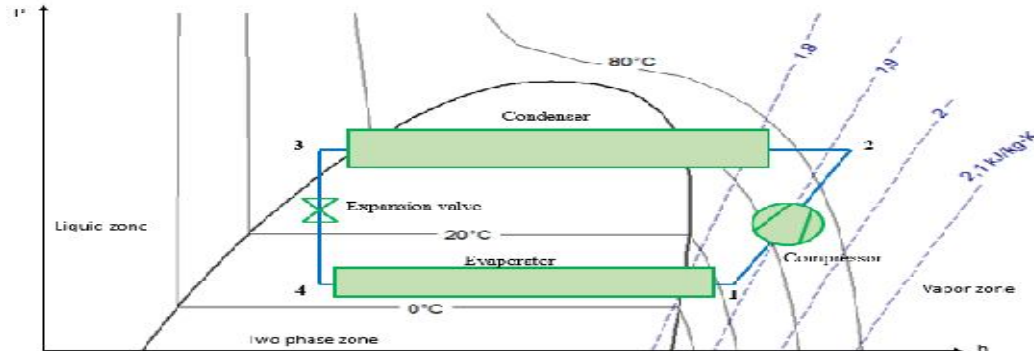
$$\text{Volumetric efficiency} = \frac{Q_f}{\text{Compressor displacement}} \times 100$$

181 Where compressor displacement is found by:

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

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

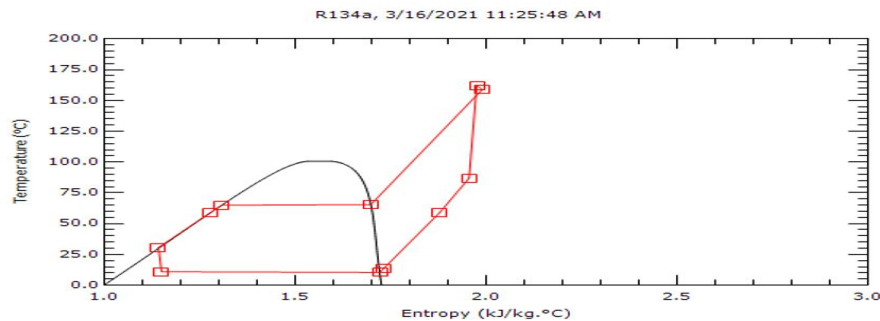
- 184 (v) To depict these settings, the subsequent parameters were based on average
 185 household air conditioning system.
 186 (vi) The simulation was carried out and the results can be seen in Figures 4 to 8.
 187 (vii) These steps are repeated for refrigerants R404A, R449A, R513A and R452A.
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189
 190 **Figure 3. Vapour compression cycle**

191 **3.4 Thermodynamic Cycle of the refrigerant during simulation**

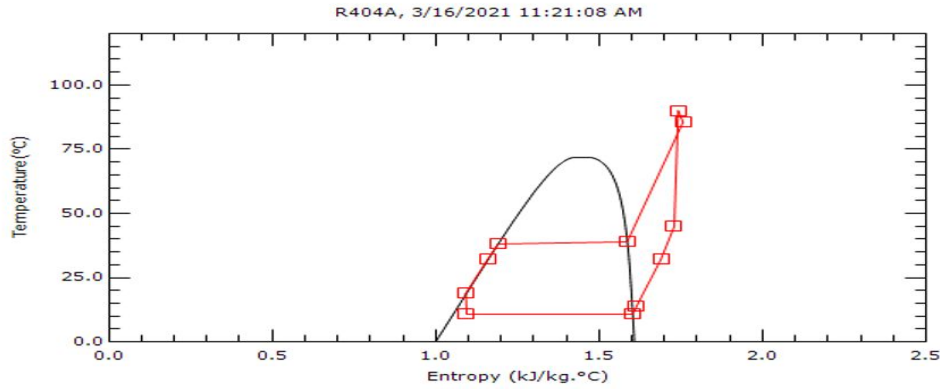
192 The CYCLE D-HX model is based on the idea of using mean effective temperature
 193 differences (T_{hx}) and temperature profiles of heat transfer fluids (HTFs) for the condenser
 194 and evaporator (Domanski and McLinden 1992), which makes it easier to account for the
 195 impacts of refrigerant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



200
 201 **Figure 4. Simulation analysis of R134A refrigerants**

202 The following specifications are required for the basic cycle simulation:

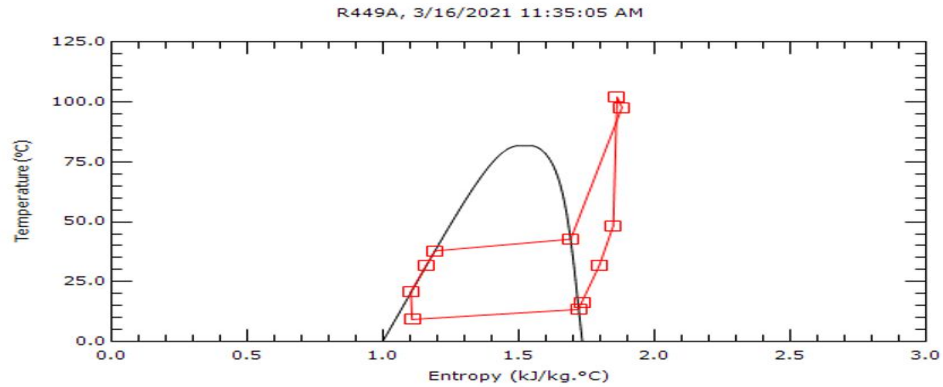
- 203 (i) The refrigerant
 204 (ii) HTF temperature profiles
 205 (iii) T_{hx} (or UA_{hx} , total heat transfer conductance) and refrigerant pressure drop in heat
 206 exchangers
 207 (iv) Overall system cooling capacity
 208 (v) Characteristics of hardware components, with the exception of the expansion device,
 209 which is characterized as isenthalpic (depend on the selected cycle configuration).
 210 The energy demands of the inside fan, outside fan, and system controls were
 211 specified.



212
213

Figure 5: Simulation analysis of R404A refrigerants

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



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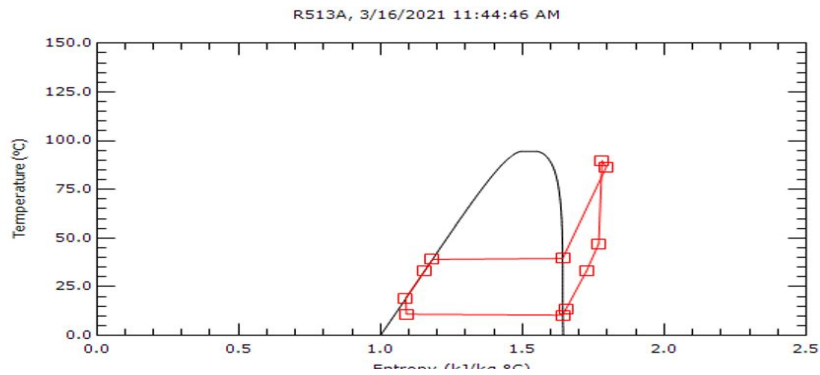
Figure 6. Simulation analysis of R449A refrigerants

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

226 Factor $\Delta p = \Delta P_{imposed} / \Delta P_{predicted} \dots\dots\dots (1)$

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

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



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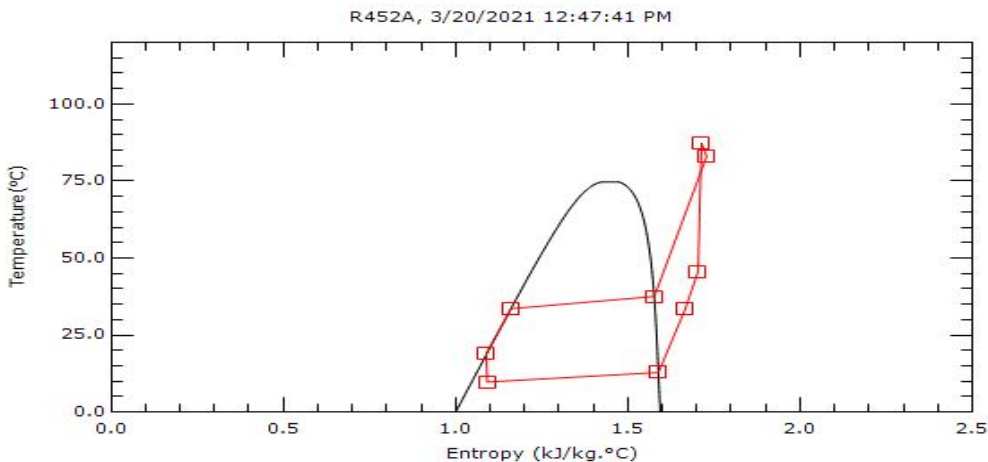
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Figure 7. Simulation analysis of R513A refrigerants

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

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

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



246

247

Figure 8. Simulation analysis of R452A refrigerants

248 **4. RESULTS AND DISCUSSIONS**

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

254 The refrigerant mass flow rate required to achieve the desired system capacity is calculated
 255 by CYCLE D-HX software utilizing the thermodynamic parameters identified during the cycle.
 256 R134A has a mass flow rate of 2.6479×10^{-2} kg/s, R404A 2.8521×10^{-2} kg/s, R449A 2.6479
 257 $\times 10^{-2}$ kg/s, R513A 2.8521×10^{-2} kg/s, and R452A 3.3344×10^{-2} kg/s.

258

259 4.1 Chemical stability and composition

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

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

272

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

273

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

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

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

283 4.2 Coefficient of performance

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

287

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

288 The COP of the refrigerants are compared in Table 4. R452A has the greatest COP of
 289 1.578, whilst R134A has the lowest.

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

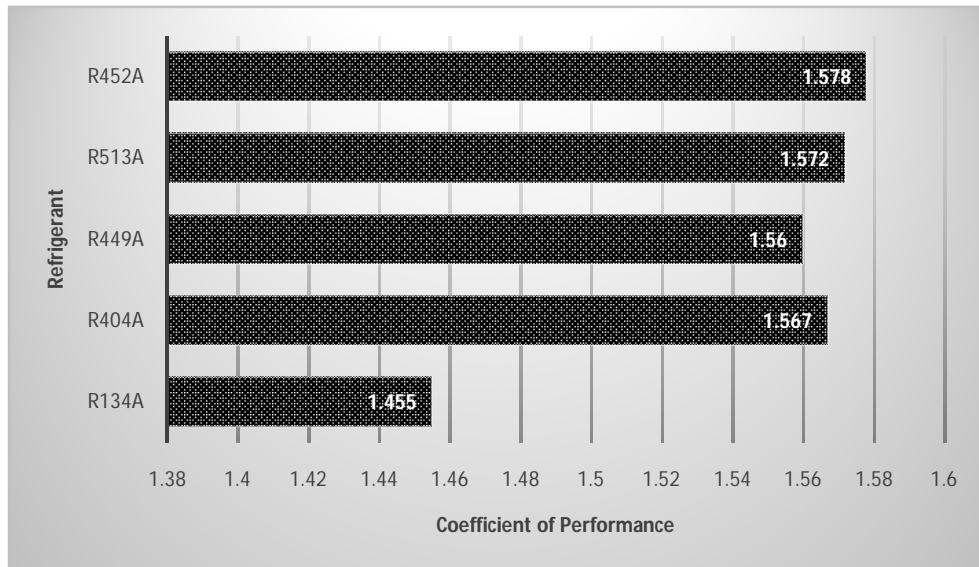


Figure 9. Coefficient of performance of the Refrigerants

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294

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

305

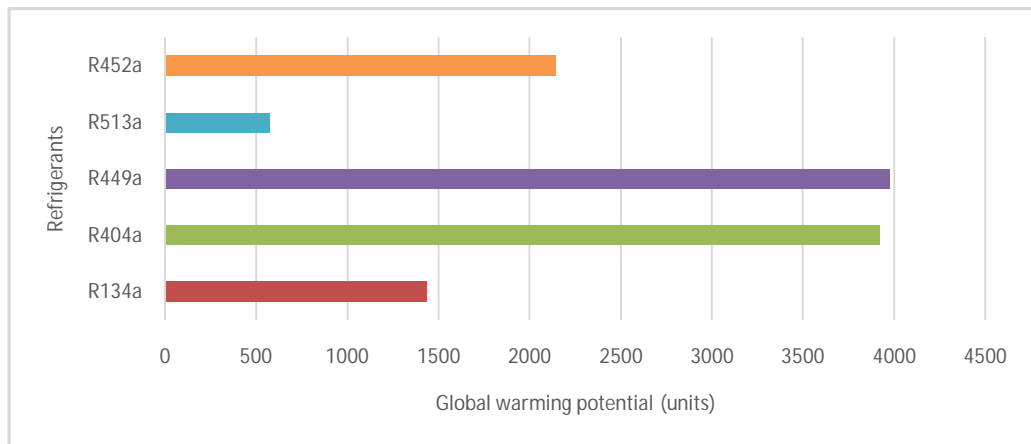
306 **4.3 Global warming and ozone depletion potential**

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

315 **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

316



317

318

Figure 10. Global warming potential of the refrigerants

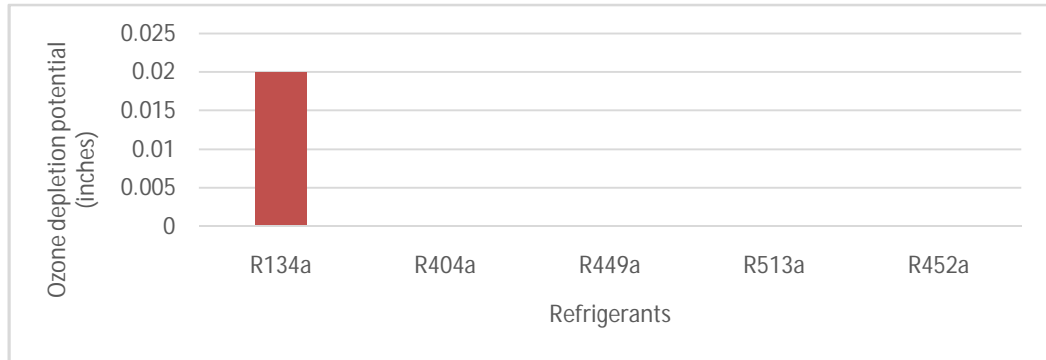
319 As a result, focus will shift to the next lowest bar, the R452A, which has a unit count of 2140.
320 It is not less than R134A, but it is reasonably near, and it has other advantageous features
321 that were previously stated, such as not being flammable or hazardous to human life as well
322 as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

331 **4.4 Temperature glide**

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

336 Table 8 shows the respective temperature glides are shown below.

337



338

Figure 11. Ozone depletion potential of the refrigerants

339

340

341

Table 6. Temperature glide in the evaporator and condenser for each refrigerant

Refrigerant	Glide(evaporator) °C	Glide(condenser) °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

342

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

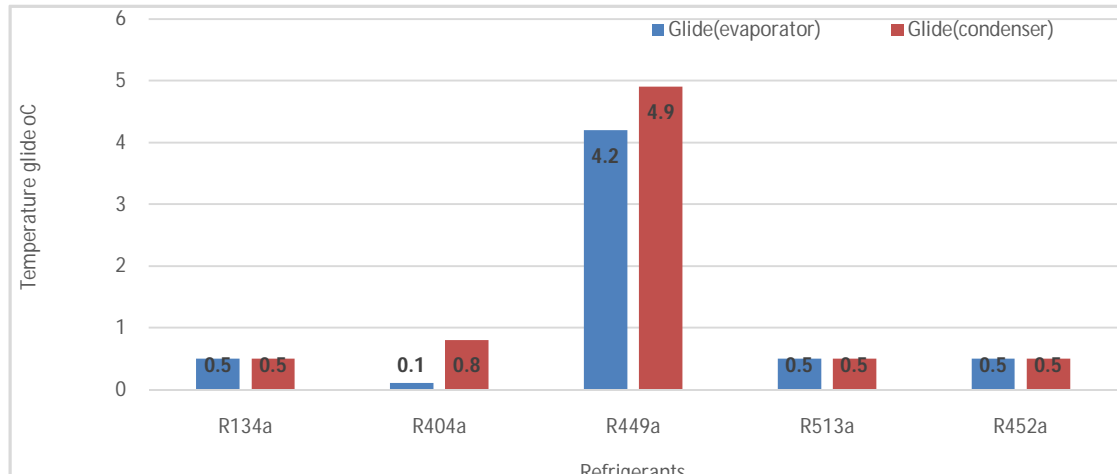


Figure 12. Temperature glide in the evaporator and condenser for each refrigerant

346

347

348

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

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

362

363 5. CONCLUSION

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

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

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

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

384

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388

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