*Journal of Advanced Research in Materials Science* 71, Issue 1 (2020) 12-31

Journal of Advanced Research in Materials Science

Journal homepage: www.akademiabaru.com/arms.html
ISSN: 2289-7992


# Development of Environmentally - Friendly and Energy Efficient Refrigerant for Medium Temperature Refrigeration Systems

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**ABSTRACT**

This research presents the development of environmentally-friendly and energy efficient refrigerant for medium temperature refrigeration systems that new azeotropic refrigerant mixture of hydrofluorocarbons and hydrocarbon that can retrofit in the refrigeration system using R404A. The medium back pressure refrigeration testing standard that follow CAN/ANSI/AHRI540 standard air-conditioning, heating, and refrigeration institute (AHRI) and The properties of refrigerants and refrigeration simulation system that used national institute of standards and technology (NIST) reference fluid thermodynamic and transport properties database (REFPROP) software and NIST vapor compression cycle model accounting for refrigerant thermodynamic and transport properties (CYCLE_D-HX) software. The methodology use decision tree function in datamining by rapid minor software that first of KDnuggets annual software poll that showed new azeotropic refrigerant mixture had cooling capacity, refrigerant effect, GWP and boiling point were lower than R404A but work and pressure for medium temperature refrigeration system of azeotropic refrigerant mixture were higher than R404A. The artificial intelligence (AI) by data mining technic can predictive environmentally-friendly and energy efficient refrigerant for medium temperature refrigeration. The result of refrigerant mixed by R134A, R32, R125 and R1270 and is consistent with the evolution of fourth-generation refrigerants that contain a mixture of HFCs and HCs which are required to produce a low-GWP, zero-ozone-depletion-potential (ODP), high-capacity, low-operating-pressure, and nontoxic refrigerant.

***Keywords:***
Refrigerant; refrigeration system; energy efficiency; environmentally friendly; data mining



## 1. Introduction

Energy use in Thailand's business sector is ranked second among overall energy users in the country, and is thus being targeted for energy-saving options [1]. The number of convenience stores in Thailand numbered to more than 20,000 locations in 2019, and this continuously increases on an annual basis [2]. The majority are open 24 hours per day, so the retail sector is the fourth largest

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https://doi.org/10.37934/arms.71.1.1231

consumer of energy in the business sector, consuming more energy than residences do [3]. The components that contribute to energy consumption of convenience stores in Thailand, ranked from highest to lowest, are refrigeration systems, air-conditioning systems, electrical equipment, and lighting [4,5]. However, proportions of energy use in convenience stores in Taiwan were previously ranked as shown in Figure 1 below [6]. The best options for reducing energy consumption in convenience stores in Thailand are high energy efficiency and an efficient energy-management system. A good example of energy savings in refrigeration systems is shown in Figure 2 below [7]. Energy savings in refrigeration systems can be achieved through decreased power consumption of the compressor, as this is the component that utilizes the most energy.

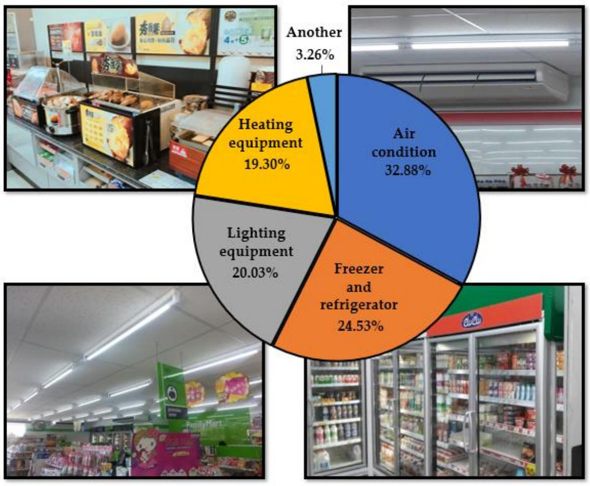


**Fig. 1.** Proportions of energy use in Taiwanese convenience stores [6]

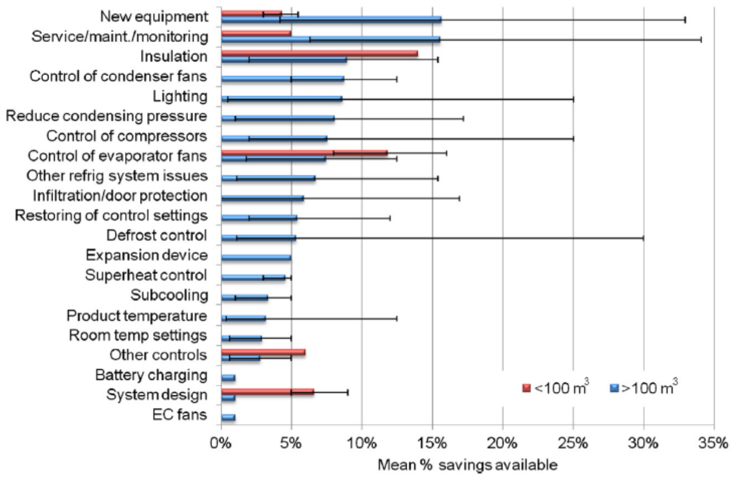


**Fig. 2.** Examples of energy savings in refrigeration systems [7]

Refrigerant trends in Thailand have shown improvements in increasing energy efficiency and decreasing global-warming potential (GWP), as shown in Figure 3 [8,9], which is related to the hydrofluorocarbon (HFC) phase-down schedule, as shown in Figure 4 [10]. First- and second-generation refrigerants were composed of natural refrigerants and hydrocarbons (HCs), both of which do not impact the environment, have low GWP, and zero ozone-depletion potential (ODP) [11–13]. R744 operates under high pressure, and is highly toxic and flammable [14–16]. Following the second generation, third-generation refrigerants were composed of chlorofluorocarbons (CFCs) [17–19] and hydrochlorofluorocarbon (HCFCs) [20–22], which are easy to use, can operate under low pressure, and are nontoxic. However, they have high GWP and ODP, contributing to ozone depletion and global warming. Therefore, the development of refrigerants has significantly decreased ODP and GWP. Moreover, third-generation refrigerants, CFCs and HCHCs, were further developed into hydrofluorocarbon (HFC) refrigerants that still possessed low GWP and zero-ODP [23–25]. Fourth-generation refrigerants are mainly hydrofluoroolefins (HFOs) with low GWP and low capacity [26–28]. Therefore, they are refrigerants that are mixed with HFCs [29–31], HFOs [32–34], and HCs [35–37]. Natural refrigerants are low-GWP, zero-ODP, high-capacity, low-pressure, and nontoxic [38–40].

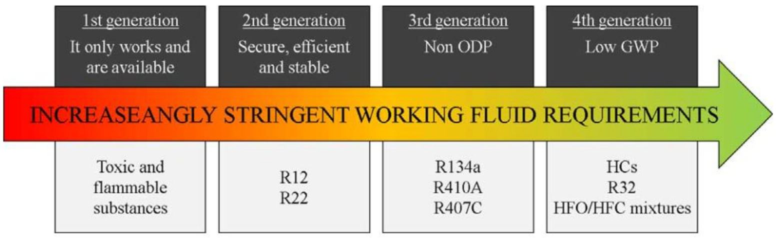


**Fig. 3.** Evolution of refrigerants [8,9]

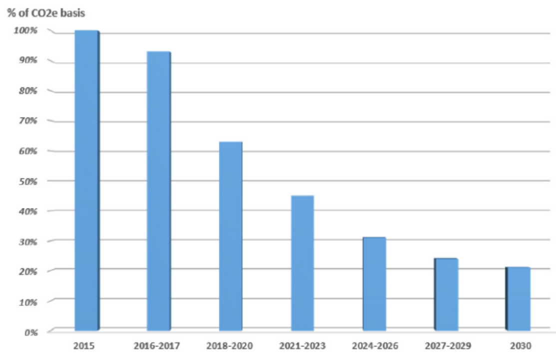


**Fig. 4.** Hydrofluorocarbon (HFC) phase-down schedule (Co2e %) [10]

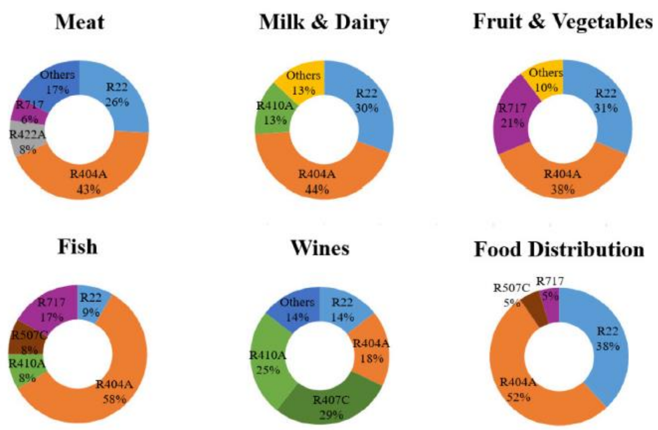


**Fig. 5.** Top refrigerants in food industry [9]

Refrigerants need to be low-GWP, zero-ODP, high-capacity, low-pressure, and nontoxic, and should thus be mixed with HCs and HFOs; however, current refrigerants are still highly flammable and have low capacity. An alternative is to incorporate other HFCs. R32 is low-GWP, zero-ODP, high-capacity, and nontoxic, but operates under high pressure and is not flammable, which is in contrast to R134A, which possesses highly similar properties but can operate under low pressure and has low capacity. Systems that operate with R22 [41], R417A [42], R417B [43], R422A [44], R422B [45], R422C [46], R422D [47], R424A [48], R433A [49], R437A [50], R438A [51] and R453A [52], were developed as an alternative to R22 and mixed with HCs and HFCs, as shown in Tables 1-4. Systems that operate with R134A [53], R450A [54], R456A [40], R513A [55], and R515A [40] were developed as an alternative to R134A, and mixed with HCs, HFCs, and HFOs, as shown in Table 5. The fourth-generation R404A was the basis for this research, and it is currently the most used refrigerant, as shown in Figure 5. R404A is an azeotropic blend of 143a/125/134a with zero ODP, and is nonflammable, nontoxic, and operates under low pressure, but has a GWP of 3922 [56]. R407A [57], R407F [58], R407H [59], R410A [60], R442A [52], R448A [61], R449A [62], R452A [63], R453A [64], and R463A [65] were developed to be retrofitted to replace R404A as shown in Table 6-9, and are mixed with HCs, HFOs, R134A, and R32. This is similar to the refrigerant that was developed for R22 and R134A but does not include R463A, which is being presented as a refrigerant for comparative purposes in this research as it is composed of R744 (carbon dioxide), which is a natural refrigerant similar to R445A [64] and R455A [65]. These conform to the refrigerant-development trend and are an alternate option that can be mixed with HFC. The refrigerant proportion that was mixed with R125 was more or less similar to that of the R32 mixture, and it also possesses Class A1 nonflammability property.

**Table 1**
Properties of R22, R417A and R417B

| Condition | LT | MT | HT | LT | MT | HT | LT | MT | HT |
|---|---|---|---|---|---|---|---|---|---|
| Refrigerant | | R22 [41] | | | R417A [42] | | | R417B [43] | |
| Composition | | R22 | | | R125/R134a/R600 | | | R125/134a/600 | |
| Mass percentage | | 100 | | | 46.6/60/3.4 | | | 79/18.3/2.7 | |
| Boiling point (°C) | | -40.80 | | | -39.10 | | | -45.20 | |
| Critical Pressure (kPa) | | 4,990 | | | 4,036 | | | 3,737 | |
| Critical Temperature (°C) | | 96 | | | 87 | | | 74 | |
| ODP | | 0.055 | | | 0 | | | 0 | |
| GWP | | 1,600 | | | 1,950 | | | 3,027 | |
| Class | | A1 | | | A1 | | | A1 | |
| Lubricant type | | MO | | | MO/AB/POE | | | MO/POE | |

**Table 2**
Properties of R422A, R422B and R422C

| Condition | LT | MT | HT | LT | MT | HT | LT | MT | HT |
|---|---|---|---|---|---|---|---|---|---|
| Refrigerant | | R422A [44] | | | R422B [45] | | | R422C [46] | |
| Composition | | R125/R134a/R600a | | | R125/R134a/R600a | | | R125/R134a/R600a | |
| Mass percentage | | 85.1/11.5/3.4 | | | 55/42/3 | | | 82/15/3 | |
| Boiling point (°C) | | -46.80 | | | -41.59 | | | -46.20 | |
| Critical Pressure (kPa) | | 3,665 | | | 3,857 | | | 3,696 | |
| Critical Temperature (°C) | | 72 | | | 82 | | | 72 | |
| ODP | | 0 | | | 0 | | | 0 | |
| GWP | | 2,530 | | | 2,526 | | | 3,085 | |
| Class | | A1 | | | A1 | | | A0 | |
| Lubricant type | | MO/AB/POE | | | MO/POE | | | MO/POE | |

**Table 3**
Properties of R422D, R424A and R437A

| Condition | LT | MT | HT | LT | MT | HT | LT | MT | HT |
|---|---|---|---|---|---|---|---|---|---|
| Refrigerant | | R422D [47] | | | R424A [48] | | | R437A [50] | |
| Composition | | R125/R134a/R600a | | | R125/R134a/R600/R600a/R601a | | | R125/134A/R600/R601 | |
| Mass percentage | | 62.1/31.5/3.4 | | | 50.5/47/1/0.9/0.9 | | | 19.5/78.5/1.4/0.6 | |
| Boiling point (°C) | | -43.50 | | | -38.70 | | | -32.65 | |
| Critical Pressure (kPa) | | 3,795 | | | 4,040 | | | 4,003 | |
| Critical Temperature (°C) | | 80 | | | 89 | | | 95 | |
| ODP | | 0 | | | 0 | | | 0 | |
| GWP | | 2,330 | | | 2,440 | | | 1,805 | |
| Class | | A1 | | | A1 | | | A1 | |
| Lubricant type | | MO/AB/POE | | | MO/AB/POE | | | MO/POE | |

**Table 4**
Properties of R438A and R453A

| Condition | LT | MT | HT | LT | MT | HT |
|---|---|---|---|---|---|---|
| Refrigerant | | R438A [51] | | | R R453A [52] | |
| Composition | | R125/134A/R32/R600/R601a | | | R125/R32/R134A/R227ea/R600/R601A | |
| Mass percentage | | 45/44.2/8.5/1.7/0.6 | | | 20/20/53.8/5/0.6/0.6 | |
| Boiling point (°C) | | -42.61 | | | -42.20 | |
| Critical Pressure (kPa) | | 4,179 | | | 4,530 | |
| Critical Temperature (°C) | | 84 | | | 88 | |
| ODP | | 0 | | | 0 | |
| GWP | | 2,265 | | | 1,765 | |
| Class | | A0 | | | A1 | |
| Lubricant type | | MO/POE | | | MO/POE | |

**Table 5**
Properties of R134A, R450A, R456A, R513A and R515A

| Refrigerant | R134A [53] | R450A [54] | R456A [40] | R513A [55] | R515A [40] |
|---|---|---|---|---|---|
| Composition | R134A | R134A/ R12354ze(E) | R134a/R32/R1234ze (E) | R134A/ R1234yf | R227ea/ R1234ze |
| Mass percentage | 100 | 42/58 | 45/6/49 | 44/56 | 12/88 |
| Boiling point (°C) | –26.07 | –23.5 | –30.75 | –28.3 | –18.75 |
| Critical pressure (kPa) | 4060 | 3814 | 4175 | 3700 | 3555 |
| Critical temperature (°C) | 101.06 | 105.87 | 102.65 | 97.7 | 108.65 |
| ODP | 0 | 0 | 0 | 0 | 0 |
| GWP | 1430 | 547 | 687 | 570 | 387 |
| Class | A1 | A1 | A1 | A1 | A1 |
| Lubricant type | POE | POE | POE | POE | POE |

**Table 6**
Properties of R404A, R407A, and R407F

| Condition | LT | MT | HT | LT | MT | HT | LT | MT | HT |
|---|---|---|---|---|---|---|---|---|---|
| Refrigerant | | R404A [56] | | | R407A [57] | | | R407F [58] | |
| Composition | | R125/R143/R134A | | | R125/R32/R134A | | | R125/R32/R134A | |
| Mass percentage | | 44/52/4 | | | 40/20/40 | | | 30/30/40 | |
| Boiling point (°C) at 1 kPa | | –46.6 | | | –45.28 | | | –46.33 | |
| Critical pressure (kPa) | | 3728 | | | 4494 | | | 4754 | |
| Critical temperature (°C) | | 72.1 | | | 82 | | | 82.6 | |
| ODP | | 0 | | | 0 | | | 0 | |
| GWP | | 3943 | | | 2107 | | | 1825 | |
| Class | | A1 | | | A1 | | | A1 | |
| Lubricant type | | POE | | | POE | | | POE | |
| Qevap (kJ/kg) | | 83.66 | | | 139.02 | | | N/A | |
| Qcond (kJ/kg) | | 159.8 | | | 198.57 | | | N/A | |
| Work (kJ/kg) | | 76.14 | | | 59.55 | | | N/A | |
| COPc | | 1.099 | | | 2.335 | | | N/A | |
| Evaporator pressure (kPa) | | 183.30 | | | 477.3 | | | N/A | |
| Condenser pressure (kPa) | | 2197.50 | | | 2284.10 | | | N/A | |
| Evaporator temp glide (°C) | –0.4 | –0.5 | N/A | 119.21 | 126.89 | 114.83 | 192.46 | 184.93 | 170.29 |
| Condenser temp glide (°C) | 0.3 | 0.3 | N/A | 216.04 | 189.24 | 166.05 | 328.41 | 266.99 | 237.2 |

**Table 7**
Properties of R407H, R410A, and R422A

| Condition | LT | MT | HT | LT | MT | HT | LT | MT | HT |
|---|---|---|---|---|---|---|---|---|---|
| Refrigerant | | R407H [59] | | | R410A [60] | | | R442A [52] | |
| Composition | | R125/R32/R134A | | | R125/R32 | | | R125/R32/R1234A /R227ea/R152A | |
| Mass percentage | | 15/32.5/52.5 | | | 50/50 | | | 31/31/30/5/3 | |
| Boiling point (°C) | | –44.6 | | | –51.6 | | | –46.5 | |
| Critical pressure (kPa) | | 4856 | | | 4811 | | | 4760 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Critical temperature (°C) | | 86.53 | | | 70.81 | | | 82.4 | |
| ODP | | 0 | | | 0 | | | 0 | |
| GWP | | 1400 | | | 1900 | | | 1888 | |
| Class | | A1 | | | A1 | | | A1 | |
| Lubricant type | | POE | | | POE | | | POE | |
| Qevap (kJ/kg) | | 148.59 | | | 155.8 | | | 142.95 | |
| Qcond (kJ/kg) | | 263.52 | | | 229.56 | | | 203.59 | |
| Work (kJ/kg) | | 114.94 | | | 73.76 | | | 60.64 | |
| COPc | | 1.293 | | | 2.112 | | | 2.357 | |
| Evaporator pressure (kPa) | | 135.00 | | | 379.10 | | | 656.8 | |
| Condenser pressure (kPa) | | 2060.40 | | | 2265.80 | | | 2915.4 | |
| Evaporator temp glide (°C) | −3.9 | −4.1 | – 3.7 | 139.33 | 188.53 | N/A | 191.98 | 184.39 | 169.63 |
| Condenser temp glide (°C) | 4.7 | 4.5 | 3.9 | 248.17 | 271.65 | N/A | 328.25 | 266.68 | 236.71 |

**Table 8**
Properties of R448A, R449A, and R452A

| Condition | LT | MT | HT | LT | MT | HT | LT | MT | HT |
|---|---|---|---|---|---|---|---|---|---|
| Refrigerant | | R448A [61] | | | R449A [62] | | | R452A [63] | |
| Composition | | R125/R32/R134A/ R1234yf/R12354ze(E) | | | R125/R32/R134A/R1234yf | | | R125/R32/R1234yf | |
| Mass percentage | | 26/26/20/21/7 | | | 24.7/24.3/25.7/25.3 | | | 59/11/30 | |
| Boiling point (°C) | | −40.1 | | | −45.95 | | | −47.2 | |
| Critical pressure (kPa) | | 4675 | | | 4662 | | | 4014 | |
| Critical temperature (°C) | | 83.66 | | | 83.85 | | | 75.05 | |
| ODP | | 0 | | | 0 | | | 0 | |
| GWP | | 1273 | | | 1282 | | | 1945 | |
| Class | | A1 | | | A1 | | | A1 | |
| Lubricant type | | POE | | | POE | | | POE | |
| Qevap (kJ/kg) | | 179.93 | | | 172.76 | | | 158.78 | |
| Qcond (kJ/kg) | | 305.77 | | | 249.11 | | | 221.17 | |
| Work (kJ/kg) | | 125.84 | | | 76.35 | | | 62.39 | |
| COPc | | 1.43 | | | 2.263 | | | 2.545 | |
| Evaporator pressure (kPa) | | 150.60 | | | 410.60 | | | 701.90 | |
| Condenser pressure (kPa) | | 2051.80 | | | 2265.90 | | | 2903.70 | |
| Evaporator temp glide (°C) | −4.9 | −4.7 | −4.4 | 178.08 | 170.94 | 157.04 | 83.97 | 92.46 | 82.56 |
| Condenser temp glide (°C) | 4.5 | 4.3 | 3.7 | 301.63 | 245.91 | 218.33 | 159.88 | 141.82 | 122.68 |

**Table 9**
Properties of R453A and R463A

| Condition | LT | MT | HT | LT | MT | HT |
|---|---|---|---|---|---|---|
| Refrigerant | | R453A [64], | | | R463A [65] | |
| Composition | | R125/R32/R134A/R227ea/ R600/R601A | | | R125/R32/R134A/R1234yf/R744 | |
| Mass percentage | | 20/20/53.8/5/0.6/0.6 | | | 30/36/14/14/6 | |
| Boiling point (°C) | | –42.2 | | | –60.13 | |
| Critical pressure (kPa) | | 4530 | | | 5283 | |
| Critical temperature (°C) | | 87.9 | | | 73.15 | |
| ODP | | 0 | | | 0 | |
| GWP | | 1765 | | | 1377 | |
| Class | | A1 | | | A1 | |
| Lubricant type | | POE | | | POE | |
| Qevap (kJ/kg) | | 184.91 | | | 178.36 | |
| Qcond (kJ/kg) | | 312 | | | 255.92 | |
| Work (kJ/kg) | | 127.56 | | | 77.56 | |
| COPc | | 1.45 | | | 2.3 | |
| Evaporator pressure (kPa) | | 121.00 | | | 342.10 | |
| Condenser pressure (kPa) | | 1808.70 | | | 2002.50 | |
| Evaporator temp glide (°C) | –5.2 | –5.1 | 165.49 | 194.65 | 186.07 | 168.25 |
| Condenser temp glide (°C) | 5.0 | 4.8 | 228.96 | 340.43 | 273.5 | 239.3 |

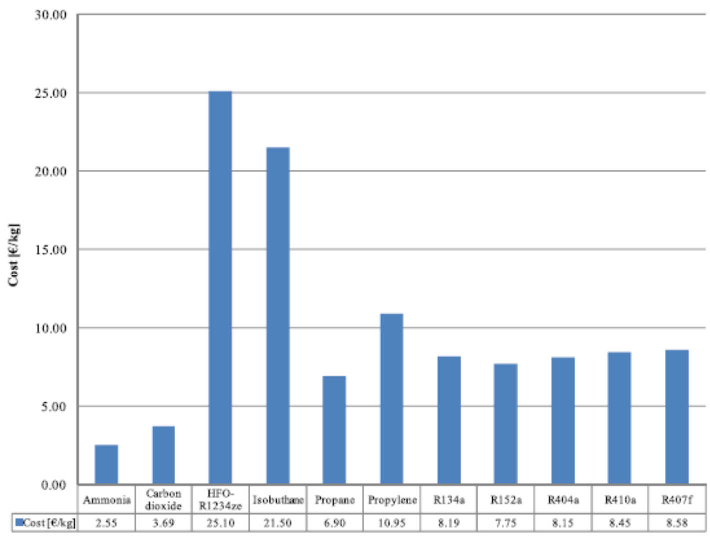


**Fig. 6.** Cost of refrigerant [43]

For the cost of refrigerant as shown in Figure 6 [43], the refrigerant should be mixed with HFOs. It also highest refrigerant cost but does not include HCs refrigerant cost compare with HFOs refrigerant cost, which is being presented as a refrigerant for comparative purposes in this research as it is composed of HCs. The properties of hydrocarbon refrigerant that class A3 high flammability as shown in Figure 7 below but zero ODP and GWP nearly zero, shown in Table 10-

11 for R170 [66], R290 [67], R600 [68], R600a [69] and Table 2 for R601 [70], R601a [71], R1150 [72], R1270 [73]. The highest boiling of R170 and R1270 were found to be -88.70 °C and -103.8 °C respectively but the critical temperature was found to be 32.17 °C and 9.5 °C. This means those are refrigerant that cannot operated in refrigerant in accordance with the CAN/ANSI/AHRI540 Air-Conditioning, Heating, and Refrigeration Institute (AHRI) standards that standard for this research [74-76]. The R290 and R1270 were found to be nearly boiling point with R22 at -42.1. °C and -47.7 °C respectively but operate at high condenser pressure that will affect to refrigerant work and cooling coefficient of performance.

**Table 10**
Properties of R170, R290, R600, R600a

| Condition | LT | MT | HT | LT | MT | HT | LT | MT | HT | LT | MT | HT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Refrigerant | | R170 [66] | | | R290 [67] | | | R600 [68] | | | R600a [69] | |
| Formula | | C2H6 | | | C3H8 | | | C4H10 | | | C4H10 | |
| Chemical name | | Ethane | | | Propane | | | Butane | | | Isobutane | |
| Boiling point (°C) | | -88.7 | | | -42.1 | | | -0.5 | | | -11.73 | |
| Critical Pressure (kPa) | | 4872 | | | 4251 | | | 3796 | | | 3629 | |
| Critical Temperature (°C) | | 32.17 | | | 96.74 | | | 151.98 | | | 134.66 | |
| ODP | | 0 | | | 0 | | | 0 | | | 0 | |
| GWP | | 3 | | | 3 | | | 3 | | | 3 | |
| Class | | A3 | | | A3 | | | A3 | | | A3 | |
| Lubricant type | | MO/POE | | | MO/POE | | | MO/POE | | | MO/POE | |
| Qevap (kJ/kg) | N/A | N/A | N/A | 388.96 | 240.37 | 223.89 | 235.72 | 261.99 | 255.88 | 207.03 | 231.52 | 223.97 |
| Qcond (kJ/kg) | N/A | N/A | N/A | 221.85 | 349.48 | 314.59 | 400.21 | 371.49 | 348.29 | 358.39 | 332.01 | 308.46 |
| Work (kJ/kg) | N/A | N/A | N/A | 221.85 | 109.11 | 90.70 | 164.50 | 109.51 | 92.41 | 151.35 | 100.49 | 84.49 |
| COPc | N/A | N/A | N/A | 1.33 | 2.20 | 2.47 | 1.43 | 2.39 | 2.77 | 1.37 | 2.30 | 2.65 |
| Evaporator Pressure (kPa) | N/A | N/A | N/A | 157.70 | 385.90 | 623.90 | 26.20 | 80.20 | 145.60 | 43.30 | 123.50 | 216.00 |
| Condenser Pressure (kPa) | N/A | N/A | N/A | 1653.10 | 1803.10 | 2269.40 | 484.30 | 535.40 | 705.00 | 670.60 | 736.80 | 955.00 |

**Table 11**
Properties of R601, R601a, R1150, R1270

| Condition | LT | MT | HT | LT | MT | HT | LT | MT | HT | LT | MT | HT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Refrigerant | | R601 [70] | | | R601a [71] | | | R1150 [72] | | | R1270 [73] | |
| Formula | | C5H12 | | | C5H12 | | | C2H4 | | | C3H6 | |
| Chemical name | | Pentane | | | Isopentane | | | Ethylene | | | Propylene | |
| Boiling point (°C) | | 36.1 | | | 27.7 | | | -103.8 | | | -47.7 | |
| Critical Pressure (kPa) | | 3370 | | | 3378 | | | 5042 | | | 4660 | |
| Critical Temperature (°C) | | 196.55 | | | 187.2 | | | 9.5 | | | 92.4 | |
| ODP | | 0 | | | 0 | | | 0 | | | 0 | |
| GWP | | 4 | | | 4 | | | 3 | | | 2 | |
| Class | | A3 | | | A3 | | | A3 | | | A3 | |
| Lubricant type | | MO/POE | | | MO/POE | | | MO/POE | | | MO/POE | |
| Qevap (kJ/kg) | 239.30 | 267.22 | 264.13 | 221.18 | 248.05 | 244.65 | N/A | N/A | N/A | 232.45 | 247.13 | 228.13 |
| Qcond (kJ/kg) | 402.16 | 376.31 | 356.72 | 374.81 | 350.99 | 331.95 | N/A | N/A | N/A | 404.89 | 358.77 | 320.62 |
| Work (kJ/kg) | 162.86 | 109.09 | 92.59 | 153.63 | 102.94 | 87.30 | N/A | N/A | N/A | 172.44 | 111.64 | 92.48 |
| COPc | 1.47 | 2.45 | 2.85 | 1.44 | 2.41 | 2.80 | N/A | N/A | N/A | 1.35 | 2.21 | 2.47 |
| Evaporator Pressure (kPa) | 4.70 | 18.10 | 37.00 | 7.20 | 25.90 | 51.20 | N/A | N/A | N/A | 199.70 | 478.10 | 764.40 |
| Condenser Pressure (kPa) | 155.80 | 175.10 | 242.20 | 201.70 | 225.40 | 307.00 | N/A | N/A | N/A | 1964.90 | 2143.80 | 2686.70 |

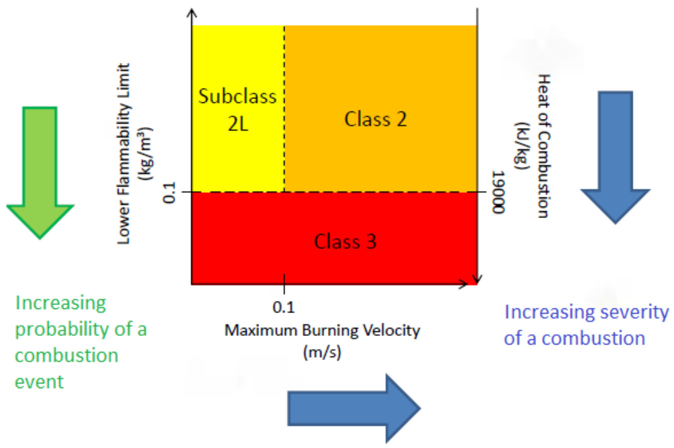


**Fig. 7.** Refrigerant classification [2]

## 2. Methodology

The medium back pressure refrigeration testing standard that follow CAN/ANSI/AHRI540 standard air-conditioning, heating, and refrigeration institute (AHRI) that showed in Table 12 as below. [74-76]. And the datamining tool for select refrigerants mass percentage that used rapid minor software that first of report of the software poll that used for data mining tool in Figure 8 as below. [77]. The Properties of refrigerants and refrigeration simulation system that used REFPROP and CYCLE_D-HX software from national institute of standards and technology [78-80] in Figure 9 as below.

**Table 12**
Standard testing for refrigeration systems [74-76]

| Temperature Point | Air Conditioning and Heat Pump | | Refrigeration | | |
|---|---|---|---|---|---|
| | Heating | Cooling | Low | Medium | High |
| Suction dew point (°C) | –15.0 | 10.0 | –31.5 | –6.5 | 7.0 |
| Discharge dew point (°C) | 35.0 | 46.0 | 40.5 | 43.5 | 54.5 |
| Suction return gas temperature (°C) | –4.0 | 21.0 | 4.5 | 18.5 | 18.5 |
| Superheat (K) | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 |
| Subcooling (K) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

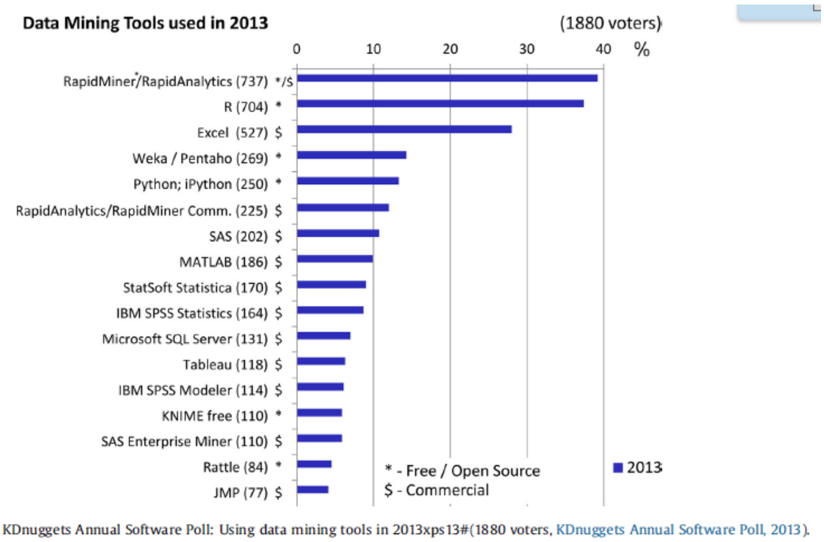


**Fig. 8.** Report of the software poll that used for data mining tool [77]

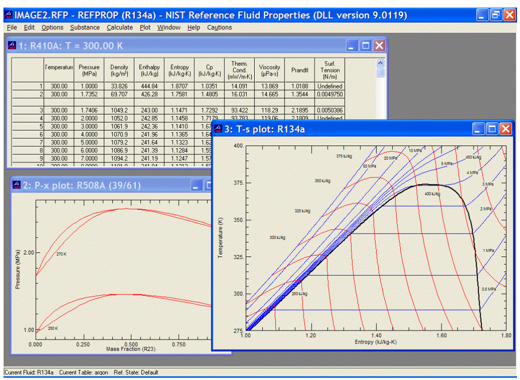


**Fig. 9.** The REFPROP software for refrigerant properties [78-80]

## 3. Results and Discussion

The refrigerants mixed by R134, R32, R125 and R1270 that can happen 4,539 type in Table 13 as below has showed the refrigerants mixed by R134, R32, R125 and R1270 by fixed R1270 in 1% for refrigerant no frame propagation class A1 and varies mass percentage of R134, R32 and R125 and the refrigerants mixed class A2 that mass percentage of R32 higher than R125 The GWP calculated by mass percentage of refrigerants and boiling point simulate by REFPROP software at 0.1 Mpa and pressure at evaporator temperature -6.5 °C and pressure at condenser temperature 43.5 °C simulate by and CYCLE_D-HX software from national institute of standards and technology [19] The refrigerant mixed were developed to low GWP, zero ODP, high capacity, low pressure, no toxify [6] that can select the refrigerant requirement from refrigerant data 4,539 type by rapid minor software that first of report of the software poll that used for data mining tool. The refrigerant requirement was class A1, boiling point lower than boiling point R404 at -46.5 °C and GWP lower than 2000. The datamining functional by decision tree in rapid minor software showed the 4 refrigerant result that follow refrigerant requirement as Figure 10, 11 and Table 14 below.

**Table 13**
The refrigerants mixed by R134, R32, R125 and R1270

| Refrigerant | R134A | R32 | R125 | R1270 | Summary | GWP | Boiling Point | Class A |
|---|---|---|---|---|---|---|---|---|
| R-No.1 | 1 | 1 | 97 | 1 | 100 | 3,366 | -47.91 | 1 |
| R-No.2 | 1 | 2 | 96 | 1 | 100 | 3,339 | -47.95 | 1 |
| R-No.3 | 1 | 3 | 95 | 1 | 100 | 3,311 | -47.98 | 1 |
| R-No.4 | 1 | 4 | 94 | 1 | 100 | 3,283 | -48.02 | 1 |
| ● | ● | ● | ● | ● | ● | ● | ● | ● |
| R-No.94 | 1 | 94 | 4 | 1 | 100 | 786 | -51.26 | 2 |
| R-No.95 | 1 | 95 | 3 | 1 | 100 | 758 | -51.30 | 2 |
| R-No.96 | 1 | 96 | 2 | 1 | 100 | 730 | -51.33 | 2 |
| R-No.97 | 2 | 3 | 94 | 1 | 100 | 3,289 | -47.76 | 1 |
| R-No.98 | 2 | 4 | 93 | 1 | 100 | 3,262 | -47.80 | 1 |
| R-No.99 | 2 | 5 | 92 | 1 | 100 | 3,234 | -47.84 | 1 |
| R-No.100 | 2 | 6 | 91 | 1 | 100 | 3,206 | -47.87 | 1 |
| ● | ● | ● | ● | ● | ● | ● | ● | ● |
| R-No.187 | 2 | 93 | 4 | 1 | 100 | 792 | -51.00 | 2 |
| R-No.188 | 2 | 94 | 3 | 1 | 100 | 764 | -51.04 | 2 |
| R-No.189 | 2 | 95 | 2 | 1 | 100 | 736 | -51.08 | 2 |
| R-No.190 | 3 | 3 | 93 | 1 | 100 | 3,268 | -47.54 | 1 |
| R-No.191 | 3 | 4 | 92 | 1 | 100 | 3,240 | -47.58 | 1 |
| R-No.192 | 3 | 5 | 91 | 1 | 100 | 3,212 | -47.62 | 1 |
| ● | ● | ● | ● | ● | ● | ● | ● | ● |
| R-No.4534 | 92 | 3 | 4 | 1 | 100 | 1,354 | -27.96 | 1 |
| R-No.4535 | 92 | 4 | 3 | 1 | 100 | 1,327 | -28.00 | 2 |
| R-No.4536 | 92 | 5 | 2 | 1 | 100 | 1,299 | -28.04 | 2 |
| R-No.4537 | 93 | 3 | 3 | 1 | 100 | 1,333 | -27.74 | 1 |
| R-No.4538 | 94 | 3 | 2 | 1 | 100 | 1,311 | -27.52 | 2 |
| R-No.4539 | 95 | 3 | 1 | 1 | 100 | 1,290 | -27.30 | 2 |

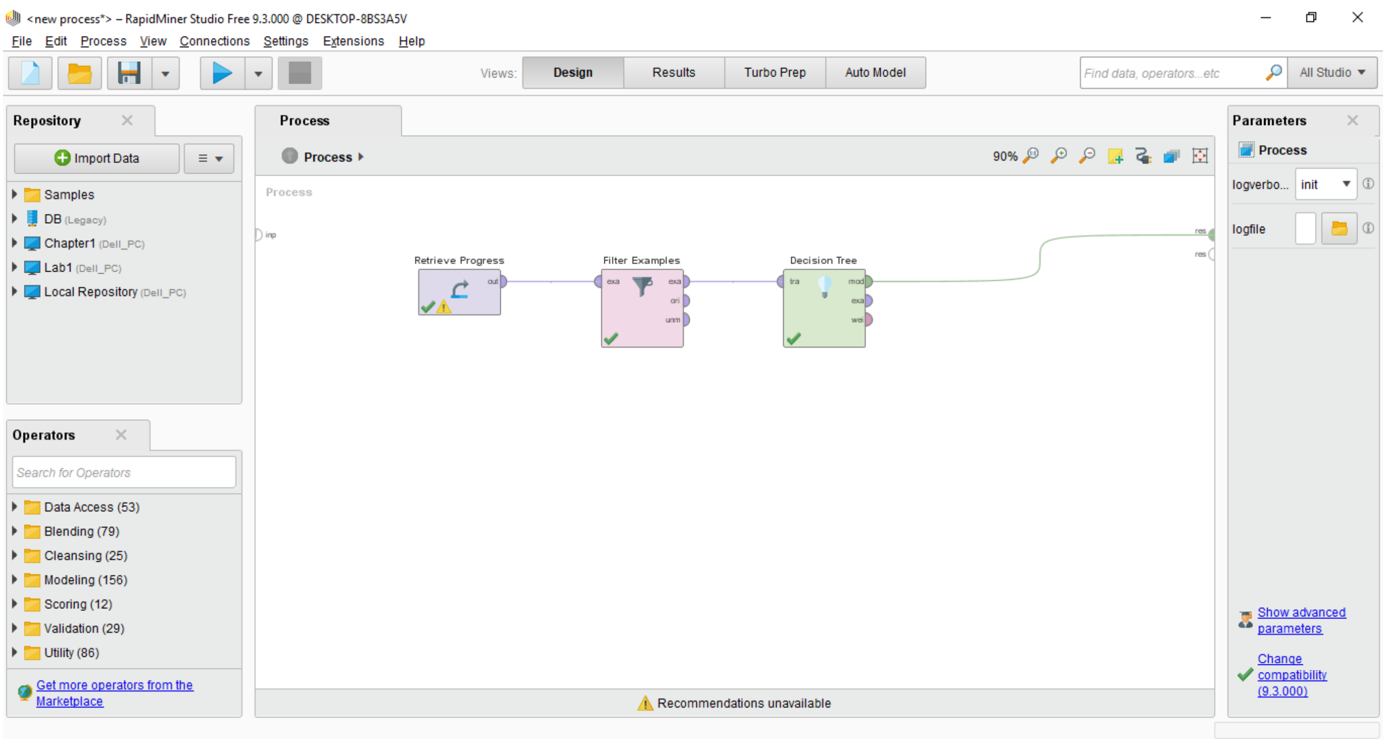

**Fig.10.** The datamining functional by decision tree in rapid minor software

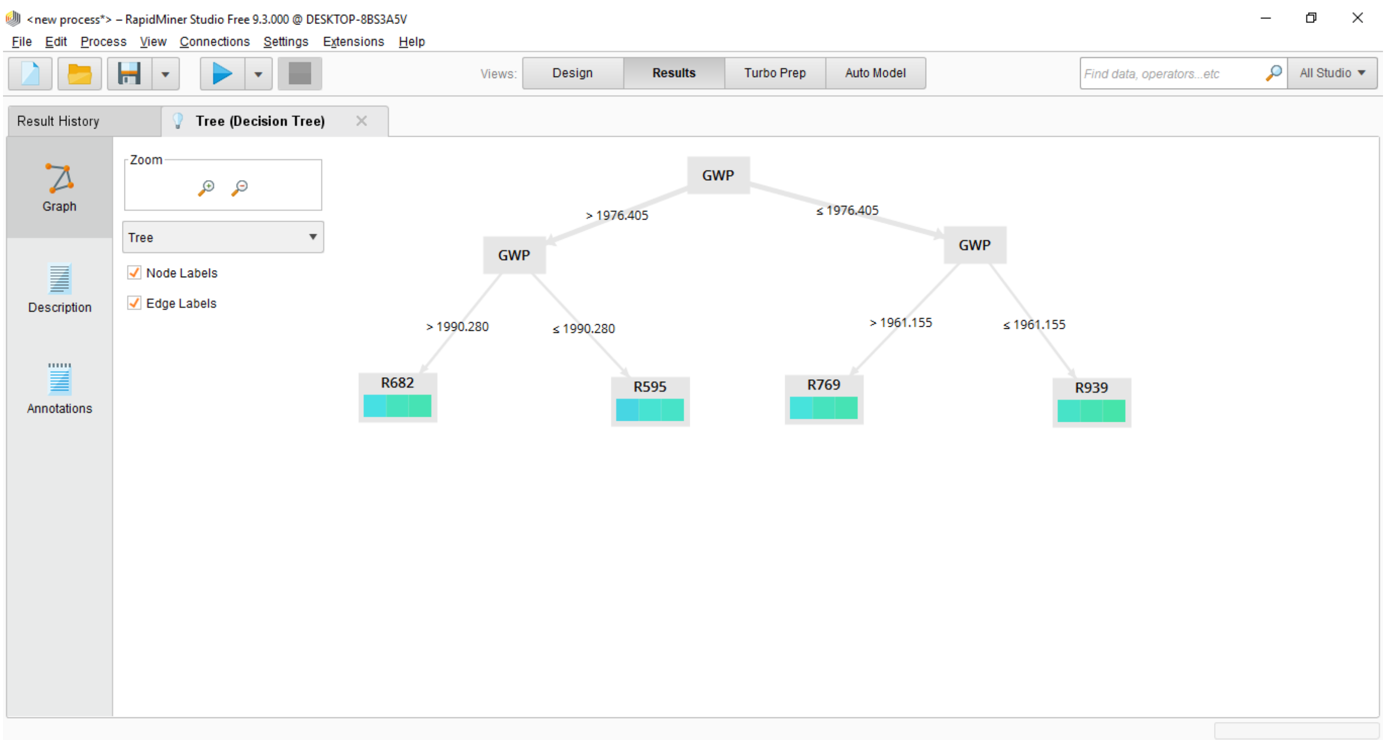


**Fig.11.** The result of 4 refrigerant that follow refrigerant requirement

**Table 14**
The4 refrigerant result by decision tree in rapid minor software

| Refrigerant | R134A | R32 | R125 | R1270 | Summary | GWP | Boiling Point | Class A |
|---|---|---|---|---|---|---|---|---|
| R-No.682 | 8 | 45 | 46 | 1 | 100 | 1,995 | -47.96 | 1 |
| R-No.595 | 7 | 46 | 46 | 1 | 100 | 1,989 | -48.21 | 1 |
| R-No.769 | 9 | 45 | 45 | 1 | 100 | 1,973 | -47.74 | 1 |
| R-No.939 | 11 | 44 | 44 | 1 | 100 | 1,958 | -47.26 | 1 |

The simulation system used REFPROP and CYCLE_D-HX software from national institute of standards and technology [19] and define new mixture form result of rapid minor software that can see properties and simulation system follow CAN/ANSI/AHRI540 standard air-conditioning, heating, and refrigeration institute (AHRI) showed in Table 14. The result of R-No.682, R-No.595, R-No.769, and R-No.939 had cooling capacity, refrigerant effect, GWP and boiling point were lower than R404A but work and pressure for medium temperature refrigeration system of all R-No.682, R-No.595, R-No.769, and R-No.939 refrigerant was lower than R404A.

**Table 14**
The simulation system used REFPROP and CYCLE_D-HX

| Condition | Medium temperature | | | | |
|---|---|---|---|---|---|
| Refrigerant | R404A | R-No.682 | R-No.595 | R-No.769 | R-No.939 |
| Qevap kJ/kg | 139.02 | 186.88 | 187.76 | 187.66 | 187.55 |
| Qcond kJ/kg | 198.57 | 270.31 | 271.52 | 271.5 | 271.45 |
| Work kJ/kg | 59.55 | 83.43 | 83.76 | 83.84 | 83.9 |
| COPc | 2.335 | 2.24 | 2.242 | 2.238 | 2.235 |
| Pressure at Tev -6.5 °C (Psia) | 69.23 | 85.95 | 86.98 | 85.09 | 83.24 |
| Pressure at Tcd 43.5 °C (Psia) | 331.28 | 422.87 | 425.77 | 420.68 | 415.61 |

## 4. Conclusions

The artificial intelligence (AI) by data mining technic can predictive environmentally-friendly and energy efficient refrigerant for medium temperature refrigeration. The result of refrigerant mixed by R134A, R32, R125 and R1270 and is consistent with the evolution of the fourth-generation refrigerants that contain a mixture of HFCs, HFOs, HCs, and natural refrigerants, which are required to produce a low-GWP, zero-ODP, high-capacity, low-operating-pressure, and nontoxic refrigerant. In the future, researchers should incorporate R744 in order to use natural refrigerants that are low-cost. The problems of high evaporator pressure and high condenser pressure that impact high refrigerant work can be solved by adjusting the composition of the refrigerant or mix using a refrigerant that operates at low pressure, thereby improving the COP of the refrigerant.

**Acknowledgement**
This study was supported by Prince of Songkla University and SANYO S.M.I. (Thailand) Co., Ltd.

**Funding Statement:** This research was funded by Prince of Songkla University and SANYO S.M.I. (Thailand) Co., Ltd.

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