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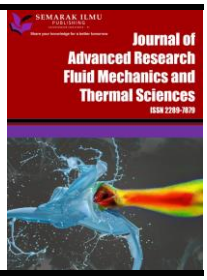

Low GWP Refrigerant R1234yf, R1234ze(z), R13I1 as an Alternative to New Zeotropic Refrigerant

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ABSTRACT

This study will present R13I1 or trifluoroiodomethane as a CFCs refrigerant, the chemical formula is CF3I. R13I1 is a halocarbon agent used in fire extinguishing agents same as R227ea. R13I1 has a GWP of 1, a boiling point of -21.9, a critical temperature of 123.3 °C and a critical pressure of 3950kPa. It can be seen that it is a refrigerant with properties similar to R134a. R1234yf and R1234ze(z) therefore can be mixed with HFCs. The result the 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 as CAN/ANSI/AHRI540 standards of the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) show that R13I1 has cooling coefficient of performance of 1.49, 2.43 and 2.79 kJ/kg which are lower than of R13I1 10.33% 8.13% and 9.40% for LT, MT and HT conditions as a result of low evaporator pressure, condenser pressure and refrigerant work .R13I1 which is a refrigerant that is mixed in low-GWP and low-GWP HFCs, as well as providing good energy efficiency zeotropic blends.

1. Introduction

Convenience stores in Thailand continue to grow every year and by 2021 there are more than 20000. In response to changing consumer behaviour to use more convenience stores. Many convenience stores are open 24 hours a day and use a lot of energy, especially refrigeration, to maintain the temperature of their products. 20,000 convenience stores use more than 800 tons of refrigerants, most of which are HFCs and CFCs, which has a negative impact on the environment. High-performance refrigerant replacement, in addition to reducing energy consumption, can also help reduce the environmental impact. The reduction in the use of HFCs in each country follows the Montral protocol as showed in Figure 1 [1], which Thailand plans to stop using HFCs by 2030. Refrigerants that were widely used in the 1st generation to try and mix them into zeotropic HFCs is natural refrigerant. R744 is used as a refrigerant to increase the cooling capacity and reduce GWP, but the working pressure of the refrigerant is high. HCs are also good as the R744, although operating pressure is less than R744, if mixed with large quantities of refrigerant it will ignite, as showed in

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Figure 2 [2]. The second still used refrigerant in the industry is CFCs, as showed in Figure 3 [3], which were introduced since the second generation of refrigerants and are still use in present. CFCs have issues with both GWP and ODP. Third generation refrigerants are HFCs refrigerants, which are both azeotropic and zeotropic refrigerants. The azeotropic HFCs still have high GWP, so multiple refrigerants are mixed with HFCs as a base to form zeotropic refrigerants. In the 4th generation or the current, refrigerants are used again by combining them with HFCs to bring the advantages of HCs and R744 is used for cooling capacity and reduction of GWP to achieve more efficient zeotropic refrigerant. The low GWP refrigerant HFO was also formed in the fourth generation to be incorporated into HFCs. The refrigerant used in most zeotropic HFCs is R134a refrigerant. HFCs R134a has GWP 1,200, boiling point of -26.1°C, Critical temperature of 101.06°C, Critical pressure 4,059 kPa. HFCs R134a refrigerant is a low GWP and low-cost refrigerant, so it is widely used and is a combination of many zeotropic refrigerants. There are two types of HFO refrigerants that are mixed in HFCs, R1234yf and R1234ze(E). HFOs R1234yf has GWP 1, boiling point of -29.55°C, Critical temperature of 94.7°C, Critical pressure 3,382 kPa. HFOs R1234ze(E) has GWP 1, boiling point of -18.95°C, Critical temperature of 109.36°C, Critical pressure 3,634 kPa. It can be seen that R1234yf and R1234ze(E) refrigerants have lower GWP than R134a, and have similar boiling points and properties, so they can be mixed to replace R134a, but R1234yf and R1234ze(E) has a high price, as showed in Figure 4 [4]. However, the refrigerant should be a non-flammable, non-toxic refrigerant and low operating pressure for energy efficiency. This research presents CFCs R13I1, the basis of this research, which is a refrigerant that is mixed in low-GWP and low-GWP HFCs, as well as providing good energy efficiency zeotropic blends.

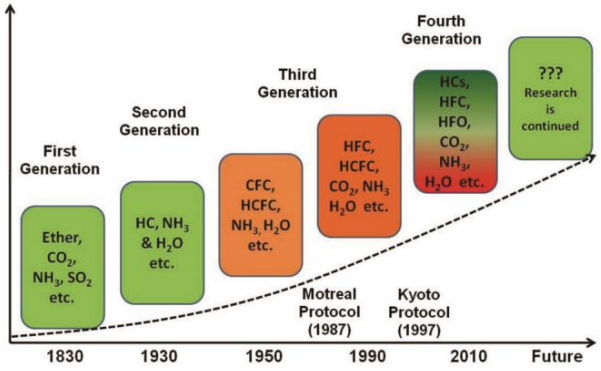


Fig. 1. Evolution of refrigerants [1]

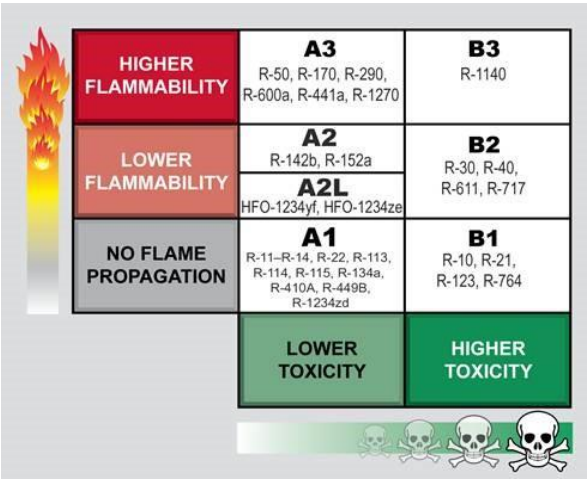


Fig. 2. Refrigerant classification [2]

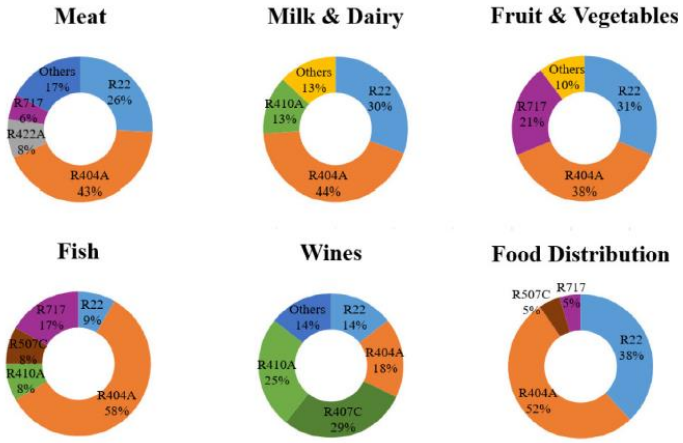


Fig. 3. Top refrigerants in the food industry [3]

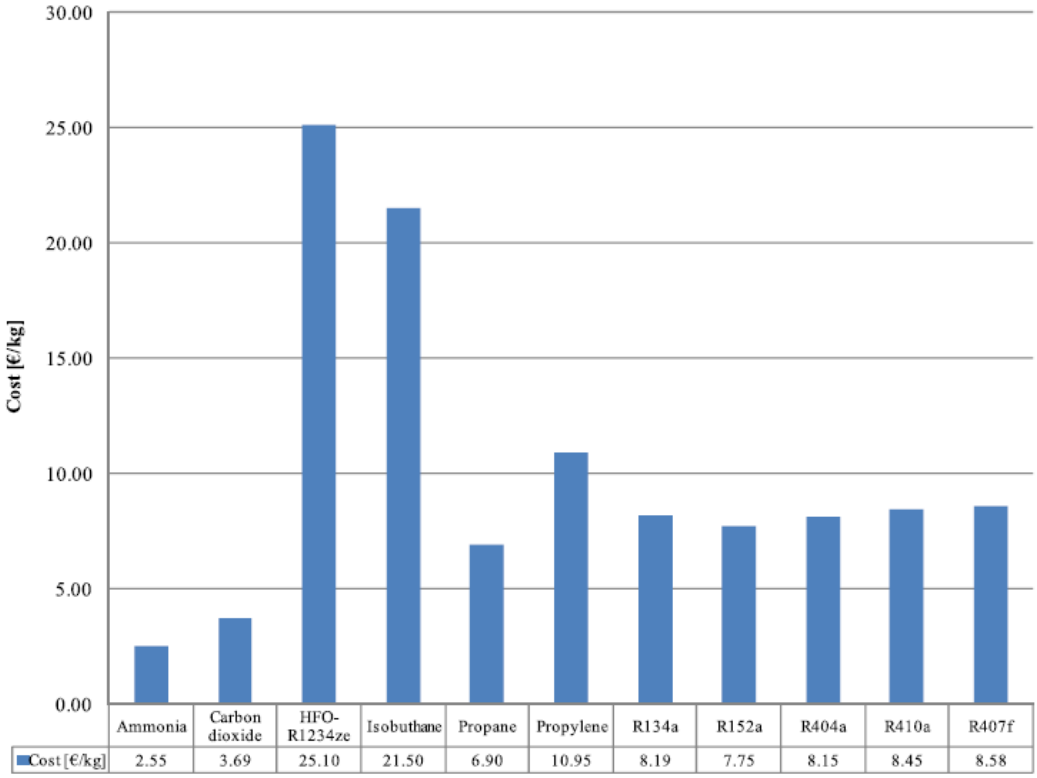


Fig. 4. Cost of refrigerants [4]

2. High Temperature for Vehicle Air Conditioning System

Currently, research of the R744A is found for the vehicle air conditioning system. While, R744A. It has the advantage of having a low GWP and non-flammable. Although, the refrigerant is cheap because it is a naturally produced refrigerant. But due to the higher operating pressure than conventional refrigerants, the design of air conditioners that use R744 refrigerant high cost due to system equipment that must withstand the operating pressure of safety devices. Therefore, it can be seen that there are rarely air conditioners in cars that use refrigerant R744. An interesting developed refrigerant is R1234yf. R1234yf with a low GWP and low operating pressure, which is easy to design the system and the cost of the system is not very high. Although the refrigerant is class A2 flammable, it is still Class A2 which is low flammable. But although the above-mentioned refrigerants are useful, but the price of the refrigerant is high, so it is still limited in certain types of cars. Therefore, at

present, R134A is still the most prevalent. And there is no refrigerant to replace, although the GWP is high, but with low operating pressure and low price, which results in low system cost, therefore, the proportion of R134a refrigerant use remains the most in air conditioning in the current, as showed in Figure 5. This research presents R13I1 refrigerant that will help solve the price problem of working pressure refrigerant and it is also a non-flammable refrigerant [5].

ASHRAE Designation	IUPAC Name	GWP20	GWP100	ASHRAE Safety Rating	LFL (vol %)	ATEL (ppm)	Refrigerant cost (US$ per kg)	Additional Per-Vehicle Cost
R-134a	1,1,1,2-tetrafluoroethane	3830	1430	A1	Not flammable	50,000	3-4	-
R-1234yf	2,3,3,3-Tetrafluoropro-pene	12	4	A2	6.5	100,000	20-30	+25 US$
R-744	Carbon Dioxide	1	1	A1	Not flammable	40,000	<1	+50-200 US$

Fig. 5. Refrigerants for vehicle air conditioning system

3. Medium Temperature for Refrigerator

The current situation of the refrigerant used in the refrigerator. There is a change, try not to use R134a by switching to a hydrocarbon refrigerant. Restrictions on the use of refrigerants classified as A3 are still very limited in preventive maintenance time, breakdown Maintenance and corrective maintenance. Because this refrigerant is flammable, it cannot be serviced in an enclosed space. Moving to open area for repairs is still a big problem. Therefore, at present, R134A is still the most prevalent. And there is no refrigerant to replace, although the GWP is high, but with low operating pressure and low price, which results in low system cost, therefore, the proportion of R134a refrigerant use remains the most in air conditioning in the current. as showed in Figure 6. This research presents R13I1 refrigerant that will help solve the price problem of working pressure refrigerant and it is also a non-flammable refrigerant same as High Temperature for vehicle air conditioning system [6-7].

Refrigerant	Cost (Tk/litre)
R12	1350
R22	500
R134a	1350
R600	1000
R600a	2200

Fig. 6. Refrigerants for vehicle refrigerator

4. Materials and Methods

R13I1 or trifluoroiodomethane as a CFCs refrigerant, the chemical formula is CF3I [8]. R13I1 is a halocarbon agent used in fire extinguishing agents same as R227ea [9]. R13I1 has a GWP of 1, a boiling point of -21.9°C, a critical temperature of 123.3°C and a critical pressure of 3950kPa [10]. It can be seen that it is a refrigerant with properties similar to R134a. R1234yf and R1234ze(z) therefore can be mixed with HFCs [11]. All refrigerant in this study uses the 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 as CAN/ANSI/AHRI540 standards of the Air-Conditioning, Heating, and Refrigeration Institute (AHRI), as shown in Table 1 [12]. Both programs are able to select the refrigerant mixture and set the proportion in order to create a new zeotropic

refrigerant. The properties of the refrigerant can use the result of the REFPROP. The result of the refrigerant system can be used CYCLE_D-HX. The results of this research were investigated and analyzed such as GWP, boiling point, refrigerant effect, heat rejection, refrigerant work, evaporator pressure, high pressure, and cooling coefficient of performance (COPc) [13].

Table 1
Medium back pressure standard testing for refrigeration systems [14-15]

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

5. Results and Discussion

The results of normal boiling point and GWP for all refrigerants, as showed in Figure 7. show that the R1234yf, R1234ze(E) and R13I1has GWP = 1 except R134a refrigerant with a GWP of 1200, which can be seen that the refrigerant used as a replacement for R134a has a significantly lower GWP value. The lowest normal boiling result is R1234yf, it is a refrigerant with a lower boiling point of R134a 11.68%. The second are R134a, R13I1 and R1234ze (E), which have fewer boiling points than R134a. 16.09% and 27.39% respectively. But when compared with cost, it can be seen that R1234yf and R1234ze (e) that are HFOs types have a much higher price. The R134a also has a high GWP. Despite its low price, the R13I1 is another low-priced option. And low GWPs are suitable to be developed.

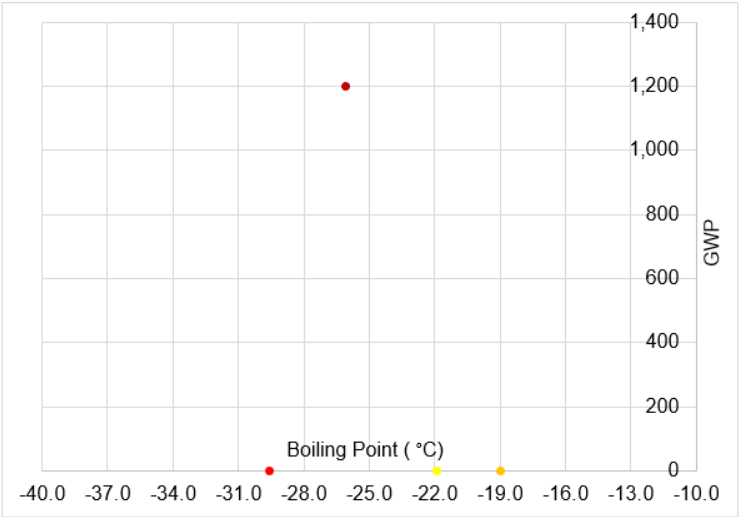


Fig. 7. Normal boiling point and GWP for all refrigerants

The result of refrigerant effect for all refrigerants, as showed in Figure 8 and Figure 9 show that highest refrigerant effect and heat rejection is R134a. R134a has a refrigerant effect of 118.55, 128.83 and 120.78 kJ/kg for LT, MT and HT conditions, respectively. For that heat rejection of 207.22, 186.44 kJ/kg and 168.60 for LT, MT and HT conditions, respectively. The lowest refrigerant effect and heat rejection is R13I1. R13I1 has a refrigerant effect of 66.70, 71.27 and 68.57 kJ/kg for LT, MT and HT conditions, respectively. For that heat rejection of 111.45, 100.55 kJ/kg and 93.16 for LT, MT and HT conditions, respectively. It can be seen that the R13I1 will have little cooling and cooling capabilities,

but with the advantage of low GWP in mixing with R13I1 zeotropic refrigerants, this can be corrected by mixing a high capacity refrigerant instead, for example: R32 or HCs.

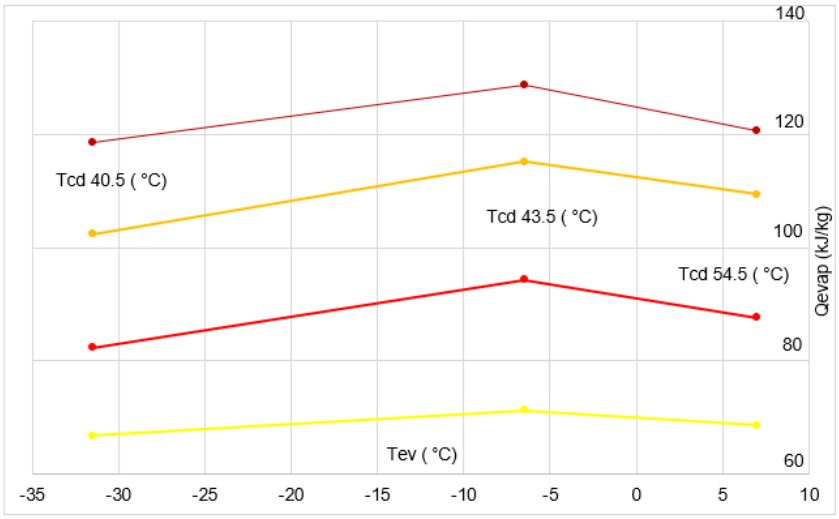


Fig. 8. Refrigerant effect: Qevap (kJ/kg) for all refrigerants

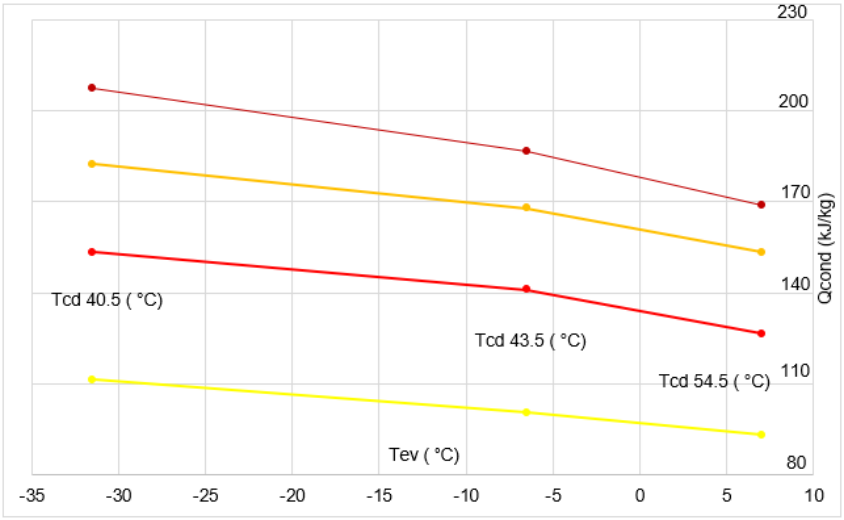


Fig. 9. Heat Rejection: Qcond (kJ/kg) for all refrigerants

The result of refrigerant work for all refrigerants, as showed in Figure 10 show that the lowest refrigerant is R13I1. R13I1 has refrigerant work of 44.75, 29.28 and 24.59 kJ/kg which are lower than of R13I1 49.53% 49.18% and 48.58% for LT, MT and HT conditions, respectively. Low work refrigerants tend to consume low energy and will result in high efficiency as a result of evaporator pressure and condenser pressure. Operating pressure will result in refrigerant having a high workload show that the lowest refrigerant is R134a. R134a has refrigerant work of 88.67, 57.62 and 47.82 kJ/kg for LT, MT and HT conditions, respectively, which corresponds to that R134a has a high operating pressure. As a result of the work of R13I1 that is 50% lower than R134a on average, it corresponds to the operating pressure of R13I1 lower than R134a as well, 18.86% and 29.54% for evaporator pressure and condenser pressure, as showed in Figure 11 and Figure 12, respectively. In terms of HFO R1234yf and R1234ze(E), both refrigerants are refrigerant work and operating pressure higher than

R13I1. R13I1 is suitable to be mixed in efficient zeotropic refrigerants because refrigerants mixed with R13I1 tend to be low refrigerant work and operating pressure and effective to be a highly efficient refrigerant. The result of cooling coefficient of performance, as showed in Figure 13 show that the highest cooling coefficient of performance is R13I1. R13I1 has cooling coefficient of performance of 1.49, 2.43 and 2.79 kJ/kg which are lower than of R13I1 10.33% 8.13% and 9.40% for LT, MT and HT conditions as a result of low evaporator pressure, condenser pressure and refrigerant work.

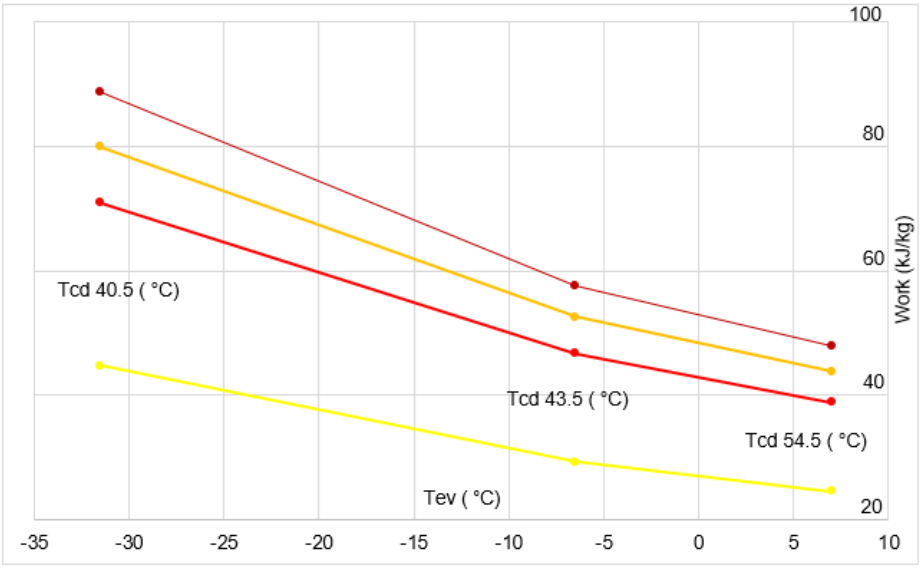


Fig. 10. Refrigerant Work: Work (kJ/kg) for all refrigerants

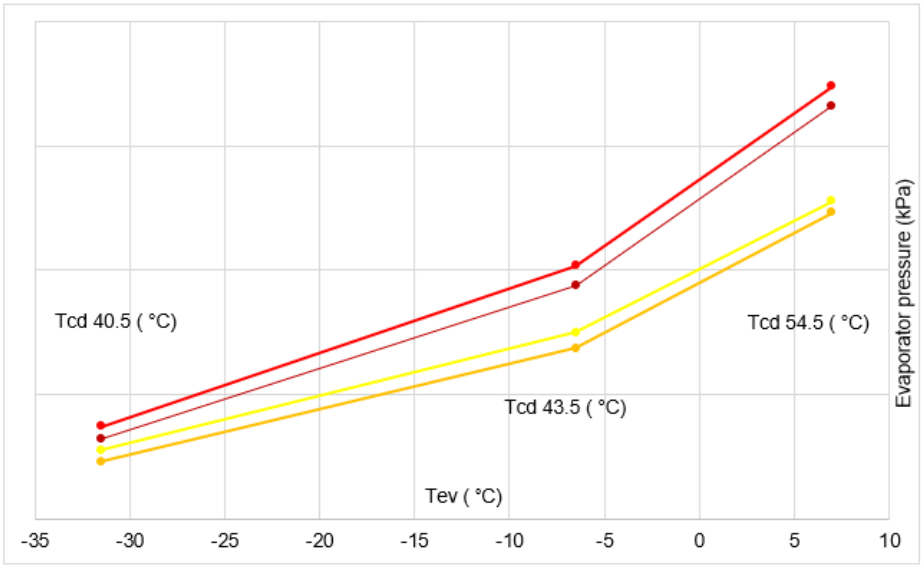
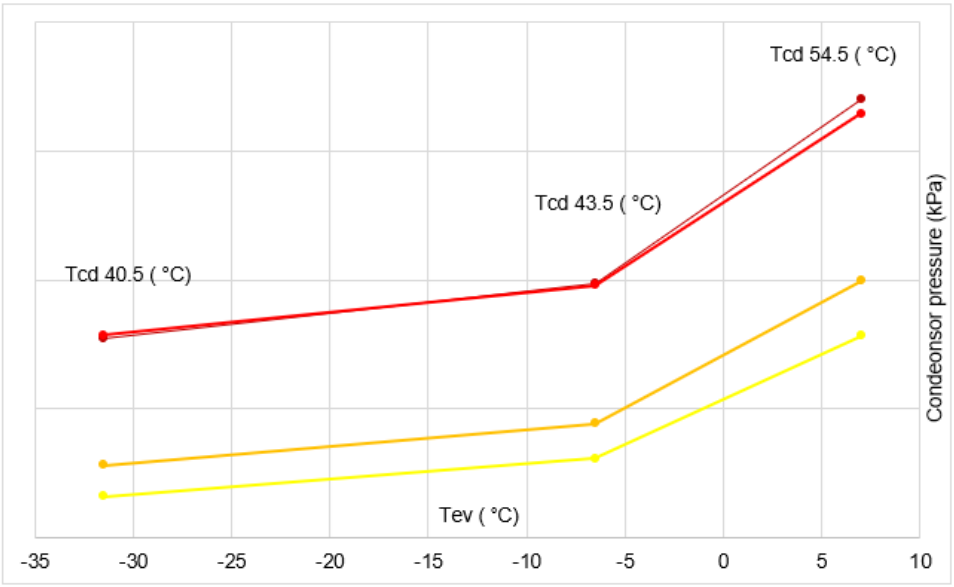
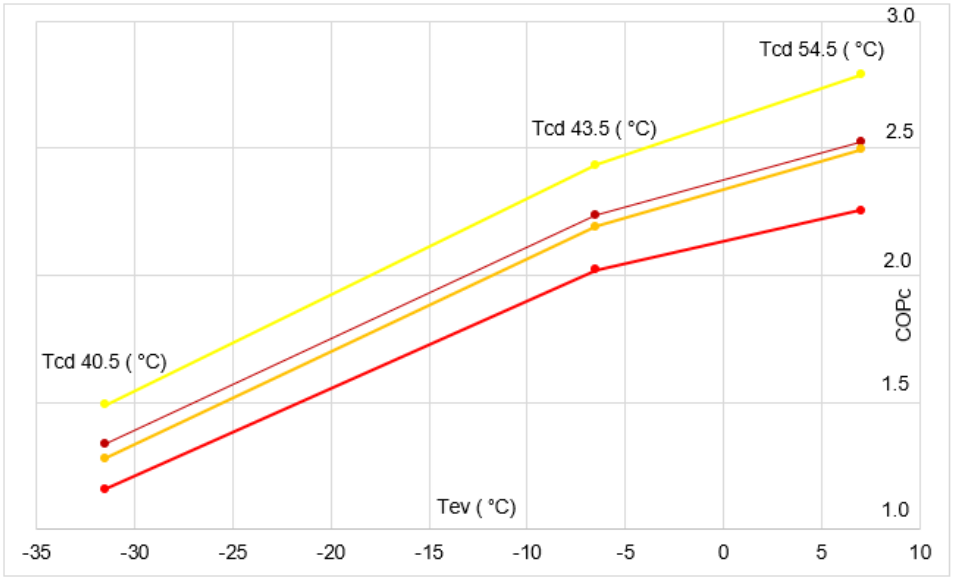


Fig. 11. Evaporator pressure for all refrigerants



• R134a • R1234yf • R1234ze(e) • R13I1

Fig. 12. Condenser pressure for all refrigerants



• R134a • R1234yf • R1234ze(e) • R13I1

Fig. 13. Cooling coefficient of performance (COPc) for all refrigerants

6. Conclusions

R13I1 or trifluoroiodomethane as a CFCs refrigerant, the chemical formula is CF3I. R13I1 is a halocarbon agent used in fire extinguishing agents same as R227ea. R13I1 has a GWP of 1, a boiling point of -21.9°C, a critical temperature of 123.3°C and a critical pressure of 3950kPa. It can be seen that it is a refrigerant with properties similar to R134a. R1234yf and R1234ze(z) therefore can be mixed with HFCs. The result the 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 as CAN/ANSI/AHRI540 standards of the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) show that R13I1 has cooling coefficient of performance of 1.49, 2.43 and 2.79 kJ/kg

which are lower than of R13I1 10.33% 8.13% and 9.40% for LT, MT and HT conditions as a result of low evaporator pressure, condenser pressure and refrigerant work. So, they can be mixed to replace R134a, but R1234yf and R1234ze(E) has a high price. However, the refrigerant should be a non-flammable, non-toxic refrigerant and low operating pressure for energy efficiency. This research presents CFCs R13I1, the basis of this research, which is a refrigerant that is mixed in low-GWP and low-GWP HFCs, as well as providing good energy efficiency zeotropic blends. the next study, the researcher is advised to mix the refrigerant that will decrease the operating pressure or increase the cooling capacity to improve the cooling system efficiency.

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